Amendment 23

To the

Northeast Multispecies Fishery Management Plan

Appendix I

Draft Fishery Data for Stock Assessment Working Group Report and SSC Sub-Panel Peer Review Report

SSC REVIEW DRAFT

Fishery Data for Stock Assessment Working Group Report

November 19, 2018

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Executive Summary

The New England Fishery Management Council formed a working group to discuss the topic of how fishery-dependent data can be used to inform stock abundance to address four main deliverables:

1) explain how fishery-dependent and fishery-independent data are used in stock assessments,

2) summarize the utility and limitations of using fishery catch rates (CPUE, catch per unit effort) as an index of abundance for Northeast Multispecies stocks,

3) identify the fishery factors and fishery-dependent data needed to create a CPUE that would be a reliable index of abundance for Northeast Multispecies stocks, and

4) compare the desired factors identified with existing conditions and data for the fishery.

How fishery-dependent and fishery-independent data are used in stock assessments
Stock assessments rely on fishery monitoring information to estimate total fishery removals and age composition as well as fishery-independent data to provide indices of relative stock abundance and age distribution. Stock assessments assume that estimates of fishery removals are accurate. Information from the various fishery monitoring programs are combined to determine landings and discards (by species, stock area, month, and fishing), fishing effort (by statistical area, month and gear), as well as size and age composition (by species, statistical area, month and gear).

Age-based stock assessments estimate abundance of each yearclass in a population based on information from fishery monitoring programs and fishery-independent surveys. Fishery monitoring data is used to derive a time series of fisheries removals (commercial landings, commercial discards, recreational landings, and recreational discards) as well as the age composition of those removals. fishery-independent surveys or fishery catch rates are used to determine whether the fishery removals came from a relatively abundant or a relatively depleted stock. Population models are fit to the available fishery and fishery-independent data to estimate a time series of stock abundance, age structure and fishing mortality. Some groundfish stocks are based on data-limited approaches, which also rely on estimates of fishery removals and indices of abundance.

Abundance indices are assumed to be proportional to stock size, so factors that might interfere with the relationship between index and stock (e.g., changes in vessel or gear characteristics) must be accounted for. Fishery-independent data is obtained primarily through research surveys, which are used to estimate relative or absolute stock abundance and sample for size and age through a planned sampling design. Fishery-independent surveys are designed to standardize for vessel, fishing gear, fishing protocol, as well as time and area. Fishery catch rates (CPUE) are more difficult to standardize because fishing effort is based on individual fishing decisions within the constraints of regulations.

The utility and limitations of using CPUE as an index of abundance for Northeast Multispecies stocks

Fishery catch rates (CPUE) are used in many stock assessment models as an index of stock abundance. These applications assume that CPUE is proportional to stock abundance, but this assumption is only valid in some situations. Fisheries are not designed to representatively sample a fish population, so trends in catch rates may not reflect trends in the stock. Fishery catch rates can be standardized to account for factors like changing patterns in fishing area, fishing season, or vessel characteristics, but some factors cannot be effectively standardized.

Stock assessments of New England groundfish currently do not use CPUE as an index of abundance in the stock assessment model. However, CPUE is used in other northeast U.S. stock assessments and was previously used in most groundfish assessments before 2008. Several more recent groundfish assessments considered CPUE as an index of abundance but did not include it as an index of abundance.

Despite the limitations of using CPUE as an index of abundance in some situations, including CPUE in a stock assessment can be informative. Including CPUE as an index of abundance has the potential to improve performance of groundfish assessments if the index is sufficiently standardized. Even if it is not used as an index of abundance in the stock assessment model, including CPUE in a stock assessment can also be valuable for providing fishery data with greater spatial and temporal resolution than fishery-independent surveys and understanding fishery dynamics. The inclusion of fishery perceptions of trends in catch rates may also improve the acceptance of stock assessment results by the fishing industry.

Fishery factors and fishery-dependent data needed for a reliable CPUE index

Several aspects of fisheries and data are needed to create a CPUE to be a reliable index of abundance for Northeast Multispecies stocks. Differences in fishing power need to be standardized so that a unit of effort and CPUE are comparable over time. Information on target species is helpful for developing a CPUE, particularly to select fishing effort targeted at the species of interest and to exclude effort that is deliberately avoiding 'choke stocks'. Catch estimates need to be accurate for an informative CPUE index, either an entire fleet CPUE or a smaller standard fleet. An understanding of fishing effort is needed to develop a CPUE, including information on fishing gear, fishing power, and an appropriate unit of fishing effort for each type of fishery. Fine-scale temporal and spatial information is helpful for measuring and standardizing fishing effort, even if catch, effort and CPUE are derived in more aggregated units (e.g., statistical reporting area, quarter-year). Ideally, the inclusion probabilities of fishery observations (i.e., the chance of each time/location observation being sampled) should be known for a CPUE series to be a representative index of abundance.

Desired factors and existing conditions

A large amount of fishery-dependent data is currently collected from fishermen in the Northeast multispecies fishery, but CPUE is not currently being used in groundfish stock assessments because of limitations in the monitoring programs (e.g., data resolution, mis-reporting, observer bias), constraints of the stock assessment process (e.g., increasing scope of assessments with limited time and resources), as well as challenges posed by current conditions in the groundfish fishery (e.g., avoidance behavior). At-sea observer coverage is based on achieving a standard of precision for discard estimates. However, the precision estimate does not account for 'observer bias' (i.e., observed trips do not represent unobserved trips because of difference in fishing behavior). Observer coverage should provide confidence that the overall catch estimate is accurate. Vessel Trip Reports (VTRs) do not record fine-scale effort data. Many VTRs report aggregate effort and by statistical fishing areas. Most of the data in VTRs is self-reported but is not verified (e.g., location, discarded catch). Vessel Monitoring System (VMS) information could be used to verify VTR location information, but such evaluations are rare.

Federally permitted seafood dealers submit weekly electronic purchase reports. Although total landings derived from dealer reports are assumed to be a census of fishery landings, recent violations document substantial mis-reporting. The magnitude of misreporting and resulting bias in estimates of landings are unknown.

Study fleets and Electronic Monitoring (EM) projects have the potential to provide greater spatial and temporal resolution of catch and effort. Both systems integrate logbooks with vessel positioning systems, and both have options for verifiable self-reported data. Electronic VTRs (eVTRs) and EM are used to monitor a portion of the groundfish fleet, but the data are not routinely used to derive CPUE.

Recommendations:

1. As a routine term of reference, a time series of CPUE should be evaluated and considered as an index of abundance in all benchmark stock assessments, not necessarily accepted as an index of abundance in the final stock assessment model.
2. For CPUE to be considered as an index of abundance in stock assessment models, CPUE must be standardized sufficiently to account for changes in vessel efficiency, gear selectivity, targeting/avoidance behavior, inclusion probabilities, spatial aggregation of fish, and hyperstability. For example, the Southeast Data and Assessment Review (SEDAR) process developed a checklist for evaluating fishery-dependent and fishery-independent indices.
3. Identifying best practices for developing a standardized CPUE index using northeast fishery monitoring data would be an appropriate topic for a research track assessment for all groundfish stocks.
4. Simulation analysis should be used to evaluate the performance of alternative approaches to developing standardized CPUE as an index of abundance.
5. Processes for soliciting fishermen's expertise for understanding factors of CPUE, fishing patterns, and targeting or avoidance behavior should be included in the stock assessment process such as workshops and questionnaires.
6. Study fleets that have similar gear, vessel size, vessel power and target species should be considered for the development of CPUE indices.
7. At-sea observer data should be used in the development of CPUE indices with fine-scale standardization, but 'observer bias' should be considered.
8. Advanced technologies (e.g., electronic monitoring systems) should be considered in the development of CPUE indices with fine-scale standardization.
9. Criteria should be developed to identify targeted fishing effort by species, including historical, fishery "footprints."
10. Appropriate units of fishing effort should be developed for each type of fishery (e.g., trawl, gillnet, and hook gears).

Background

At the September 2017 meeting, the New England Fishery Management Council passed a motion from the Groundfish Committee: "*to request that the Executive Committee discuss convening a Working Group to identify and/or improve methods for using monitoring data in stock assessments to estimate stock biomass*." The Council discussed the Working Group at the December 2017 meeting to clarify that the Working Group was formed to explore the use of catch-per-unit-effort (CPUE) in stock assessments as an index of abundance. During the discussion of 2018 priorities, the following motion was adopted (emphasis added): "*to amend the priorities for Groundfish for 2018 to include all regulatory requirements and Amendment 23 and by clarifying that work on Amendment 23 includes utilization of workshops/expanded PDT meetings for development of technical elements i.e. EM, DSM etc. and <u>a working group to discuss the topic of how fishery-dependent data can be used to inform stock abundance</u>*."

In January 2018, the Council's Executive Director recommended that "*The Council and the NEFSC should convene a working group with four main deliverables:*

(1) Explain how fishery-dependent and fishery-independent data are used in stock assessments. This should include an explanation of how different data elements are used and interact in an age-based analytic assessment.

(2) Summarize the theoretical utility and limitations of using CPUE/LPUE as an index of abundance for Northeast Multispecies stocks. List recent (GARM III or later) efforts to create a CPUE for any of these stocks and the results of those efforts (i.e. successful/unsuccessful, used in analytic assessment, etc.).

(3) Without regard to existing fishing practices, regulations, or monitoring systems, identify the fishery factors and fishery-dependent data needed to create a CPUE that would be a reliable index of abundance for Northeast Multispecies stocks.

(4) *Compare the desired factors identified with existing conditions and data for the fishery. This should be a gap analysis of factors and data needed, as well as the analytical approaches necessary, to create a CPUE that would be a reliable index of abundance for Northeast Multispecies stocks.*"

A Working Group was formed with membership from New England Fishery Management Council staff, Science and Statistical Committee (SSC), Northeast Fisheries Science Center (NEFSC), NOAA's Greater Atlantic Regional Office (GARFO), university, state agency and NGO scientists as well as the fishing industry. Four meetings were held (April 26 2018, June 25 2018, August 6 2018, September 7, 2018; New Bedford MA) to review the expected deliverables, develop a work plan, review information relevant to deliverables and form recommendations. Meetings were open and contributions were welcome from all participants. Final recommendations were developed at the September 7th meeting and were reviewed on a conference call (November 2, 2018), and the consensus report was developed by correspondence.

Deliverable 1:

Explain how fishery-dependent and fishery-independent data are used in stock assessments. This should include an explanation of how different data elements are used and interact in an age-based analytic assessment.

1.1 Types of Stock Assessments

What are the types of stock assessments, and what data are used in them?

Several general approaches are used for assessments of New England groundfish stocks (NEFSC 2017, Table 1). The most informative stock assessments are age-based analytical assessments. However, assessments of some groundfish stocks are based on data-limited approaches, either because information is not sufficient to support age-based assessments or age-based assessments are not reliable.

Age-based analytic stock assessments rely on fishery monitoring information to estimate total fishery removals and age composition as well as fishery-independent data to provide indices of relative stock abundance and age distribution. Data-limited stock assessments rely on fishery monitoring information to estimate total fishery removals (and size distribution for some stocks) and fishery-independent data to provide indices of relative stock abundance or estimates of absolute stock abundance (and size distribution for some stocks). All stock assessments assume that estimates of fishery removals are accurate. Even data-limited stock assessments that are based on survey trends require some information on fishery removals to derive catch advice.

1.2 Data Used in Stock Assessments

What fishery-dependent and independent data are used in stock assessments?

Fishery-dependent data is collected through fishery monitoring, with the primary purpose of estimating removals. There are also many secondary objectives of fishery monitoring such as sampling size and age composition, estimating fishing effort, and estimating fishery catch rates. These objectives are achieved through collection of different fishery data elements:

- Dealer reports provide a census of landings, and Vessel Trip Reports (VTRs) provide a census of fishing effort by stock area, and the two are linked to derive landings by stock area.
    - Data for trip reports are either from paper logbooks or electronic vessel trip reports (eVTRs).
- At sea monitoring (at-sea monitoring program, ASM, and Northeast Fisheries Observer Program, NEFOP) is primarily used to estimate discarded catch.
    - Discards are quantified on observed trips and expanded to an estimate of discards on trips that do not carry an observer or at-sea monitor.

    - NEFOP observers collect biological information (size structure and age samples) from discarded fish in order to characterize the age structure of discards.
- Port samplers collect biological information (size structure and age samples) from landed fish in order to characterize the age structure of the kept catch.
- The Marine Recreational Information Program (MRIP) monitors catch and effort of recreational fisheries.
- Electronic Monitoring (EM) can be used in place of at-sea monitors to collect spatially specific information on fishing activity and discards. Several EM alternatives are currently under consideration through exempted fishing permits, but the programs are small (~10% of the active groundfish fleet) and relatively recent. EM is used to quantify discards for those vessels participating in experimental fishing permit programs, but is not currently used in assessments for purposes beyond catch accounting. EM data has the potential to be included in assessments for additional purposes in the future as these programs are ongoing.
    - In some cases, EM is used to estimate discards (audit or census approach). Cameras collect information on the number and size distribution of discarded fish, which is used to derive discard weight. The age structure of the discarded catch would need to be estimated based on the length frequency information. Haul level information on kept catch would be provided by the captain through an electronic vessel trip report.
    - In other cases, EM is used to verify that groundfish are not discarded at sea (maximum retention approach). In this instance, dockside monitors are used to quantify the magnitude of groundfish catch, and the catch is sampled dockside in order to collect biological information.
- Study fleet combines spatially explicit eVTRs with focused biological sampling.

Information from the various fishery monitoring programs are combined to determine landings and discards by species, statistical area, month, gear (and market category for landings); fishing effort by statistical area, month and gear; and length, weight and age by species, statistical area, month and gear.

Fishery-independent data is obtained primarily through research surveys, which are used to estimate relative or absolute stock abundance and sample for size and age through a planned sampling design. Surveys are usually conducted on research vessels using standardized, commercial fishing gear. Industry-based surveys involve commercial fishing vessels that are commissioned to conduct surveys, but industry-based surveys have had limited application in New England groundfish stock assessments.

1.3 How are Data Used in Stock Assessments

How are fishery-dependent and independent data used in stock assessments

1.3.1 Age-based Assessments

Age-based stock assessments estimate abundance of each yearclass in a population based on information from fishery monitoring programs and fishery-independent surveys. Fishery monitoring data is used to derive a time series of fisheries removals (commercial landings, commercial discards, recreational landings, and recreational discards) as well as the age composition of those removals. fishery-independent surveys or fishery catch rates are used to determine whether fishery removals came from a relatively abundant or a relatively depleted stock. Population models are fit to the available fishery and fishery-independent data to estimate a time series of stock abundance, age structure and fishing mortality. Some age-based models can fit to size composition data rather than age composition.

Data from several fishery monitoring programs are used to derive fishery removals for New England groundfish stocks. Commercial landings for each groundfish stock are derived from a merger of vessel trip reports and dealer reports. Age composition of commercial landings is derived from port samples of size and age distribution. Discard rates from observed trips are expanded to all trips to estimate commercial discards. Age composition of commercial discards is derived from observer samples of size and age distribution. Recreational catch and size composition is derived from the Marine Recreational Information Program. All of these estimates of removals and age composition are combined to derive total removals and age composition.

Estimates of fishery removals provide valuable information on productivity of the fish population. In the simplest sense, the scale of fishery removals is the minimum population estimate for each year, because there has to be enough fish in the population to support the estimated removals. So, the greater the removals, the greater the minimum population estimate. However, fish also die from natural causes, and many survive each year, so that the true population size is considerably greater than the estimate of fishery removals. The time series of removals offers information on sustained productivity, but more information is needed to determine if the estimated removals were produced by a relatively large stock or a relatively small stock.

Samples of size and age distribution of fishery catch are informative for estimating mortality rates and recruitment of young fish. More old fish in fishery samples can indicate relatively high survival and low mortality rates, whereas fewer old fish in fishery samples can indicate relatively low survival and high mortality rates. More young fish in fishery samples can indicate relatively strong recruitment. Tracking yearclasses through time helps to estimate recruitment and mortality from age composition. Fishery samples of age structure are also influenced by size and age selectivity (i.e., smaller-younger fish can escape fishing gear, and larger-older fish are more vulnerable to fishing). So, fishery-independent surveys of size and age distributions are also valuable for estimating recruitment and mortality rates.

An estimate of fishery removals provides a minimum stock estimate, but relative indices of stock abundance are needed to estimate the abundance associated with fishery removals. When abundance indices are relatively high, the estimated fishery removals are interpreted to have come from a relatively abundant stock, with relatively low fishing mortality. When abundance indices are relatively low, the estimated fishery removals are interpreted to have come from a relatively depleted stock, with relatively high fishing mortality.

Abundance indices are assumed to be proportional to stock size. If an index is to track stock abundance, then factors that might interfere with the relationship between index and stock (e.g., changes in vessel or gear characteristics) must be accounted for. Fishery-independent surveys are designed to standardize for vessel, fishing gear, fishing protocol, as well as time and area, and there are no attempts to increase fishing efficiency. When changes to survey protocols are introduced, they often involve experiments to evaluate the effect of the changes.

Fishery catch rates (catch per unit of effort, CPUE) are more difficult to standardize because fishing effort is based on individual fishing decisions within the constraints of regulations (e.g., choice of vessel, fishing gear, fishing protocol, time and area). Fishery regulations and individual choice complicate the use of fishery catch rates as abundance indices in stock assessments. As a result, fishery-dependent indices must be standardized after the data are collected using statistical methods.

Fishery-independent surveys and fishery-dependent CPUE are related to stock size, assuming that they are proportional to stock abundance, and that 'catchability' of the survey or the fishery is constant by age throughout the time series. 'Catchability' is a combination of fishing gear efficiency (i.e., the proportion of encountered fish that are captured) and availability of fish to the gear (i.e, the overlap of the fish population and the fishery or survey in space and time).

All age-based assessments of New England groundfish stocks use fishery-dependent data for catch estimates (landings and discards) and age composition, and fishery CPUE was traditionally used in many groundfish stock assessments, but fishery CPUE is not currently used in any of the New England groundfish stock assessments because of difficulties standardizing fishery CPUE.

Problems with using fishery CPUE were first identified in herring fisheries when purse seine indices of stock sizes were used in the assessment. The stock size indices remained stable as large herring fisheries off Norway, in the North Sea and on Georges Bank collapsed in the late 1960s and early 1970s. Catch per set proved to be a poor index of stock size, because catch per set is an index of school size, not an index of the size of the stock and did not take searching time into account. Catch per night or per day could have been better indices of abundance, but there was a strong movement to conclude that purse seine catch and effort data was useless as an index of stock size. There were also problems with technological changes (fish detection, power block etc.). Notwithstanding this, for one of the small herring stocks in Newfoundland, biomass estimates from an assessment using aerial surveys as an index of stock size matched the purse seine CPUE.

As an alternative to fishery CPUE, the Northeast Fisheries Science Center was a pioneer in using fishery-independent surveys for abundance indices, with the autumn survey starting in 1963, and the spring survey starting in 1968. The Canada Department of Fisheries and Oceans (DFO) started its summer surveys on the Scotian Shelf and in the Gulf of St. Lawrence in 1970 and off Newfoundland in 1978. The UK started its groundfish survey in the North Sea in 1975, and the European Union has been funding demersal surveys in the Mediterranean since about 1995.

fishery-dependent indices of stock size continue to be used in many stock assessments in the U.S. and worldwide. For example, tuna fisheries are distributed too widely to be surveyed. fishery-dependent indices of abundance are used regularly in Mid-Atlantic, South Atlantic, and Gulf of Mexico stock assessments. These fishery-dependent indices are constructed using gear or fleet-specific catch per unit effort (CPUE) data (e.g., commercial longline, recreational charter boat). Appendix 1 includes an explanation of the use of fishery-dependent indices of abundance in the Southeast Data and Assessment Review (SEDAR) process, as well as a worksheet developed in 2010 by Southeast Fisheries Science Center (SEFSC) staff to help evaluate both fishery-dependent and fishery-independent indices of abundance for inclusion in SEDAR stock assessments.

1.3.2 Empirical Approaches

Data-limited stock assessments in New England monitor relative or absolute stock abundance or biomass, and catch advice is based on information from fishery monitoring and fishery-independent surveys. Fishery monitoring data is used to derive a time series of fisheries removals (commercial landings, commercial discards, recreational landings, and recreational discards). fishery-independent surveys or fishery catch rates are used to determine whether the fishery removals came from a relatively abundant or a relatively depleted stock.

There are three general types of empirical approaches used to assess New England groundfish stocks: the survey expansion approach, the smoothed survey approach, and AIM (An Index Method). The survey expansion approach estimates a swept area biomass estimate from an average of spring and fall fishery-independent biomass indices. An exploitation rate, which is a function of recent catch estimates, is applied to the swept area biomass estimate to generate catch advice. The smoothed survey approach creates a smoothed biomass index from an average of spring and fall fishery-independent biomass indices. The proportional rate of change over the most recent three years of the smoothed index is estimated, and that rate of change is applied to average catch from the most recent three years to generate catch advice. In both approaches, fishery-dependent data are used to estimate total removals. The AIM approach differs from the other empirical approaches, because it directly incorporates fishery-dependent data. The AIM approach uses fishery-dependent annual catches and fishery-independent biomass indices to estimate relative fishing mortality rates and stock replacement ratios.

1.4 Northeast Multispecies Assessments

What types of assessments are used for Northeast groundfish stocks?

The 20 stocks of Northeast groundfish use both age-based analytical assessments and empirical approaches. As of the latest operational assessments conducted in 2017, eleven stocks had analytical assessments, and nine had other, including empirical, assessments (NEFSC 2017, Table 1). Table 2 provides a summary of data used from catch and survey information in each groundfish assessment for the 2017 Operational Assessments.

Table 1: Summary of 2017 Operational Assessments, including model type, estimates of biomasses and fishing mortality rates in 2016, and biological reference points for groundfish stocks. Note: Atlantic halibut is not included as the assessment for this stock was conducted in a separate process; Atlantic halibut has an empirical assessment (from NEFSC 2017).

Table 6: Summary of Operational Assessment estimates of biomasses and fishing mortality rates in 2016 and biological reference points for groundfish stocks. Reference points are not estimable for some stocks. Terminal biomass estimates for CODGB and YELGB are for 2017 rather than 2016.

Stock	Model type	B_{2016} (mt)	B_{MSY} (mt)	$\frac{B_{2016}}{B_{MSY}}$	F_{2016}	F_{MSY}	$\frac{F_{2016}}{F_{MSY}}$	MSY (mt)	ρ adj?	Comments
CODGM	ASAP (M=0.2)	3,046	40,604	0.08	0.228	0.17	1.31	7,049	No	
CODGM	ASAP (M-ramp)	3,262	59,714	0.05	0.237	0.18	1.34	10,502	No	
CODGB	Empirical	7.237			0.174				No	Smoothed survey indices used to estimate biomass
HADGB	VPA	290,324	104,312	2.78	0.309	0.35	0.88	24,372	Yes	
HADGM	ASAP	47,821	6,769	7.06	0.137	0.46	0.30	1,547	No	
YELCCGM	VPA	1,191	4,640	0.26	0.314	0.27	1.15	1,154	Yes	
YELSNEMA	ASAP	152	1,860	0.08	1.09	0.34	3.20	511	Yes	
FLWGB	VPA	3,946	7,600	0.52	0.117	0.52	0.22	3,500	Yes	
FLWSNEMA	ASAP	4,360	24,687	0.18	0.21	0.34	0.62	7,532	No	
PLAUNIT	VPA	13,351	13,503	0.99	0.111	0.22	0.51	2,924	Yes	
WITUNIT	Empirical	14,563			0.035				No	Average survey biomass, exploitation ratio used
REDUNIT	ASAP	359,970	247,918	1.45	0.011	0.04	0.29	9,318	Yes	
HKWUNIT	ASAP	21,276	30,948	0.69	0.066	0.18	0.36	4,867	Yes	
POLUNIT	ASAP (base)	183,907	105,510	1.74	0.036	0.26	0.14	19,427	Yes	Flat top selectivity model was used for sensitivity testing
POLUNIT	ASAP (flat top)	72,889	60,738	1.20	0.079	0.25	0.32	11,692	Yes	see above
CATUNIT	SCALE	652	1,612	0.40	0.002	0.22	0.01	232	No	
FLDGMGB	AIM	0.36	2.06	0.17	0.222	0.34	0.65	700	No	Biomass in kg/tow. F values reflect exploitation rate
FLDSNEMA	AIM	0.329	0.253	1.30	1.733	1.92	0.90	500	No	Biomass in kg/tow. F values reflect exploitation rate
OPTUNIT	Index-based	0.223	4.94	0.05	0.221	0.76	0.29	3,754	No	Biomass in kg/tow. F values reflect exploitation rate
FLWGM	Empirical	2,585			0.086	0.23	0.37		No	30+ cm biomass, exploitation ratio used
YELGB	Empirical	3,118			0.009				No	Average survey biomass, exploitation ratio used

Table 2: Summary of data used in each groundfish assessment for the 2017 Operational Assessments. Note: Atlantic halibut is not included as the assessment for this stock was conducted in a separate process (from NEFSC 2017).

Table 3: Data used in each assessment. The column heads are US commercial landings (US c-lnd), US commercial discards (US c-dis), US recreational landings (US r-lnd), US recreational discards (US r-dis), Canadian catch (CA cat), Northeast Fisheries Science Center spring, fall and winter surveys (NE S, NE F and NE W), Massachusetts spring and fall surveys (MA S and MA F), Maine/New Hampshire spring and fall surveys (ME/NH S and ME/NH F) and Canadian Department of Fisheries and Oceans February survey (DFO S).

	Catch					Surveys							
Stock	US c-lnd	US c-dis	US r-lnd	US r-dis	CA Cat	NE S	NE F	NE W	MA S	MA F	ME/NH S	ME/NH F	DFO S
CODGM	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	No	No	No
CODGB	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
HADGM	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No
HADGB	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	No	Yes
YELCCGM	Yes	Yes	No	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No
YELSNEMA	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	No	No	No
FLWGB	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	No	Yes
FLWSNEMA	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No
REDUNIT	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No	No	No
PLAUNIT	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No
WITUNIT	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No	No	No
HKWUNIT	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	No	No
POLUNIT	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No
CATUNIT	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	No	No	No	No
FLDGMGB	Yes	Yes	No	No	No	No	Yes	No	No	No	No	No	No
FLDSNEMA	Yes	Yes	No	No	No	No	Yes	No	No	No	No	No	No
OPTUNIT	Yes	Yes	No	No	No	Yes	No	No	No	No	No	No	No
FLDWGM	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No
YELGB	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	No	Yes

Table **3** provides a more detailed summary of the data components used in groundfish assessments, including the fishery-dependent and fishery-independent data sources that contribute to each of those components, and a description of the information provided by these data sources.

Table 3*:* A general description of data components used in SAW/SARC assessments, the data sources that contribute to each of those components, and a description of the information provided by those data sources. Age data typically are not available for commercial discards and recreational landings and discards. Therefore, age-length keys are borrowed from other sources for those components. Canadian catch and survey indices are provided by the Canadian DFO.

Data Component	Source	Description
Fishery-Dependent		
Commercial landings at age	Dealer reports	Landings
	VTR	Area allocation
	Port biological samples	Lengths and ages
Commercial discards at age	ASM	Discards
	NEFOP	Discards
	NEFSC surveys	Borrowed age-length keys
	Port biological samples	Borrowed age-length keys
Recreational landings at age	Angler intercept survey	Landings
	Coastal household survey	Angler effort
	NEFSC surveys	Borrowed age-length keys
	Port biological samples	Borrowed age-length keys
	Angler intercept survey	Discards

Recreational discards at age	Coastal household survey	Angler effort
	NEFSC surveys	Borrowed age-length keys
	Port biological samples	Borrowed age-length keys
Catch weights at age	Port biological samples	Lengths and ages
	NEFSC surveys	Length-weight relationship
Fishery-Independent		
Indices at age	NEFSC surveys	Survey catch
		Survey effort
		Lengths and ages
	State surveys	Survey catch
		Survey effort
		Lengths and ages
Maturity	NEFSC surveys	Maturity
Natural mortality	Varies by stock	Natural mortality

Deliverable 2:

Summarize the theoretical utility and limitations of using CPUE/LPUE as an index of abundance for Northeast Multispecies stocks. List recent (GARM III or later) efforts to create a CPUE for any of these stocks and the results of those efforts (i.e. successful/unsuccessful, used in analytic assessment, etc.).

2.1 Theoretical Utility and Limitations of CPUE and LPUE

Fishery catch per unit effort (CPUE), or landings per unit effort (LPUE), is often considered to be proportional to stock abundance. However, this assumption is only valid in some situations. In a fishery-independent survey, information is collected using a rigid sampling design, with a focus on standardization of collection methods, representativeness of stations, stratification, and known or estimated 'inclusion probabilities' (i.e., the chance of each population unit being sampled). The resulting index is assumed to be a function of the sampling design alone, and does not consider variation in capture efficiency or availability. In general, high capture probabilities will result in more precise estimates of abundance since measurement error will be reduced, and this principle is often used to justify the use of commercial fishing vessels for surveys. However, it is equally important to consider the other factors of a scientific survey that allow the sampled population to represent the unsampled population.

One of the most important features of a scientific design is that inclusion probabilities are known. Typically, the probability of a particular station is known and every location within a stratum has an approximately equal probability of being sampled. All surveys have some minor violations of perfect random sampling (e.g., untowable bottom, increasing conflicts with fixed gear), but such violations are assumed to be negligible. In a commercial fishery, the inclusion probabilities are far from equal, because fishing effort is usually where the fish are, and one or more vessels repeatedly fish at the same location. Such samples provide useful information on the local abundance of the resource, but they may not represent areas outside of the fishing grounds. For more information on this topic, Sarndal et al. (1992) provide a general explanation of inclusion probabilities and the role they play in survey sampling. For real world examples, Smith et al. (2009) and Smith et al. (2017) discuss inclusion probabilities as they relate to the sampling of sea scallops. The Marine Recreational Information Program (MRIP) website explains how they use inclusion probabilities, which they refer to as selection probabilities, to generate recreational catch estimates (https://www.st.nmfs.noaa.gov/recreational-fisheries/Understanding-Estimation/estimation-methods).

A fishing fleet includes a mixture of vessels with variations in the abilities to capture fish. Therefore, catchability of the fleet varies over time of year, area fished, weather conditions and many other factors (Maunder et al. 2006). These factors increase the variability of fishery CPUE and can make it difficult to extract an index of stock abundance from the variability. This difficulty was recognized as early as the mid 1950's. Beverton and Holt (1957) identified some of the factors influencing CPUE, particularly the importance of spatial fishing patterns. Statistical models are commonly used to derive an index of abundance by standardizing other factors of variability in CPUE (e.g., Maunder and Punt 2004). Similar to fishery-independent survey designs, standardized CPUE indices can be biased or difficult to estimate. Model development can be complicated and models often do not explain much of the variability in CPUE.

Fishery CPUE and fishery-independent survey indices may not be correlated, because of the disparity between the objective of maximizing profits under continually changing resource abundance, regulatory constraints, prices and costs and the objective of conducting a fishery-independent survey with known inclusion probabilities. The entire purpose of standardization methods is to account for the underlying factors in CPUE and isolate and abundance index.

2.2 Use of CPUE in Stock Assessments in the Greater Atlantic Region

Summaries of fishery CPUE as an index of abundance have recently been prepared by Hennen (2018, Appendix 2) and O'Keefe et al. (2015, Appendix 3). Both reports address the overall use of CPUE in regional stock assessments. O'Keefe et al. (2015) provide more details on the rationale for inclusion or exclusion of CPUE as documented in the stock assessment reports and also makes recommendations for future work. Below we provide a summary of CPUE/LPUE usage in some key groundfish stock assessments.

Cod (Gulf of Maine) - CPUE was used as an index in the stock assessment model before 2012. After the 2011 Gulf of Maine cod assessment, the Scientific and Statistical Committee (SSC) identified CPUE as one of four topics that warranted further investigation. SSC members did not agree on whether CPUE should be used as an index of abundance to tune the stock assessment, with some supporting the idea and others considering it inappropriate. The cod benchmark assessment included a CPUE working group that was convened in August 2012 in Gloucester, MA. As a result of that meeting, several analyses were prepared, including an LPUE index for the commercial fleet and another for the recreational fleet. A report from the workshop concluded that neither commercial, nor recreational CPUE was a useful index of abundance, because cod became aggregated in the Gulf of Maine in the late 2000's and catch rates increased while abundance declined.

Cod (Georges Bank) - LPUE was not used as an index of abundance in the stock assessment model, but was estimated prior to 1998. The 2012 Working Group (see above) re-examined CPUE as an index and concluded neither commercial, nor recreational LPUE was a useful index of abundance. Management changes beginning in 1994 changed the spatial pattern of the fishery, effectively breaking the time series. In addition, the LPUE index included only US landings while the stock straddles the Hague line. The recreational LPUE index was not considered representative due to small sample size as well as the cross boundary issues concerning fish landed in Canada.

Witch flounder - LPUE was included in stock assessments until 1999, but LPUE was excluded from the stock assessment model in 1999 because of uncertainty associated with the 1994 change in effort reporting. In 2015 the NEFSC partnered with GMRI to hold a series of meetings throughout New England designed to improve the stock assessment process and data streams feeding into the assessments. The series culminated with a workshop in November 2015. One of the outcomes of that workshop was the funding (by the NEFMC, NEFSC, and EDF) of a research project to develop a groundfish CPUE index for the 2016 witch flounder benchmark assessment. Alternative series of CPUE were developed for consideration in the SAW62 witch flounder stock assessment. Based on reports of recent avoidance behavior, catch rates of targeted fishing effort were derived from dealer records of LPUE from trips that caught >=40% witch flounder and observer records of a target fleet in the western Gulf of Maine. The standardized catch rate series have similar trends, but the dealer data had some statistical challenges and the observer data did not have adequate sample size in some years. A series of standardized dealer LPUE for trips with >=40% witch flounder was the preferred CPUE index (Cadrin and Wright 2016). The dealer-logbook series was included in a sensitivity run for the analytic SCAA model that was ultimately not accepted by the peer review panel.

White Hake - LPUE was used in stock assessments before 2012. Multiple LPUE series from gillnets and trawls were examined for the 2012 benchmark. The LPUE series were not expected to perform well due to area closures and other management changes affecting effort. The index showed different trends when only directed trips (as opposed to all trips, or all trips where some threshold proportion of the total landings were white hake) were used to determine effort. Some, but not all, of the variants of the LPUE index correlated well with the survey trends, but there was little interest in using it in the model and it was dropped. Although the LPUE series were not included in the stock assessment model, they were more strongly correlated to the stock estimates than fishery-independent survey indices (O'Keefe et al. 2015) suggesting that they were accurate indicators of relative stock size despite the concerns about closed areas and other management changes.

Haddock (Gulf of Maine) - LPUE was not used as an index of abundance in the stock assessment model, but was examined by the 2012 Working Group. LPUE was not considered a reliable index of stock abundance by the Working Group. It was not possible to clearly define effort for this stock since it was difficult to tell which trips were targeting haddock. LPUE trend was not correlated with the other indices of abundance used in the assessment model.

Haddock (Georges Bank) - CPUE was included in early stock assessments, but has not been included in stock assessment models since 1998.

Pollock - CPUE was examined in 2010, but not used in assessment. CPUE was not used in the assessment because of limitations in the calculation of effort due to regulatory changes over time (Days at Sea limits, closed areas, etc…).

Yellowtail flounder - CPUE was included in early stock assessments, but has not been included in stock assessment models since 1991. CPUE was examined in 2012, but an index of abundance could not be created, due to complications resulting from the changing management regime (closed areas, DAS regulations, etc…) and the shift from a directed fishery to a bycatch fishery which made calculation of effort intractable.

Redfish - CPUE was used as an index of abundance until the 2008 assessment. The CPUE index was abandoned in the 2008 assessment because of a sharp reduction in directed redfish trips.

Halibut - Halibut is a data-poor stock, and the 2017 assessment was unable to determine stock status. Funding by the NEFMC, NEFSC, and EDF supported a research project to develop a groundfish CPUE index for halibut. Halibut fishermen from Maine were interviewed and surveyed to determine the factors that influence halibut catch rates, and the identified factors were incorporated as predictor variables in the CPUE standardization process. Results suggested stable or increasing catch rates from 2002–2017, and the influence of location, soak time, depth and month on halibut CPUE (Hansell et al. 2018). The CPUE series could serve as an input for future analytical assessment models.

In general, commercial CPUE was included in many stock assessments up to the mid 1990's. Usage increased in the late 1980's particularly following the development of CPUE standardization methods (Gavaris 1980). The standardization method allowed investigators to identify and standardize the effects of area, vessel class, and season on CPUE. The absence of interactive effects with year and selection of cases based on percent of total catch can produce biased results (Appendix 4). Subsequent improvements in statistical methods eliminated many of the problems with earlier methods but do not address issues of excluding observations of low CPUE.

The implementation of mandatory Vessel Trip Reports in 1994 resulted in a sharp break in the use of CPUE in stock assessments. Attempts to reconcile earlier CPUE metrics from Port Agent interviews met with limited success, and the absence of any formal overlap in methodologies precluded estimation of calibration factors. If stock conditions and regulations had remained constant, the new VTR could have constituted a new time series of relative abundance metrics. Unfortunately, increasingly stringent management measures, particularly for groundfish, further compromised the use of commercial CPUE. For example, the closures of large areas on Georges Bank and in Southern New England resulted in the displacement of vessels to other areas. Such management changes created a year-area interaction effect.

Fisheries management measures from the mid-1990s to mid-2000's included trip limits, a series of fine-scale effort controls, and vessel buy-back programs. Fishermen, often in collaboration with science partners, introduced various gear modifications to alter the selectivity of species, particularly in trawls. Interactions with protected species led to modifications of mesh sizes, especially in gillnet fleets. Not all of these changes were adequately captured in the VTRs, especially when conservation-oriented gears were employed. Assuming that the catchability effects of the modified gears observed in experiments were realized in actual fishing conditions, the consequence of not recording the changes would be to increase the variability of CPUE observations.

Perhaps the biggest change occurred when groundfish sectors were introduced, for the majority of the groundfish fleet, in 2010. Annual catch limits were imposed, and fisherman could choose to participate in sectors to trade quotas and adjust effort to meet economic objectives. Based on historical catches of individual vessels, a portfolio of total catch was assigned to each sector. The uneven biological production of various species created huge disparities in relative abundance and subsequent catch limits. As many species co-occur the inability to selectively harvest abundant species without exceeding catch limits on depleted stocks led to the concept of "choke species". These conditions led to further distortions of CPUE as fishermen tried to avoid "choke species". Selecting targeted fishing effort (e.g., by identifying a spatial and seasonal 'footprint' of targeted fishing effort) can be used to derive a CPUE index of abundance by filtering out avoidance behavior.

Collectively, these factors led to the exclusion of CPUE in groundfish stock assessments. Examination of fishery-dependent CPUE and comparison with fishery-independent measures has been informative, especially for Gulf of Maine cod, where concentration of the fishery on a shrinking footprint was evident in both types of surveys. The exclusion of CPUE when multiple changes occur is not exclusively an East Coast phenomenon. On the west coast, CPUE usage in models decreased around 2000 as summarized in Fields et al. (2006): *"In practice however, fishery CPUE data are often considered suspect as an index* *of stock abundance for a variety of reasons. For example, catch rates may be stable in the face of stock declines as a result of increasing fishing power or changing spatial patterns in effort (Hilborn and Walters 1992; Walters 2003). Furthermore, management measures can substantially alter the integrity of fishery-dependent data, particularly for resources that are considered overfished or depleted and consequently become subject to efforts by managers to reduce or control catches. For example, in response to declines in rockfish abundance, trip limits off the USA West Coast have become increasingly restricted over time (e.g. Fig. 2), culminating in complete non-retention of some species and massive closures of habitat in recent years. As a result, for all but one of the nine assessments in Table 1 that included commercial CPUE indices, the index was truncated by 2000 because of difficulties interpreting catch rates given the impact (perceived or otherwise) of regulatory changes. CPUE indices based on data from recreational fishers have largely continued to be used for several West Coast groundfish assessments where fishery-independent surveys are lacking or particularly imprecise. Standardization of these CPUE data typically involves analysis of the spatial (depth) and temporal (seasonal) restrictions that primarily affected catch rates in these fisheries (Maunder and Punt 2004; Stephens and MacCall 2004) so there is some confidence that the standardized annual index represents the trend in stock abundance."* However, contrary to the summary in this excerpt from Field et al. (2006), CPUE is still used in many U.S. west coast stock assessments (e.g., gopher rockfish, vermilion rockfish, yellowtail rockfish, yelloweye rockfish, Bering Sea pollock, …).

2.3 Potential Utility of CPUE and LPUE

Although limitations have been identified, there is potential utility of CPUE in the assessment process, perhaps outside of formal models. CPUE provides greater spatial and temporal resolution than fishery-independent surveys (e.g., year-round versus snapshots) and a large increase in the number of observations feeding into the model. Groundfish assessments have been performing poorly, and some surveys have been delayed or curtailed due to vessel problems. The use of a CPUE series may help to stabilize model trends and outputs, resolve conflicting trends in the models, and could improve model performance during a time when there were major changes to survey operations, and to the groundfish management structure. There is also recognition that use of CPUE in assessments may improve industry buy-in to model results, and greater value added from monitoring. For CPUE to be considered as an index of abundance in stock assessment models, CPUE must be standardized sufficiently to account for changes in vessel efficiency, gear selectivity, targeting/avoidance behavior, inclusion probabilities, spatial aggregation of fish, and hyperstability.

Fishery-dependent CPUE data can have uses in an assessment beyond serving as an index of stock abundance. For example, a CPUE index can provide a perspective of what the fishery sees regarding a particular stock, which can be compared to what a scientific survey index reveals about that stock. Such a comparison could serve as a springboard for exploring factors (e.g., changes in the distribution of fishing and survey effort over time) that might explain perceived differences between the two indices.

Deliverable 3:

Without regard to existing fishing practices, regulations, or monitoring systems, identify the fishery factors and fishery-dependent data needed to create CPUE that would be a reliable index of abundance for Northeast Multispecies stocks.

The Fishery Data for Stock Assessment Working Group identified the following fishery factors and fishery-dependent data that are needed to create a CPUE to be a reliable index of abundance for Northeast Multispecies stocks. The answer to the Council's question was approached by initially identifying ideal conditions for developing CPUE series that can accurately index stock abundance so that these ideals can be considered in the monitoring plan.

3.1 Homogeneous fleet

For an ideal CPUE for Northeast multispecies stocks, each vessel and each unit of fishing effort would have the same fishing power (i.e., the fishery fleet would be homogeneous across the entire stock area of a particular species or suite of species, and would be homogeneous with respect to vessel size, fishing power, gear used, captain skill level, and seasonality). The fleet would have been operating in the same manner throughout the desired time period for the CPUE. However, some of these factors may be beyond what is needed to create an informative CPUE series. For example, vessel size, area and season effects can be standardized, and the factor of similar captain skill level does not necessitate that this be the same captain fishing throughout the time period, as even captains' experience levels change over time. Past information could be used to develop homogeneous fleets from preexisting data to calculated historical CPUE or to work with current vessel operators to develop homogeneous fleets for CPUE moving forward.

3.2 Target species and avoidance species information

Critical fishery-dependent data needed for developing a CPUE is accurate target species information, because the targeted trips are used to estimate the effort component (i.e., the denominator) of the CPUE equation. Equally important is accurate avoidance species information, because including trips that avoid the target species in your CPUE analysis might negatively bias the resulting indices. Target species should be single species, unless the fleet is truly targeting multispecies stocks, and is not avoiding certain stocks. Target and avoidance species should be known before fishing begins to avoid specifying targeting based on what was caught after the fact.

3.3 Accurate Catch Information

Accurate, well-reported catch (landings and discards) information is needed for developing a CPUE for groundfish stocks. Catch data that is misreported or poorly reported will not produce a useful CPUE index. Although a census of catch can be informative, it is not required, because CPUE is a relative index. For example, observer data can be used for information on catch and catch rates. It is most useful for discard estimates, as kept/landed catch information is not the primary target of observer data collection (NEFSC FSB 2016). Observer data is the only method currently available for quantifying the magnitude of discards. However, electronic monitoring is currently being evaluated as an alternative or supplement to observer data through Exempted Fishing Permits, and in the future if adopted for wider use by the fleet, could be used for discard estimates as well. In practice, VTRs are useful only for landings and LPUE.

3.4 Understanding of Effort

An understanding of fishing effort is needed to develop a CPUE for groundfish stocks. This includes information on the fishing gear used and fishing power of the vessel. Gear information should be as specific as possible, and should note gear modifications with conservation objectives (e.g. haddock separator trawl, Rhule trawl). It is necessary to know both historical fishing effort and current fishing effort. Like catch data, accurate effort data is essential for creating a useful CPUE index. Vessel efficiency ideally would be stationary across time and space, or changes in vessel efficiency would need to be standardized. An appropriate unit of fishing effort is needed for each type of fishery. For example mobile gear effort can be measured in time (e.g., hours towing) or area swept, but fixed gear requires alternative units of effort (e.g., soak time, number of hooks, length of gillnets, …).

3.5 Fine Scale (tow-by-tow) Effort and Location Information

To create a CPUE for groundfish stocks, it is ideal to have tow-by-tow information. Catch and effort data can always be aggregated at the trip or higher level, but cannot be disaggregated if data at the tow level is not collected. Tow-level data is particularly important if a vessel targets different species on different tows within the same trip. In this case, the trip level information will simply be an average of the vessel's effort across the range of target species, and not be useful for creating a CPUE.

3.6 Inclusion Probability

The inclusion probabilities for observations from a fishery (i.e., the probability that fish at a given location will be sampled) should be known to construct a CPUE index. These inclusion probabilities are used to weight the observations so that observations from areas of high fish density, which are repeatedly sampled by the fishery, are not given undue weight in the CPUE calculations compared to areas of lower fish density, which may be sampled rarely or not at all by the fishery. Ignoring the inclusion probabilities (i.e., assuming they are equal across the entire distribution of the stock) could lead to positively biased estimates of CPUE, because the CPUE estimates would be based primarily on repeated observations from high fish density areas, where fishing effort is concentrated. It would be like repeatedly sampling the population of New York City, and assuming those observations could be used to estimate the population density of the entire United States.

Deliverable 4:

Compare the desired factors identified with existing conditions and data for the fishery. This should be a gap analysis of factors and data needed, as well as the analytical approaches necessary, to create a CPUE that would be a reliable index of abundance for Northeast Multispecies stocks.

4.1 Introduction

The mismatch between fishermen's perceptions of what fish stocks are available on their fishing grounds and results from recent assessments for several New England groundfish stocks has caused a renewed interest in examining the use and utility of CPUE in assessments. Fishermen generally have a greater trust in the information they collect and a greater understanding of catch and effort statistics than fishery-independent data and model results. Additionally, fishermen may be able to accurately identify trends in catch rates based on historical knowledge of spatial and temporal species distributions, marketability, and business planning. A large amount of fishery-dependent data is currently collected from fishermen participating in the Northeast multispecies fishery (see Table 4), but indices such as LPUE and CPUE have not been used in recent groundfish stock assessments. This results from limitations of the current data streams (data resolution, potential bias) and limitations of the assessment process (limited time, and resources), and challenges posed by current conditions in the groundfish fishery compared to the ideal factors needed for a CPUE (e.g., avoidance behavior). We provide an overview of the existing data, identify gaps, and challenges, and provide recommendations for the enhanced use of fishery-dependent data to inform stock assessments.

Table 4: Types of fishery-dependent data collected from required reports for the Northeast Multispecies complex (O'Keefe et al., 2017).

Data Type	Vessel Trip Report (VTR)	Vessel Monitoring System (VMS)	Dealer Report	Observer Reports (NEFOP)	At-Sea Moinitoring (ASM)	Dockside Monitoring
Vessel Permit	X	X	X			X
Operator Permit	X	X				
Area Fished (statistical area)	X					X
Area Fished (Lat/Lon)		X		X	X	
Time Fished	X	X		X	X	
Landed Species (for sale)	X		X	X	X	X
Landed Species (not sold)				X	X	
Discarded Species	X			X	X	
Species Disposition				X	X	
Landing Date			X	X	X	X
Landing Port			X	X	X	X
Dealer Demographics			X			
Market Category			X			
Landed Species Price			X			
Tow Duration		X		X	X	
Steaming Time		X				
Vessel Characteristics				X	X	
Gear Characteristics				X	X	
Target Species				X	X	
Biological Information				X		

The fishery monitoring system includes the process for deciding the sampling rates (e.g., the portion of trips sampled by observers, the number of port samples), the selection processes for samples, fishery definitions, data collection, data analysis, communication and data access. The current fishery monitoring system was designed to meet many evolving objectives (e.g., enforcement, monitoring, stock assessments, and facilitation of other management requirements). The current fishery-dependent data collection programs were developed based on a sequence of changing needs, so the result is a complex system, with many redundant data streams, that may not be optimal to meet current needs.

4.2 Overview of Current Fishery-Dependent Data Collection Systems and Identification of Gaps

Fishery-dependent data involves the standardized collection of information from fishing operations. Landings from commercial fisheries are monitored through a census of dealer records and mandatory vessel trip reports (VTR/eVTR) from fishermen. State landings also contribute to the total observed removals. The biological attributes of landings are monitored by port agents who collect length and age samples. Federal and industry-funded observers collect data on species composition, and the amount, size, and age composition of catch (landings and discards) at sea on commercial fishing vessels. In the recreational fishery, both landings and discards must be estimated from samples. In addition, social and economic data are collected through a variety of surveys that target specific segments of the fishing industry (crew, owners). These socio-economic surveys provide insights into the costs, wages and wellbeing. In the following sections the various fishery-dependent data collection programs, their strengths, and limitations relative to CPUE, are described in relation to the Northeast multispecies fishery.

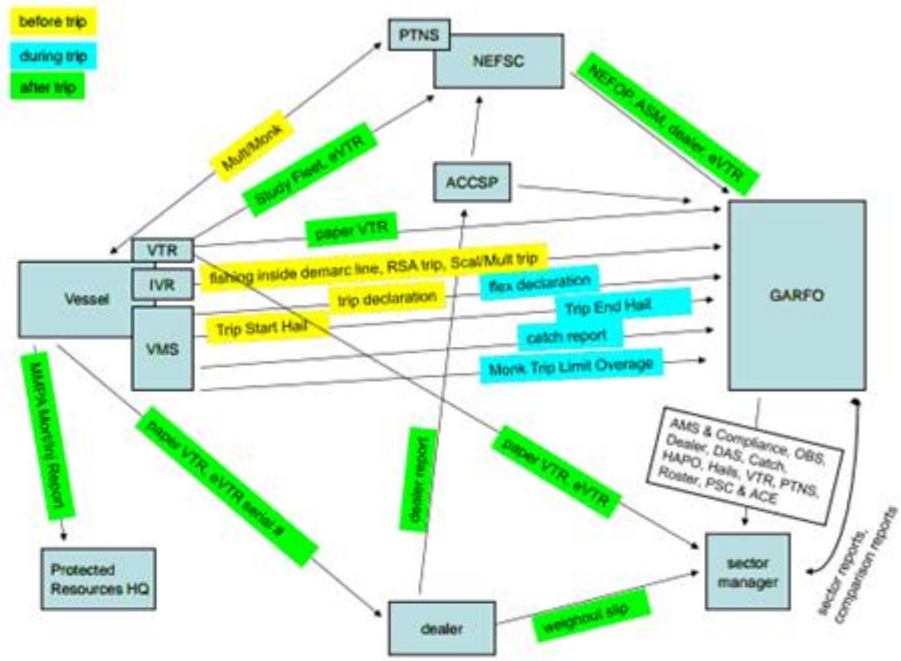

Figure 1: Fishery-dependent data flow chart for northeast multispecies Sector vessels, developed for the Northeast fishery-dependent Data Visioning Workshop (Figure credit: Daniel Salerno, fishery-dependent Data Mapping Exercise).

4.2.1 Observer Program

The Fisheries Sampling Branch (FSB) at NEFSC collects, maintains, and distributes data from fishing trips that carry at-sea monitors. FSB manages two separate but related monitoring programs: the Northeast Fisheries Observer Program (NEFOP) and the At-Sea Monitoring (ASM) Program. Although each program is tailored to meet specific monitoring objectives, the programs function similarly.

Table 5: Comparison of the duties and requirements for ASM Monitors and NEFOP observers.

Tasks and Requirements	**ASM Monitor**	**NEFOP Observer**
Program Objective	Groundfish Sector Catch Accounting	SBRM Discard Estimation
Bachelor's Degree	No (high school diploma or equivalency)	Yes
NMFS Training Duration	11 days	15 days
Data Collection	Basic & Focused	Advanced & Diverse (more logs/sheets, higher complexity, greater variety)
Biological Sampling	Length frequencies of certain key fish only (few physical samples)	High degree and diversity of catch sampling, including collection of biological samples and necropsies of mammals, turtles, birds, fish, and crustaceans
Amount of Gear Issued	45 items	85 items
Supplemental Research Projects	No	Yes

Observer Responsibilities

- Conduct a pre-trip safety inspection;
- Communicate observer duties and data collection needs with vessel crew;
- Collect economic information, such as trip costs (i.e. price of fuel, ice, etc…);
- Collect fishing gear information (i.e. size of nets and dredges, mesh sizes, and gear configurations);

- Collect tow-by-tow information (i.e. depth, water temperature, wave height, and location and time when fishing begins and ends);
- Record all kept and discarded catch (fish, sharks, crustaceans, invertebrates, and debris) on observed hauls (species, weight, and disposition)
- Record kept catch on unobserved hauls (species, weight, and disposition);
- Collect actual catch weights whenever possible, or alternatively, weight estimates derived by sub-sampling;
- Collect whole specimens, photos, and biological samples (i.e. scales, ear bones, and/or spines from fish, invertebrates, and incidental takes); and
- Assemble information on interactions with protected species, such as sea turtles, porpoise, dolphins, whales, and birds.

The observer's goal is to collect actual weights whenever possible, and alternatively, weight estimates using a variety of subsampling methods when collection of actual weights is not possible. The Northeast Fisheries Science Center Fisheries Sampling Branch Observer Operations Manual provides detailed sampling priorities for each fishery. In general, observers' first priority is to collect actual weights on priority discards (for ASM, these are groundfish species, and for NEFOP, these are groundfish, commercially important species, and target species). Next, observers should collect actual weights on non-priority discards, followed by actual weights or estimates of kept catch.

The NEFOP program's resources are finite, and FSB relies on national priorities (endangered or protected species), fishery management priorities determined by the New England and Mid-Atlantic Fishery Management Councils, and scientific priorities related to stock assessments to determine priorities for the NEFOP observer program. These program priorities, and the Standardized Bycatch Reporting Methodology (SBRM) that identifies relative fleet contribution to discards, guide the allocation of NEFOP coverage resources to fishing trips. Federally-funded observer coverage proved by NEFOP to meet SBRM requirements partially satisfies the total monitoring coverage for groundfish sectors. Sectors are required to design, implement, and pay for any portion of trips not covered by NEFOP. The Council has modified the monitoring requirements for Northeast multispecies sectors several times since they were established in Amendment 16 to the Northeast Multispecies Fishery Management Plan, most recently in Framework 55, which became effective on May 1, 2016. The updated regulatory requirements related to the monitoring coverage rate standard are found at 50 CFR 648.87(b)(1)(v)(B) and require that:

> 1. Sampling coverage must be sufficient to at least meet the precision standard specified in the Standardized Bycatch Reporting methodology, a 30% coefficient of

variation, at the overall stock level for each stock of regulated species and ocean pout and to monitor sector operations, to the extent practicable, in order to reliably estimate overall catch by sector vessels;

2. Sampling coverage shall reflect the primary goal of the program, to verify area fished, as well as catch and discards by species and gear type, in the most cost-effective means practicable, as well as the other goals and objectives;

3. Sampling coverage will be based on the most recent 3-year average of the total required coverage level necessary to reach the required coefficient of variation for each stock;

4. Sampling coverage that will apply is the maximum stock-specific level after filtering out healthy stocks;

5. Healthy stocks are defined as those in a given fishing year that are not overfished, with overfishing not occurring according to the most recent available stock assessment, and that in the previous fishing year have less than 75 percent of the sector sub-ACL harvested and less than 10 percent of catch comprised of discards.

The total monitoring coverage, ultimately, should provide confidence that the overall catch estimate is accurate enough to ensure that sector fishing activities are consistent with National Standard 1 requirements to prevent overfishing while achieving on a continuing basis optimum yield from each fishery. However, the precision target of the Standardized Bycatch Reporting Method does not account for 'observer bias' (i.e., observed trips do not represent unobserved trips because of difference in fishing behavior).

Table 6: Target and realized coverage rates for groundfish sectors, fishing years 2010-2017.

Fishing Year	NEFOP target coverage level	ASM target coverage level	Total target coverage level	Realized coverage level
FY 2010	8 %	30 %	38 %	32 %
FY 2011	8 %	30 %	38 %	27 %
FY 2012	8 %	17 %	25 %	22 %
FY 2013	8 %	14 %	22 %	20 %
FY 2014	8 %	18 %	26 %	25.7%
FY 2015	4 %	20 %	24 %	19.8%
FY 2016	4 %	10 %	14 %	11.1%
FY 2017	8 %	8 %	16 %	n/a*

For more information on these programs:

https://www.greateratlantic.fisheries.noaa.gov/ro/fso/reports/Sectors/ASM/FY2018_Multispecies_Sector_ASM_Requirements_Summary.pdf

4.2.2 Fishing Vessel Trip Reports (Logbooks)

The vessel owner or operator of any vessel issued a valid Federal fishing permit (or one who is eligible to renew a limited access permit) must maintain on board the vessel an accurate fishing log. The owner/operator is also required to submit to NMFS, for each fishing trip, a report regardless of the species taken. If no fishing trip is made during a week or month a report stating that must be submitted to NMFS. With the exception of vessels fishing under a surf clam or ocean quahog permit, at least the following information and any other information required by the Regional Administrator must be provided: Vessel name; USCG documentation number (or state registration number, if undocumented); permit number; date/time sailed; date/time landed; trip type; number of crew; number of anglers (if a charter or party boat); gear fished; quantity and size of gear; mesh/ring size; chart area fished; average depth; latitude/longitude (or loran station and bearings); total hauls per area fished; average tow time duration; hail weight, in pounds (or count of individual fish, if a party or charter vessel), by species, of all species, or parts of species, such as monkfish livers, landed or discarded; dealer permit number; dealer name; date sold, port and state landed; and vessel operator's name, signature, and if applicable the operator's permit number (50 CFR 648.7).

A new VTR is required to be completed each time a vessel changes gear type, mesh size, or statistical area during a fishing trip. All species caught, including all protected species, are required to be reported on the FVTR.

Table 7: Data collected in each FVTR (Credit: SBRM Omnibus Amendment)

Vessel, crew, operator	**Gear**	**Commercial Catch**
Vessel name	Gear type	Pounds kept (by species)
USCG documentation number	Quantity and size	Pounds discarded (by species)
or State registration number	Mesh/ring size	Sea turtle incidental take
Federal permit number		Skates by size category
Number of crew	**Location**	
Number of anglers (charter/party)	Chart area (statistical area)	**Charter/Party Catch**
Vessel operator's name	Average depth	Number kept (by species)
Signature of vessel operator	Latitude/longitude *or*	Number discarded (by species)
	Loran station and bearings	
Trip Information		**Sale/Landing**
Date/time sailed	**Effort**	Dealer permit number
Date/time landed	Number of hauls	Dealer name
Commercial *or* charter/party trip	Tow/soak time duration	Date sold
		Port and state landed

Limitations of the initial VTR data sets were described by the SARC in 1996 (NMFS 1996). Since then, many of these limitations have been addressed. In particular, subsequent peer reviews through numerous SARCs and a review by the National Research Council (1998) have identified the strengths, weaknesses, and appropriate uses of the VTR data from the Northeast. VMS data can be used as a tool to monitor the accuracy and completeness of VTRs, and guide efforts to improve VTR compliance, but such evaluations of VTRs are rare. The number of vessels which are potentially underreporting statistical areas on a frequent basis is small relative to the total number of vessels submitting VTRs. Improvements are needed in the compliance of VTR reporting regulations, particularly among those vessels likely to be fishing on multiple fish stocks. Given the manageable size of the problem and availability of tools to monitor these data, the quality of self-reported data should be monitored and improved through targeted outreach and education activities.

4.2.3 Dealer Reports

Since May 1, 2004, all federally permitted seafood dealers, or any individual acting as a dealer, have been required to submit weekly electronic purchase reports to NMFS. The reports are required to provide a detailed report of all fish purchased or received for a commercial purpose, other than solely for transport on land (50 CFR 648.7). Specifically dealer purchase reports are required to include the; dealer name; dealer permit number; name and permit number or name and hull number (USCG documentation number or state registration number, whichever is applicable) of vessel(s) from which fish are purchased or received; trip identifier for each trip from which fish are purchased or received from a commercial fishing vessel; date(s) of purchases and receipts; units of measure and amount by species (by market category, if applicable); price per unit by species (by market category, if applicable) or total value by species (by market category, if applicable); port landed; cage tag numbers for surf clams and ocean quahogs, if applicable; disposition of the seafood product; and any other information deemed necessary by the Regional Administrator. If no fish are purchased or received during a reporting week, a report so stating must be submitted. Dealer purchase reports are compiled and submitted to NMFS through one of two approved software packages specifically developed for this purpose or through a file upload process. Although total landings derived from dealer reports are assumed to be a census of fishery landings, recent violations document substantial mis-reporting. The magnitude of misreporting and resulting bias in estimates of landings are unknown.

Dealer reports are assumed to be the best source for comprehensive estimates of total landings and the resulting revenue generated. They can be used by the dealers for tax preparation purposes and as legal documentation of the purchase and sale of the landed catch.

Starting in 2012, in addition to dealer purchase reports, dealers, or any person acting in the capacity of a dealer, that purchases fish from a vessel enrolled in a sector, or the common pool must provide “a copy of any weigh-out documents or dealer receipts for that particular offloading event to the dockside monitor and vessel and allow the dockside monitor to sign a copy of the official weigh-out document or dealer receipt retained by the dealer, or sign a dockside monitoring report provided by a dockside/roving monitor that verifies the amount of each species offloaded, as instructed by the Regional Administrator”. Dockside monitoring is no longer required.

4.2.4 Study Fleet Program

The Cooperative Research Study Fleet program at the Northeast Fisheries Science Center collects self-reported catch (landed and discarded) from commercial vessels with electronic logbooks. The Study Fleet program was initiated in 2002 with the dual objectives of: (1) assembling a study fleet of commercial New England groundfish vessels capable of providing high resolution (temporal and spatial) self-reported data on catch, effort and environmental conditions while conducting normal fishing operations; and (2) developing and implementing electronic reporting hardware and software for the collection, recording, and transferring of more accurate and timely fishery-based data (GMA 2001, Palmer et al. 2007). The program also provides an opportunity for fishermen and scientists to work in partnership on various research projects, fosters a collaborative relationship and gives industry members a stake in the science being conducted by the Northeast Fisheries Science Center.

The Study Fleet program has evolved through three phases. Phase I focused on development of the electronic logbook software and concurrent hardware testing. Phase II began in September 2004 and expanded the size of the fleet while continuing testing, evaluation, and refinement of the software. Phase III began in 2006 and continues to the present, with further improvements and emphasis on data transmission methods including wireless, gathering additional oceanographic data, and data feedback loops for fishermen. The current Study Fleet (Phase III) is a fully functioning program of over forty paid participant vessels electronically reporting tow level fishery-dependent data during normal fishing operations for all trips. The Cooperative Research Branch periodically publishes a solicitation for new study fleet participants and vessel captains self-select to apply. If qualified, they become paid participants. Participation is continuous based on mutual agreement between the Captain and NEFSC. The Captains are required to report catch and discards on every tow. Vessel involvement is capped based on the budget of the program. Digital collection of environmental data and enhanced bio-sampling of target and bycatch species are also part of the program. Electronic reporting helps reduce data entry, transcription, and recall errors, reduces NMFS staff- hours needed to enter data, and makes catch and discard data available faster than paper reports.

Study Fleet and Northeast Fishery Observer Program (NEFOP) data on the Northeast shelf were compared at the end of phase II (Palmer et al. 2007) and again during phase III in 2014 (Bell et al. 2017) (summarized below). Direct comparison of the two data sources indicated that they were very similar, though not identical. The two programs were created with different goals; however, both have the potential to contribute to assessments and management.

Due to the relatively small size, geographic focus, and design of the Study Fleet program, it has limitations in its ability to represent the dynamics and habits of all fishing fleets on the Northeast US Shelf. Unlike the NEFOP/At-Sea-Monitor programs, Study Fleet was not designed as a statistical sampling program and has a large number of recorded trips from a self-selected group of vessels that may or may not represent the dynamics of the entire fleet. The program itself currently contains about forty vessels that generally fish southern New England and Mid Atlantic compared to the 269 vessels that landed groundfish in 2016 (Murphy et al. 2018). There are thousands of Study Fleet records from individual tows providing excellent information, but the tows are largely with trawl gear and provide reasonable coverage for a select number of species. Due to funding-capped participation, the Study Fleet data do not provide information for the broad suite of stocks and gears needed to account for discards across all taxa and fleets managed on the US Northeast Shelf (Wigley et al. 2006). In addition, the geographic base for many of the current Study Fleet vessels may not be well suited to represent vessels fishing in other areas, such as the Gulf of Maine. In some cases, however, Study Fleet may provide better coverage for fleets such as the small mesh fishery in New England.

Despite the non-random sampling design of Study Fleet, the discard estimates across the entire fishing fleet for some species show general agreement between the two programs (Bell et al. 2017). In select cases, the Study Fleet data had similar discard estimates as NEFOP/ASM, but lower levels of uncertainty. This suggests that in limited circumstances, Study Fleet may potentially act as sub-samples of the larger groundfishing fleets. If this is true, an expanded use of Study Fleet, or study fleet like information could be appropriate after accounting for the limitations, including taking into account the need for area specific estimates, and instituting appropriate audit checks. The majority of the data do show general agreement between the two programs.

To compliment observer information, self-reported data may be of use where the Study Fleet coverage in a particular fleet is quite high and therefore a proportion of the data could be vetted with NEFOP/ASM data. Self-reported catch data could be of use where observer coverage is limited or lacking, or if there are specific questions surrounding geographic locations that are well sampled by Study Fleet vessels (Starr 2010). Self-reporting by industry has often been used in Europe and elsewhere for data limited cases (Starr and Vignaux 1997, Dobby et al. 2008, Hoare et al. 2011, Miona et al. 2015). It may be possible to statistically sample the Study Fleet data and combine it with the NEFOP/ASM data in particular situations. Statistically combining data from the two programs would increase the pool of available information and potentially reduce the estimates of uncertainty. Cross checking data records between the two programs could have value for quality control across both programs, however, the utility may be limited given the small size of the Study Fleet program.

Two of Study Fleet's largest contributions have been in the development of electronic reporting in the Northeast (including the software, data transfer, work flow and regulatory hurdles) as well as the relationship building between the fishing industry and the Science Center. Historically, Study Fleet data has been used for single projects or for researching specific questions. The enhanced bio-sampling portion of the program has consistently provided samples for maturity studies and other work around life history parameters. Study Fleet data has been brought into planning processes for offshore wind and management areas because of the high spatial resolution of the information including temperature and depth sensors on the nets specifying exactly where the tows occurred. Study Fleet information was one of the key data sources used in a recent NEFSC/GARFO study evaluating appropriate initial business rules for the groundfish Electronic Monitoring program. Gear studies have occurred and the habitat suitability work for the Butterfish and Mackerel stock assessments were done with Cooperative Research staff and some Study Fleet vessels. The partnerships developed through the program have also created a framework from which cooperative research can be conducted such as some of the catchability and gear comparison work.

4.2.5 Port Sampling

For some species, size distributions can be used to develop a CPUE index for a size category (e.g., to exclude small sizes that have greater uncertainty in species identification). Biological samples have been collected from New England's fishing ports since the 1930's. The stated purpose of the port sampling program is "to estimate length, age and species composition that assist in the characterization of the commercial catch" (Biological Sampling Work Instructions 1.0 and 3.0). Biological samples are collected from federally permitted fishing vessels that have been fishing for federally managed species within the US Exclusive Economic Zone (EEZ).

On a daily basis, samples are collected based on quarterly listings of desired samples provided by NEFSC. Samples are collected throughout the year; the specific sampling design depends on the anticipated landings. The Biological Sampling Coordinator (BSC) audits and compares the gathered biological data with the list of data requested by NEFSC, from this comparison the BSC produces a “Concerns Document” that is distributed to the field staff. The Concerns Document provides field staff with an overview of the needed samples. It is the responsibility of the field staff (samplers) to identify and target landings that may have the species needed to fulfill the required sampling needs. The sampler may utilize VMS email, hail lines, or other industry contacts / local knowledge to locate desired landings. A basic sample consists of 100 fish measured, and 25 selected on a stratified basis for aging (with the exception of shellfish) and the aggregate weight of the measured fished (BSWI 2.0). The biological data gathered is based on species and market category specific guidelines provided by NEFSC.

The port-sampling program provides crucial data on the composition of landings. Program strengths include the flexible and cost effective nature. However, the program also faces a number of significant challenges. One of the issues is the difficulty locating some needed samples (particular strata, species, and gear types may be under sampled due to the difficult nature in locating and sampling landings from these categories). Increased communication (in real-time) between vessels and samplers may aid in the collection of better data (Cadrin and Keiley, 2014).

An additional challenge faced by a dock-side sampling program stems from the regulatory process. The introduction of ‘no possession’ limits for many species eliminates these stocks from the sampling pool. This may have unintended consequences in the stock assessments and also puts more weight on the need for accurate discard and catch data from observed and unobserved trips.

The utility of port samples may also be compromised if there is misreporting of area-fished. If the stock area is miss-assigned to sampled fish due to misreporting this error results a mischaracterization of landings in the stock assessment. Multiple area trips also provide a number of challenges throughout the data collection and assessment processes. Port samples are not collected from trips that fished in multiple areas because samples cannot be attributed to stocks. The lack of samples from multiple-area trips may introduce bias (by excluding these types of trips from the data collection process) and could result in some species or market categories being undersample.

For more information on this program:
https://www.nefsc.noaa.gov/fsb/manuals/2013/NEFSC_Biological_Sampling_Manual.pdf

4.3 Bridging the Gap – Recommendations for Improved Collection and Use of fishery-dependent Data in Stock Assessments

Improving the potential utility of fishery-dependent data for stock assessments and management may require changes to the data collection programs, data analysis and assessment processes. CPUE series are more likely to be representative of stock trends when the fleet covers the entire stock area and is relatively homogeneous with respect to fishing power, seasonality, captain skill, etc. For example, fishery-dependent longline catch rates are the primary index of abundance for the Canadian Atlantic halibut assessment. Indices developed from inshore-only vessels have properties similar to scientific surveys that cover only part of the resource area. Inter-annual but unknown variations in availability will be confounded with abundance. Because the groundfish fleet is not homogeneous, approaches such as the use of index fleets, or footprints may be necessary. In addition, the available data streams that provide fishery-dependent data are not perfect; while improvement of these data streams should be a priority, equally important is the need to understand the uncertainties, biases and implications of the utility of these data streams.

4.3.1 Use of Index Fleets to Develop CPUE Indices

Although CPUE series are more likely to be representative of stock trends when there is a homogenous fleet of vessels that covers the entire stock area of a particular species throughout the period, this does not preclude the ability to develop a CPUE for groundfish stocks. Instead, a CPUE index could be developed by identifying groups of fishermen that display more consistent behavior (in terms of fishing practices) over a time series in a particular area within a species footprint, or expected area of species distribution. This would involve compiling a group of vessels that have similar gear, vessel size, vessel power and target species. Although such a CPUE index may not be representative of the entire stock, it could provide additional information for fine-scale spatial areas and may provide some information on general trends, or could be used in conjunction with other indices. CPUE indices developed from vessels operating in one area within the stock boundary (for example, inshore area only) have properties similar to scientific surveys that cover only part of the resource area.

In order to determine an appropriate time period for developing a CPUE, a timeline of changes in fishing gear, vessel characteristics, personnel, and other factors affecting catchability, ideally on a vessel-by-vessel basis, is desired. Such information could be used to identify periods of time where catchability appears to be relatively stable for a fleet or for a subset of a fleet, where it might be feasible to construct a CPUE index. CPUE must be standardized sufficiently to account for any changes in vessel efficiency, gear selectivity, targeting/avoidance behavior, inclusion probabilities, spatial aggregation of fish, and hyperstability.

The multispecies fishery encompasses a diversity of fleets, target species, and fishing practices, which complicates the development of CPUE/LPUE indices. The fishery is also managed under two different regimes, sectors (a quota based catch share system), and the common pool (effort control based on days-at-sea and trip limits). However, the majority of the groundfish fleet are currently enrolled in sectors. To enable the use of CPUE/LPUE indices in this fishery “index fleets” may be needed. An index fleet can be a subset of the fishery that is identified as having similar effort over a period of time (for post processing and analysis), or a fleet could be “designed” moving forward (a study fleet type concept). This would involve standardization of the fleet across vessels characteristics and fishing behavior.

Collaborating with fishermen to identify index fleets and trends in catch rates could enhance efforts to develop standardized CPUE indices. The Sector management system, which has been in place in New England since 2010, includes mechanisms to collect data on target species, influences of management intervention on catch and effort, operating costs, and species marketability. Efforts should be made to work collaboratively with members of the Sector system to extract fishery-dependent information that can be used to identify index fleets, such as information on target species (and avoidance behavior), spatial and temporal patterns in fishing, and changes in catch and effort as a result of management intervention and economic considerations. The Sector system could be utilized to collect this information from fishermen, for example, through regular meetings with Sector members to collect such information to identify index fleets, or perhaps through surveys distributed to Sector members designed to collect information on fishing operations.

The “Review of Northeast Fishery Stock Assessments” report suggested establishment and use of a subset of fishing vessels to provide more detailed logbook data than are recorded in the mandatory VTRs. The Northeast Fisheries Science Center developed the Study Fleet in 2002 with the objective of assembling a subset of commercial New England vessels capable of providing high resolution (spatial and temporal) self-reported data on catch, effort and environmental conditions while conducting “normal” fishing operations. The program was intended to provide stock assessment scientists with more precise and accurate fishery-dependent data (e.g., more precise estimates of fishing effort, spatially explicit catch, and discard locations) and to improve the understanding of catch rates and species assemblages (NEFSC, 2007). Additionally, it was noted that the collaborative nature of the Study Fleet pilot program could create a channel through which stock assessment scientists and industry members could directly communicate and share information that would serve as the basis for future collaborative research projects (Murawski 2002).

The domain of influence of study fleet data should be investigated further. These data have fine-scale information that might ultimately be important for an overall estimate of fishery-dependent abundance measure. These data might also be useful for determining the effective sample size of such information. For example, repeated towing at the same site will confirm local abundance and if indicative of high catch rates, will enhance the profitability of the trip. However, they are not independent measures of abundance and should be downweighted when combined with data from other trips. Similar considerations apply when evaluating multiple vessels from the same port fishing in the same area at the same time.

CPUE indices from Study Fleet have been submitted as working papers to stock assessments, but this is not a consistent data stream such as the federal and state trawl surveys and the landings data. A consistent workflow including a quality control process similar to NEFOP and a standard method to calculate CPUE or process additional data could result in greater use of Study Fleet catch data. Because of the large amount of tow level data and direct interaction with the vessels themselves, knowledge of what is being targeted at the haul level could be incorporated to potentially produce catch rate estimates for specific species in specific areas. Study Fleet could also provide a useful means to tackle many of the research recommendations that are produced during each stock assessment.

Currently, the Study Fleet program has greater representation in Southern New England and the Mid Atlantic. This likely has more do to with existing conditions and opportunity than a strategic plan. The Program may benefit from a steering committee to identify additional areas where the fisheries information could benefit assessments and management, potentially aid in shaping its focus, and identify future challenges where additional data by fleet, species, or sector could inform management decisions.

4.3.2 Identification of Historical, Stock Specific, Fishery "Footprints"

An important factor to account for when creating a CPUE is that fishing vessels concentrate their efforts where the fish are found, and so observations from fishing vessels tend to be clustered in particular areas. These observations cannot be extended beyond the fishing area since areas outside of the fishing zone are not sampled and have unknown inclusion probabilities. Observations need to have a known or approximate probability of inclusion to allow for appropriate weighting. This can be addressed by developing a set of stock specific inclusion probabilities across the shelf that could be used as weighting factors for fishery-dependent data. A comprehensive summary of expected seasonal footprints for abundance, drawn from expert judgment would be valuable, in terms of informing this probability in a design-based approach. Due to the collective potential to extract relatively reliable tow-level granularity from VMS, NEFOP and ASM data, these datasets should be examined as a way of evaluating the current stock-specific footprints of the fishery with respect to historical footprints in an approach that would weight observations post-hoc.

One question is whether it is possible to determine the inclusion probability of observations from fishing vessels given the use of closed areas as a part of the management regime, as these closed areas have changed the availability of access to fish throughout the fishery time period. It should be noted that equal probability cannot be achieved, even with surveys, and so care should be taken to ensure that fishery-dependent data like a CPUE is not held to a higher standard than fishery-independent data.

Development of a footprint would require the incorporation of historical knowledge of the stock and fishery distribution. Development of a footprint based only on status quo conditions would likely lead to a biased outcome. Simulation studies could be used to explore the sensitivity to these conditions.

4.3.3 Defining Effort

Discussions on the utility of fishery-dependent data and the use of CPUE and LPUE indices often focus on the estimates of catch (or landings). However, the appropriate definition of effort is critical to the development of these indices and use of fishery-dependent data. For some gears, it is easy to define a unit of effort for the purpose of calculating CPUE. For example, a single haul would represent a unit of effort for trawl gear. For other gears, it is not so easy to define a unit of effort. For example, with hook and line gear, the jig drift could be hours long, and for gillnets all placed in the same area, it can be difficult to determine whether these are all one unit of effort or multiple units of efforts. The relationship between catch and effort would need to be explored when determining the appropriate unit of effort.

Several Stock Assessment Workshops have noted the lack of fine scale information as a challenge to incorporating fishery-dependent data, specifically CPUE in assessment models. Additionally, changes in technology, efficiency and behavior have been cited as reasons why CPUE information is not informative as an index of stock abundance. Collection of more detailed information about target species, fishing location, and vessel, operator and gear characteristics could enhance our understanding of fishing behavior under changing management scenarios, and provide the necessary level of detail to construct CPUE indices. These enhancements could be obtained through modification to the data collection systems. In addition to refining the data collected, collaboration between fishing captains, gear manufacturers, and scientists on the gear definitions, fishing practices, and factors that impact effort is recommended. A workshop focused on developing agreed upon definitions of effort units for different gear types with Center scientists, and members of the fishing industry is a recommended first step in refining how we collect, interpret and utilize effort information.

There are challenges with collecting the information on effort needed to construct a CPUE. Accurate characterization of target species may prove difficult to obtain. Target and avoidance species should be known before fishing begins, which in theory is straightforward information to obtain, but in practice is less defined, as fishermen typically make decisions about where to fish for a particular species, however, once in that location, they are somewhat bound by the species available to them in that area. The post hoc determination of “target” species is likely to induce biases of unknown magnitude that vary over time. Appendix 4 provides some details on how this bias arises when post hoc criterion are applied to define target species. Steps could be taken to improve the collection of target species information in the Observer program, perhaps through outreach with fishermen to explain the importance of this data piece in understanding fishing effort and considering the development of CPUE. Additionally, while stationary vessel efficiency across time and space is desired for CPUE, information on effort for developing a CPUE could be obtained by accounting for changes in vessel efficiency across time (in particular) and space and providing model-based estimates of these changes. These vessel efficiency changes may include changes in gear, such as doors, mesh, sweeps, etc., and changes in technology such as sensors, fishfinders, etc. Workshops with members of the fishing industry, or fishermen's surveys, where fishermen could share information on such vessel efficiency changes would be useful for obtaining information needed to account for changes that impact fishing effort when considering a CPUE.

4.3.4 Collecting the Data: Leveraging the At-Sea Monitoring and Northeast Observer Programs

Observer estimates of catch rates fulfill many of the desirable features of a CPUE time series. First, it is the only method currently approved for quantifying the magnitude of discards. In practice, VTR are useful only for landings because discards cannot be validated from VTRs. Second, random selection and independent observation are advantages, however, the "observer effect" may compromise the utility of such data. Bias is important with respect to magnitude and trend. If the magnitude of the observer effect is a few percent, it will be small relative to natural variations. Small, consistent biases may be acceptable.

Recent analyses (Demarest 2018; Appendix 5) demonstrates that fishing vessels in the Northeast groundfish fishery alter their behavior in response to observers. Generally, the most pronounced effects are seen across trip duration, kept catch, kept groundfish and trip revenue. Observer presence has the smallest effect on the number of groundfish market categories and non-groundfish average prices, but even here differences are observed. Incentives to alter fishing behavior have varied across time. Prior to sector implementation, discards had no direct cost to fishermen and trip limits required discarding certain species. These factors may have reduced the incentive to alter fishing practices in response to an observer, noting that gillnet vessels did demonstrate a significant behavioral response prior to sectors. After full sector implementation, the accountability of discards and the application of sector/gear specific discard rates to unobserved trips, together with the potential catch of constraining stocks, increased the incentive to change behavior in response to an observer. The data show a trend for three key metrics–in almost all circumstances vessels appear to retain fewer fish, fish for less time and obtain lower revenues when an observer is on board. Persistent differences such as higher average groundfish prices with an observer on board (trawl vessels) and emerging differences like a greater number of market categories retained with an observer (gillnet vessels) indicate that the composition of catch on observed trips is different. This suggests that data collected by observers are not merely a compressed representation of unobserved fishing practices but, rather, they may be non-representative along critical dimensions such as proportions and quantities of fish discarded and retained.

A well-designed observer program would have representative coverage. Although greater observer coverage is expensive, it has potential to provide better data of the spatial scale that is desired by management. In addition, higher coverage may reduce the bias currently observed, increasing the utility of the data for constructing CPUE indices. Increased observer coverage would improve data quality, and accurate catch data are a necessary component to creating a CPUE for groundfish stocks. Complete observer coverage would provide a whole fleet index and avoid the issue of observer bias. Although increased observer coverage would reduce, or eliminate some of the current problems, it is not a complete fix.

4.3.5 Collecting the Data: Use of Technology to Improve Data Quality

Self-reporting tools are valuable in that they generally have lower initial costs, are not overly complex or difficult to integrate into fishing operations, and are generally more acceptable to industry as they give the fishing vessel and crew increased responsibility for reported data. Integration of self-reporting tools with independent monitoring tools allows for cross-checking and audit of self-re-ported data and also increases incentives within the industry to provide accurate self-reported data. The limitations of self-reported catch data are well known (e.g., Walsh et al. 2002, NMFS 2004). Electronic reporting and electronic monitoring represent additional ways to collect and record catch and discard data for compliance and monitoring.

Electronic reporting (e.g. electronic logbook, eVTR, FLDRS) generally refers to the recording and transferring of data electronically instead of with a paper-based system. In general, electronic reporting has the potential to reduce transcription errors and time needed to enter data from paper-based system by auto-populating fields and using simple quality control measures, while at the same time improving the timeliness by which the data is available for use. Depending on the configurations, an electronic reporting system can integrate with GPS or VMS data already being collected.

There are a number of electronic reporting software packages in use on fishing boats in New England, some developed by NMFS and some by private providers. GARFO's current policy establishes the technical standards for reporting, therefore enabling public and private entities to develop effective software tools that deliver required data and meet the needs of the fishing industry.

Electronic monitoring uses on-board systems that can include cameras, gear sensors, data storage, and GPS units that capture video or photo recordings of fishing activity with associated sensor and positional information. Electronic logbooks can also be integrated to record catch and discard information. Electronic monitoring system configurations vary, but typically consist of cameras focused on specific areas of the vessel where gear is deployed/recovered, fish are sorted and processed as well as along the rails where discarding occurs. Electronic monitoring can be implemented at a variety of scales, from basic requirements such as tracking slippage events (catch discarded before being brought on board) and takes of protected species to documenting discards to full species-specific accounting of catch and discards. Electronic monitoring is often considered an alternative to human at-sea monitors, but it can also be used to complement human monitors. There are a number of electronic monitoring projects currently underway in the Greater Atlantic region as well as many projects throughout the United States (https://www.fisheries.noaa.gov/national/fisheries-observers/electronic-monitoring) and the world.

Depending on the desired goals, electronic monitoring is a means for collecting fisheries dependent data that can be less biased, more transparent and verifiable. Video collected at sea is reviewed on shore by trained reviewers to collect required information, produce reports, and verify compliance. Video review protocols can vary; in some programs 100% of the video is reviewed, while in other programs a portion of the video is reviewed. Video data can be stored and re-reviewed in the future if necessary.

In general, two different models have been used to implement electronic monitoring programs: partial coverage and full coverage (including audit approaches). In the partial coverage model, vessels equipped with electronic monitoring systems are required to run the system only on trips for which they are selected. This mimics partial observer coverage, but does not eliminate the opportunity for bias as vessels know when the system is in use.

In the full coverage model, the video is recording during 100% of a fishing trip. For review purposes, the audit option requires only a portion of the video to be reviewed randomly to validate the vessel’s eVTR. Each discarded fish is handled to enable species ID and a length measurement. If the comparison of VTR-reported discarded weights and video review estimates is within predetermined ranges, the VTR is used for catch accounting. When the comparison with the eVTR is outside acceptable ranges, the EM report or a fixed/assumed discard rate can be used for catch accounting. Vessels with repeated trips outside accepted ranges will be evaluated for continued participation in the program. This model is typically suited for vessels with lower discard volumes. A different full coverage option exists for vessels that are required to use maximized retention for catch handling. In this option, there are minimal discards at sea, and most catch is accounted for by human dockside monitors. The video is reviewed to confirm compliance with applicable discard rules. Video review costs for Maximized Retention are typically lower than in the audit option, but dockside monitoring is required. The audit option is typically easier for vessels with higher discard volumes since there are fewer changes to typical catch handling procedures. Under the audit and Maximized Retention models, the cameras are always recording so the potential for any bias is basically eliminated and without a human observer on board, questions about safety at sea or other concerns around human observers are removed. Reducing the number of human observers, however, could reduce biological sampling unless augmented by port side sampling.

Several studies have shown that electronic monitoring can produce data of similar or greater quality to human observer data. There generally is a learning curve as captains modify catch handling techniques to meet review requirements and minimize processing time.

While electronic monitoring can monitor and verify vessel compliance, like any system there are still challenges in implementation. Video quality can be reduced under certain conditions (e.g. fogged over lenses, vessel turned into the sun). The cost of electronic monitoring can be variable based on the program's goals, objectives, and requirements. Technical specifications and performance standards are critical to establish early in program design because they can affect both costs and program effectiveness in meeting regulatory requirements. Video review and data storage costs currently make up a significant portion of overall program costs, through technology advancements and systems design will likely dramatically reduce both the cost and time of review in coming years. As electronic monitoring continues to expand, it has the potential to produce high quality, unbiased fisheries dependent data that could be used to improve fisheries management measures.

4.3.6 Best Practices for Soliciting and Using Fishermen's Knowledge

Analyses that miss important attributes of fishing behavior will be misleading. Similarly, perceptions of abundance that are unsubstantiated by data or apply to a limited spatial domain will be equally misleading. For some species, there is a large gap between fishermen's perceptions and stock assessment results. To bridge this gap there may be some value in a formal liaison/training program that goes beyond the necessarily cursory training that occurs in Marine Resource Education Program (MREP)-like programs.

One possible approach is the expansion of the MREP program to include a longer-term pairwise training/collaboration of experienced fishermen with analysts. The fishermen would gain a greater appreciation of the limitations of existing data and the analyst could test novel hypotheses with existing data. Both parties would need to be held in high regard by their respective disciplines. Such a collaboration will not be useful if its benefits accrue only to the two parties. So it would be equally important that the results of such collaborations are widely disseminated, probably via the Council process. This would require some sort of grant to support industry participation and a memorandum of understanding with NMFS.

The utility of fishery-dependent data is not limited to the development of CPUE indices. Fishermen's observations of stock trends, such as spatial distribution, abundance, size and age structure could be of great utility to stock assessment scientists and managers alike if these data were collected in a rigorous, scientific format. These data could be used to inform trends, validate (or call into question) survey or assessment results, and inform potential research and data needs.

ICES disseminates a survey that solicits information from fishermen on fish stocks and fishery trends that is formally included in the assessment and management process (see Appendix 6). A survey of North Sea fishermen in five countries - Belgium, Denmark, England, the Netherlands, and Scotland - has been carried out annually since 2003 (following a pilot in 2002) with the aim of making their knowledge of the state of fish stocks available to fisheries scientists and fisheries managers. Results of the survey are provided to the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). The questionnaire-based survey collects information on vessel size and fishing gear type, on the status of key fish species, and on the fishermen's economic circumstances (further information on the survey is provided in Appendix 6) across 10 areas of the North Sea. These areas are based on the standard roundfish sampling areas defined by ICES. The purpose of this questionnaire is to ensure that fishermen's knowledge of the state of fish stocks is considered during the development of TACs. Questionnaires are translated and circulated to North Sea fishermen by national coordinators representing coordinating organizations in the five participating countries. These coordinating organizations consist of industry associations.

This model could be adapted to US fisheries. In the groundfish fishery, we have the advantage of having a network of sectors, and reporting mechanisms that could be adapted to include this type of survey or data collection.

An alternative strategy would be to modify the current format of the pre-assessment meetings. The industry outreach meetings are generally perceived as lip service, and have limited utility with regard to the development or refinement of the stock assessment. The timing of these meetings is one aspect that should be modified. Industry input should be solicited before the assessment is run, to enable the assessment scientist enough time to digest and utilize the information/feedback provided. Surveys could also be used to collect information prior to assessments to get broader input, followed up by a working meeting to discuss trends and implications, and provide an opportunity for a discussion between the groups.

Regardless of the specific platform for dissemination, a survey must be well designed to enable interpretation and use of the information.

4.3.7 Use of Simulation Studies to Examine the Utility of CPUE

Observations that are based on a scientific survey have well known asymptotic properties and are in part, justified by the expectation that these studies will yield meaningful results. However, much depends on satisfying the underlying assumptions about measurement, selection of sampling units, appropriateness of stratification, etc. And of course, any given design can occasionally yield results that are very far from the true value.

Correspondence between a CPUE measure and the derived abundance in an assessment is somewhat circular. Correspondence in such situations is valuable only if the assessment itself is correct. Almost any model will work well when the fishing mortality is high. All models have problems when fishing mortality is low because the ratio of observed to unobserved mortality decreases and reliance on the assumptions that generate the unobserved mortality increases.

Coherence between the CPUE measure and fishery-independent indices can beg the question of the value of redundant indices in a model fitting context. Of course in the real world, affirmation of trends from independent sources is valuable for acceptance of results. However, the possibility that the CPUE measure is more representative of the true state of nature cannot be excluded when the basis of comparison is based only on the coherence with model results.

Simulation studies conditioned on the known (or perceived) properties of the multispecies groundfish fishery would be instructive. Simulations would also clarify the importance of several prevailing practices:

1. Selection of trips based on target species;
2. Selection of trips based on percent composition of the target species. Such measures will be biased, but the bias may not be important in all cases; and,
3. Interpretation of signals derived from CPUE estimates where abundance in unobserved areas must be imputed. (eg. What would catch rates in closed areas have been?)
4. Examine the impacts of regulations and/or misreporting on an index of CPUE
5. Test the development and biases of different CPUE analytical methods

It is understood that the output from such analyses would only be as good as the operating model.

4.3.8 Improving the Stock Assessment Process

The utilization of CPUE indices within the assessment framework, has been limited by time, and resources to assess the uncertainties, limitations, and potential biases associated with the various data streams. The utility of fishery-dependent data for informing stock assessments will likely vary between stocks, and fisheries, but is a valuable source of information that should not be overlooked.

Based on our review of the use and utility of CPUE/LPUE information in stock assessments of New England groundfish prior to 1994, as well as in assessments of stocks in the Mid-Atlantic region, Southeast region, and ICES and ICCAT assessed stocks, we propose recommendations to reconsider CPUE data in future assessments of the groundfish stocks. These recommendations build upon previous suggestions with an objective of integrating existing information and supplementing current data collection systems.

Despite some limitations, a significant amount of fishery-dependent data are currently available for analysis. These data could be examined by assessment, academic or non-government scientists outside of the stock assessment process to determine the utility of including CPUE and LPUE information. Lack of time and resources during stock assessment workshops have been cited as reasons why extensive analyses of CPUE information have not been conducted (O’Keefe 2017). Efforts to standardize fishery-independent survey data have been conducted outside of assessments, resulting in availability of reviewed information for use in assessment models. Similar efforts could be applied to fishery-dependent data prior to benchmark assessment for New England groundfish stocks. Additionally, the SAW55 review recommended that NEFSC should allocate more resources into developing new methods that have potential to substantially improve assessment precision and accuracy. This could include further exploration into CPUE.

Meaningful utility of CPUE / LPUE indices can be external to analytical assessment models. Recognizing the standard for inclusion as an input to an analytical model is high, it should not preclude its use external to the model as a comparative signal to the model outputs. Coherence, or a lack thereof, between fishery-dependent signals of relative abundance and independent indices used in the model should be seen as optimum.

The terms of reference for benchmark stock assessments set the scope of topics, analyses and issues to be covered by the assessment Working Group. Formal inclusion of evaluation of standardized CPUE and LPUE as an explicit component of the generic term of reference on fishery data could help to ensure that the topic is addressed (i.e., "investigate the utility of commercial or recreational LPUE as a measure of relative abundance"). There is opportunity for public comment and input, there is an explanation of the rationale for inclusion or exclusion of the data, all possible uses of the information have been considered, and the use and utility of CPUE and LPUE can be reviewed externally by assessment review committees. This recommendation complements the previous recommendation to examine fishery-dependent data utility outside of the assessment process. Compiling the appropriate data and determining suitable methods for standardizing CPUE should be completed prior to the assessment, so that results can be used to address a specific term of reference for evaluation of the utility of the information for assessment purposes. Identifying best practices for developing a standardized CPUE index using northeast fishery monitoring data would also be an appropriate topic for a research track assessment for all groundfish stocks.

When considering CPUE as an index of abundance for a particular groundfish stock, it is recommended that the assessment scientist follow SEDAR/Southeast best practices for using CPUE as indices of abundance by filling out a similar worksheet used to evaluate use of fishery-dependent and fishery-independent indices of abundance in assessments (Appendix 1). SEDAR assessments routinely use fishery-dependent indices of abundance, and the evaluation worksheet serves to provide those constructing the indices with a checklist of the information that should be provided to the SEDAR Data Workshop for proper evaluation, and provide the Data Workshop's Indices of Abundance Working Group with guidance on what points to consider when evaluating an index of abundance. Such a practice would be useful for evaluating CPUE as an index of abundance for groundfish stocks.

4.3.9 Considerations and Best Practices when Using CPUE

Consider using shorter time series for inference rather than trying to build a model for the entire history. For example, calibrating fishing practices before and after introduction of sectors may not be possible. The “super model” that explains every intervention over the last 50 years may be impossible. Focus on shorter time intervals where the cumulative effects of interventions and fluctuations in abundance are smaller.

Some important considerations for developing a standardized CPUE index:

1. Changes over time that have implications for estimating catchability
    a. Changes in reporting methodology: Port agents to mandatory VTR
    b. Changes in gear efficiency
    c. Improvements in vessel technology, especially GPS and other electronics
    d. Changes in regulatory or economic incentives, e.g., Sectors management of groundfish
    e. Changes in area access, e.g., Georges Bank fishery closures, scallop harvest areas, Gear Restriction Areas (GRA) in Mid Atlantic.
    f. Changes in other regulations (especially trip limits, individual quotas)

2. Statistical issues
    a. Model complexity
    b. Interactive factors
    c. Extracting an annual effect can be difficult, especially when interactive effects are present

3. Unequal probability sampling—basic idea is to downweight observations from sites with high probabilities of inclusion.
    a. Basic stratified survey
    b. Cluster sampling considerations
    c. Horvitz-Thompson, Hansen-Hurwitz estimators

4. Other approaches
    a. Observer program estimates of CPUE
    b. VTR + VMS
    c. Observer Data + SASI
    d. Homogenous fleet

Specific recommendations:

1. Use Observer program data to generate CPUE (i.e., landings plus discards per trip or other unit of effort)
    a. Advantages
        i. Vessel selection is randomized
        ii. Observations are standardized and documented
        iii. Observations are available on a tow by tow basis
        iv. Fishing areas are known
        v. Multiple years of data are available
        vi. SBRM methods can be used to estimate average CPUE
    b. Disadvantages
        i. "Observer effect" may alter area fished, trip duration, targeting.
        ii. Avoidance of random vessel selection
        iii. Shifting selection criteria prior to SBRM, e.g., protected, monitoring of US-Canada trips, etc.

2. Use synoptic methods such as VMS, Swept-Area-Sensitivity-Impact model, expert knowledge to estimate inclusion probabilities
    a. Advantages
        i. Fishing areas by species have been estimated
        ii. Inclusion probabilities should be functions of habitat and as such should be considered relatively stable quantities.
        iii. Multiple years of survey data could also be used to estimate potential fishing areas
    b. Disadvantages
        i. Resolution of information may be too coarse, e.g., Stat Area only on VTR, single point for entire trip, absence of multiple trip information, gear codes may not be sufficient for specialized gear.

3. Use estimated inclusion probabilities to appropriately weight samples from
    a. VTR
    b. Study Fleet
    c. Observed trips
    d. Survey data

4. Test proposed methods using simulated data.
    a. There appear to be relatively few tests in the literature with realistic conditions

b. Proposed methods should be able to handle time x area interactions
c. Develop imputation or extrapolation methods for cases where primary fishing areas change over time (See Walters 2003).

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Appendices

Appendix 1: Use of fishery-dependent indices of abundance in SEDAR assessments

Fishery-dependent indices of abundance are used regularly in Southeast Data, Assessment, and Review (SEDAR) stock assessments, due to a lack of long term, high quality fishery-independent survey data. These fishery-dependent indices are constructed by Southeast Fisheries Science Center (SEFSC) staff using gear or fleet-specific catch per unit effort (CPUE) data (e.g., commercial longline, recreational charter boat).

Trips targeting the species of interest are identified using a data subsetting techniques developed by Stephens and MacCall (2004). The Stephens and MacCall method is an objective approach in which a logistic regression is used to estimate the probability that the target species could have been encountered given the presence or absence of other species reported from the trip.

Various standardization methods are used to construct the fishery-dependent indices of abundance. The most commonly used approach in SEDAR assessments is the delta lognormal model approach (Lo et al. 1992). This method combines two separate general linear model (GLM) analyses. The first GLM analysis models the proportion of positive trips, assuming a binomial error distribution. The second GLM analysis models the catch rates on successful trips, assuming a lognormal error distribution. A set of factors is identified as possible influences on the proportion of trips that landed the target species and on the catch rate of that species. For example, a commercial longline index for Gulf of Mexico tilefish (*Lopholatilus chamaeleonticeps*) considered as factors: year, season, subregion, longline length, number of days at sea, size of crew, distance between hooks, and number of hooks fished (McCarthy 2010). All 2-way interactions among significant main effects are examined. A forward stepwise regression procedure is used to determine the set of fixed factors and interaction terms that explain a significant portion of the observed variability.

In 2010, a worksheet was developed by SEFSC staff to help evaluate indices of abundance for inclusion in SEDAR stock assessments. The worksheet served two functions. First, it provided those constructing the indices with a checklist of the information that should be provided to the SEDAR Data Workshop for proper evaluation. Second, it provided the Data Workshop's Indices of Abundance Working Group with guidance on what points to consider when evaluating an index of abundance. This worksheet was used first in the assessments of Gulf of Mexico tilefish (SEDAR 2011a) and yellowedge grouper (*Epinephelus flavolimbatus*; SEDAR 2011b). The worksheet has been used in most SEDAR benchmark assessments since then.

The worksheet is used to evaluate fishery-dependent and fishery-independent indices of abundance constructed using a variety of statistical methods. Therefore, not every section of the worksheet is applicable to each index evaluated. The worksheet includes sections describing data sources, methods, model diagnostics, model results, and a special section for when multiple model structures are considered. Each section includes multiple evaluation criteria, with space to score information availability and make general comments on each criterion. The Working Group's recommendation for accepting or rejecting the index is reported, along with the justification for that recommendation. The justification can include instructions for revising the index, to have it reconsidered by the Working Group.

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Appendix 1

Evaluation of Abundance Indices of [Species Name]: [Index Name]

DESCRIPTION OF THE DATA SOURCE

	Not Applicable	Absent	Incomplete	Complete	Working Group Comments:
1. Fishery Independent Indices					
A. Describe the survey design (e.g. fixed sampling sites, random stratified sampling), location, seasons/months and years of sampling.					
B. Describe sampling methodology (e.g. gear, vessel, soak time etc.)					
C. Describe any changes in sampling methodology (e.g. gear, vessel, sample design etc.)					
D. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).					
E. What species or species assemblages are targeted by this survey (e.g. red snapper, reef fish, pelagic).					
F. Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.					
2. Fishery Dependent Indices					
A. Describe the data source and type of fishery (e.g. commercial handline, commercial longline, recreational hook and line etc.).					
B. Describe any changes to reporting requirements, variables reported, etc.					
C. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).					
D Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.					
METHODS					
1. Data Reduction and Exclusions					
A. Describe any data exclusions (e.g. gears, fishing modes, sampling areas etc.). Report the number of records removed and justify removal.					
B. Describe data reduction techniques (if any) used to address targeting (e.g. Stephens and MacCall, 2004; gear configuration, species assemblage etc).					
C. Discuss procedures used to identify outliers. How many were identified? Were they excluded?					

	Not Applicable	Absent	Incomplete	Complete
2. Management Regulations (for FD Indices)				
A. Provide (or cite) history of management regulations (e.g. bag limits, size limits, trip limits, closures etc.).				
B. Describe the effects (if any) of management regulations on CPUE				
C. Discuss methods used (if any) to minimize the effects of management measures on the CPUE series.				
3. Describe Analysis Dataset (after exclusions and other treatments)				
A. Provide tables and/or figures of number of observations by factors (including year, area, etc.) and interaction terms.				
B. Include tables and/or figures of number of positive observations by factors and interaction terms.				
C. Include tables and/or figures of the proportion positive observations by factors and interaction terms.				
D. Include tables and/or figures of average (unstandardized) CPUE by factors and interaction terms.				
E. Include annual maps of locations of survey sites (or fishing trips) and associated catch rates ***OR*** supply the raw data needed to construct these maps (Observation, Year, Latitude, Longitude (or statistical grid, area), Catch, Effort).				
F. Describe the effort variable and the units. If more than one effort variable is present in the dataset, justify selection.				
G. What are the units of catch (e.g. numbers or biomass, whole weight, gutted weight, kilograms, pounds).				
4. Model Standardization				
A. Describe model structure (e.g. delta-lognormal)				
B. Describe construction of GLM components (e.g. forward selection from null etc.)				
C. Describe inclusion criteria for factors and interactions terms.				
D. Were YEAR*FACTOR interactions included in the model? If so, how (e.g. fixed effect, random effect)? Were random effects tested for significance using a likelihood ratio test?				
E. Provide a table summarizing the construction of the GLM components.				
F. Summarize model statistics of the mixed model formulation(s) (e.g. log likelihood, AIC, BIC etc.)				
G. Report convergence statistics.				

Working Group Comments:

MODEL DIAGNOSTICS

Comment: Other model structures are possible and acceptable. Please provide appropriate diagnostics to the CPUE indices working group.

	Not Applicable	Absent	Incomplete	Complete	Working Group Comments:
1. Binomial Component					
A. Include plots of the chi-square residuals by factor.					
B. Include plots of predicted and observed proportion of positive trips by year and factor (e.g. year*area)					
C. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).					
2. Lognormal/Gamma Component					
A. Include histogram of log(CPUE) or a histogram of the residuals of the model on CPUE. Overlay the expected distribution.					
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.					
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.					
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.					
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.					
F. Include plots of the residuals by factor					
3. Poisson Component					
A. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).					
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.					
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.					
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.					
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.					***The feasibility of this diagnostic is still under review.***
4. Zero-inflated model					
A. Include ROC curve to quantify goodness of fit.					
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor).					
C. Include QQ-plot (e.g. Student dev. residuals vs. theoretical quantiles), Overlay expected distribution.					

MODEL DIAGNOSTICS (CONT.)

	Not Applicable	Absent	Incomplete	Complete	Working Group Comments:

D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.

E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.

MODEL RESULTS

A. Tables of Nominal CPUE, Standardized CPUE, Observations, Positive Observations, Proportion Positive Observations and Coefficients of Variation (CVs). Other statistics may also be appropriate to report

B. Figure of Nominal and Standardized Indices with measure of variance (i.e. CVs).

IF MULTIPLE MODEL STRUCTURES WERE CONSIDERED:

(***Note: this is always recommended but required when model diagnostics are poor***.)

1. Plot of resulting indices and estimates of variance
2. Table of model statistics (e.g. AIC criteria)

	Date Received	***Workshop Recommendation***	***Revision Deadline ******	***Author and Rapporteur Signatures***
First Submission				
Revision				

The revision deadline is negotiated by the author, the SEDAR coordinator and the CPUE rapporteur. The author **DOES NOT** *commit to any* **LEGAL OBLIGATION** *by agreeing to submit a manuscript before this deadline. The maximum penalty for failure to submit a revised document prior to the submission deadline is rejection of the CPUE series.*

Justification of Working Group Recommendation

Appendix 2: Hennen 2018

The following summary was prepared by Dan Hennen at the Northeast Fisheries Science Center and reviewed by Mike Simpkins. It has been reproduced in its entirety for inclusion in the working group report of the FDSA.

CPUE as an Index of Abundance in Stock Assessments

Catch per Unit Effort (CPUE) is used in some regions to index the abundance of stocks. It is most commonly employed where there are limitations to fishery-independent data sources (e.g. many stocks in the SE US).

When there are more robust alternatives available, using CPUE as an abundance index is problematic. Fisheries are subject to regulations that affect catch rate, such as limits on the days at sea (DAS, an effort control) or changes to the fishing season, and areas open to fishing. Regulations are not constant over time. Therefore comparing catch rates through time requires adjustments to account for changes in the behavior of fishers resulting from the changes to regulations. These can be difficult to model and often leave the analyst in a situation where it is unclear whether a change in CPUE is due to a change in regulations or a change in stock abundance. The challenge posed by changing regulations is further complicated by the fact that fisheries are non-random relative to space. If fishing is concentrated on areas of high density, or areas near ports, CPUE will not follow total abundance. Generalization of CPUE to the entire stock can be particularly challenging if the fishery does not occur in a substantial portion of the stock area. In this case, assumptions about the abundance in unfished areas are required. Gear efficiency changes over time in commercial (or recreational) operations. Reductions in handling time, increases in vessel speed or efficiency, better fish detection, or catching power, all can cause changes in catch rate. These are unlikely to accrue in the fishery systematically, as they are adopted unevenly throughout the fleet, and are difficult to track or isolate with modelling. Finally, fisheries that garner the most interest tend to be the most depleted. These fisheries are likely to have an important bycatch component. Bycatch can be challenging to track, in terms of magnitude, but particularly in terms of effort. The question of which trips, or how much of any given trip, to include as “effort” for calculating bycatch is particularly thorny. In the northeast, bycatch is generally less reliably estimated before 2005 because of low coverage rates in the observer program.

When fishing practices and regulations are dynamic, it is hard to be sure that CPUE is tracking abundance. The only option for checking the performance of CPUE as an index (in most situations) is to compare it to an independent measure of abundance. When CPUE and the independent measure agree, that can result in more confidence in both measures, though there may be limited value in inputting both into an assessment model because of redundancy and covariance/colinearity in the measures. When the two measures diverge, CPUE is typically considered unreliable because of the reasons listed above.

Background Literature

There is a fairly extensive literature on the use of CPUE as an index of abundance. It is given several pages in "Quantitative Fisheries Stock Assessment" by Hilborn and Walters.

Notable peer reviewed articles include several by Maunder (e.g. Maunder and Punt, 2004, Maunder et al 2006), Walters (Walters, 2003), and Harley (Harley et al, 2001). These and several others are briefly summarized here.

Non NEFSC Reports

There was a dedicated CPUE workshop at GMRI in November of 2015 (see Narrative), which included contributions from several non-NEFSC folks. A report from SMAST (O'Keefe et al. 2015) considered how Fisheries Dependent Data (FDD) and particularly CPUE was used in groundfish assessments, (see summary).

NEFSC Reports

Cod (GOM) - CPUE used as index before 2012.

> A workshop was convened in 2012 to address the apparent disconnect between CPUE and Fisheries Independent Data (FID) based trends. A report from the workshop concluded that neither commercial, nor recreational CPUE was a useful index of abundance. Cod became aggregated in the Gulf of Maine in the late 2000's and catch rates increased while abundance declined. This is the most extensive examination of CPUE as an index that NEFSC has conducted.

Cod (GB) - LPUE not used as an index of abundance, but was estimated prior to 1998.

> The 2012 WG (see above) re-examined CPUE as an index and concluded neither commercial, nor recreational LPUE was a useful index of abundance. Management changes beginning in 1994 changed the spatial pattern of the fishery, effectively breaking the time series. In addition, the LPUE index included only US landings while the stock straddles the Hague line. The recreational LPUE index was not considered representative due to small sample size as well as the cross boundary issues concerning fish landed in Canada.

Haddock (GOM) - LPUE not used as an index, but examined in 2012 WG.

> LPUE was not considered a reliable index of stock abundance by the WG. It was not possible to clearly define effort for this stock since it was difficult to tell which trips were

targeting haddock. LPUE trend was not correlated with the other indices of abundance used in the assessment model.

White Hake - LPUE used before 2012.

LPUE was examined for the 2012 benchmark. A priori it was not expected to perform well due to area closures and other management changes affecting effort. The index showed different trends when only directed trips (as opposed to all trips, or all trips where some threshold proportion of the total landings were white hake) were used to determine effort. Some, but not all, of the variants of the LPUE index correlated well with the FID trends, but there was little interest in using it in the model and it was dropped.

Pollock - CPUE examined in 2010, but not used in assessment.

CPUE was not used in the assessment because of limitations in the calculation of effort due to regulatory changes over time (Days at Sea limits, closed areas, etc…).

Yellowtail flounder - Examined CPUE in 2012.

No index could be created for this stock, due to complications resulting from the changing management regime (closed areas, DAS regulations, etc…) and the shift from a directed fishery to a bycatch fishery which made calculation of effort intractable.

Tilefish - Uses CPUE as an index.

Tilefish do not have a FID survey trend. CPUE is the only index of abundance in the assessment.

Bluefish - Uses recreational CPUE as an index of abundance.

The recreational CPUE index is possibly the most important index in the assessment model.

Scup - thorough examination of CPUE as an index in 2015, but it is not used in the assessment.

The scup assessment WG thoroughly explored using CPUE as an index of abundance. They used several data sources for catch, including: dealer reports, VTR data, observer data, recreational vessel VTR, MRFSS and MRIP data, and commercial study fleet data. Data limitations included: some data sources included only landings, effort was difficult to determine because it was not clear which trips were scup targeted, and because changes to management and data reporting have made it hard to build a consistent time series.

Witch flounder - Thorough examination of CPUE as an index in 2015, but it is not used in the assessment.

The witch flounder WG evaluated CPUE indices from several data sources for their utility as indices of abundance. These included: dealer reports (at several different proportions of total trips base on threshold witch flounder catch levels) , VTR, and Observer program data. Each of the CPUE indices from data sources presented various limitations to their utility as an index of abundance. The dealer data included only landings and was no definitive reason to prefer one set of total trips over another to use for effort determination. The VTR and observer data probably underestimated discard rate. There was also concern over how changes in management regulations have affected effort over time. A cooperative study fleet longline survey was also considered as a source for an abundance index, but the survey time series was short and no witch flounder had been caught.

Striped bass - used MA commercial CPUE and CT recreational CPUE indices until 2009.

Both CPUE indices were removed in 2009 due to possible errors in the index (CT) and the determination that anglers were targeting aggregations (MA).

Northern shrimp - CPUE calculated but not used as an index of abundance in the assessment.

Not considered a reliable index of abundance because of increasing fisher efficiency over time, seasonal changes in efficiency, attrition of successful harvesters, and seasonal shifts in shrimp distribution.

Redfish - CPUE used as an index of abundance until 2008 assessment.

The CPUE index was abandoned in the 2008 assessment because of a sharp reduction in directed redfish trips.

Monkfish - CPUE is calculated but not used as an index of abundance in the assessment.

Monkfish CPUE is not considered a reliable index of abundance because much of the catch is taken in a multispecies fishery and effort is difficult to define. Data collection methods have also changed over time. Regulatory changes have also complicated the estimation of effort.

Squid - LPUE was calculated for the 1996 assessment and provided an initial estimate of biomass.

The LPUE index was abandoned in the 2002 assessment because of changes in data collection procedures and problems determining catch location.

Fluke - (In progress) CPUE is being evaluated as an index of abundance in the assessment.

Data sources being considered include: dealer data from trawl fisheries, VTR data from trawl fisheries, observer data, MRFSS and MRIP data, and recreational VTR data. Reports are in draft form and not linked here.

Clams - CPUE is calculated for each assessment, but is not used as an index of abundance.

Surfclam and ocean quahog CPUE are not considered reliable indices of abundance because the fishery is highly aggregated in space. Fishers work in small areas until density is depleted below a threshold level of economic return and then shift to a new location. CPUE is not well correlated to total abundance.

Black sea bass - Recreational CPUE was developed and used in the 2016 assessment.

CPA (catch per angler) was used as an index of abundance in the model and was fit well in the southern region of the spatial model. The fit was not as good in the northern region.

Multispecies Stock Assessments

Maunder et al (2006) point out that CPUE is a particularly poor index of abundance for multispecies frameworks. The reason for this is that the catchability coefficients for different species are different, even if those species are caught by the same gear. The species that is caught most effectively will deplete at a faster rate than the other species. The other caveats mentioned above, catchability changing over time, target shifting in the fishery and changes in regulations, etc., all apply to multispecies fisheries as well.

Appendix 3: O'Keefe et al.

FISHERY DEPENDENT DATA IN NEW ENGLAND GROUNDFISH STOCK ASSESSMENTS

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BACKGROUND

Several groundfish stocks in New England are currently overfished and have shown inadequate recovery despite historic low fishing effort and increasingly strict fishing regulations. Fishery-independent data sources, specifically federal surveys, have shown declines in biomass and abundance for certain species (NEFSC, 2015c). While surveys provide information on trends in population status, fishery-dependent data sources provide the magnitude of fishery removals and may be useful to examine spatially- and temporally-specific fishing patterns and enhance our understanding of management and environmental influences on fish populations (Hilborn and Walters, 1992). Fishery management interventions, however, pose challenges to incorporating fishery-dependent data in stock assessments. Fishermen, scientists and managers are calling for a renewed examination of data systems, specifically catch-per-unit-effort (CPUE) indices that might overcome scientific challenges and provide finer scale insights into complex population dynamics.

CPUE is commonly used as an index of abundance for stock assessment. Similar to the way fishery-independent surveys are related to stock size, CPUE is assumed to be proportional to stock abundance:

$$CPUEt = q\ Nt$$

where q is a catchability coefficient and Nt is stock size at time t. The relationship assumes that catchability is constant throughout the time series. CPUE is typically standardized to account for factors of catch rate that are not related to stock size (e.g., Maunder & Punt, 2004).

The Environmental Defense Fund (EDF) worked with the University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST) to examine expanded use and utility of fishery-dependent data in fish stock assessments. Although the majority of stock assessments incorporate catch data (landings and discards), CPUE information is not currently used in any of the New England groundfish stock assessments. Based on a review of historical use of CPUE in groundfish assessments, we propose possible opportunities to reconsider this information for the groundfish assessments, which could help to reconcile what fishermen see on the water with the results of analytical analyses.

OBJECTIVE

The objective of this study was to determine how fishery-dependent data, specifically CPUE, has been used to inform the stock assessments of New England groundfish. The report includes a summary of the types of fishery-dependent data that are available and used in the assessment process, an evaluation of the rationale for the inclusion or exclusion of CPUE information in assessments, and recommendations for possible reconsideration of CPUE information in the assessments of New England groundfish stocks.

DATA TYPES

Several types of fishery-dependent data are collected to support the assessments and management of stocks included in the Northeast Multispecies Fishery Management Plan. Regulated data collection for harvesters and seafood dealers include information on catch (landings and discards), fishing location and time, and biological characteristics (length and weight). Table 1 summarizes some of the types of fishery-dependent data collected through regulated reports for the Northeast Multispecies complex. Information from the various reporting requirements are combined to determine landings and discards by species, area, season and gear; effort by area, season and gear; length, weight and age by species by area, season and gear; and catch per unit effort (CPUE). Fishery-dependent information from voluntary data collection programs has also been used to support bycatch avoidance (O'Keefe and DeCelles, 2013; Bethoney et al., 2013; Gauvin et al., 1995), risk pooling of quota (TNC, 2012; Holland and Jannot, 2012), and optimized harvest strategies (Dunn et al., 2013). There are also several types of data that are collected by fishermen through collaborative research that can support stock assessments and management advice. Table 2 summarizes some of the types of data collected by fishermen in the New England region to address specific research questions and improve uncertainties in stock assessments and catch-setting advice.

FISHERY-DEPENDENT DATA IN STOCK ASSESSMENTS

There are currently 13 species managed as 21 stocks in the Northeast Multispecies Fishery Management Plan (NEFMC, 2015; Table 3). The assessments for all 21 stocks include landings and discard data derived from fishery-dependent data reporting. For some stocks, information from both the commercial and recreational sectors of the fishery is utilized in the assessments. Recreational catch is included in assessments of all stocks that have (or had) a substantial recreational catch (e.g., Gulf of Maine cod, haddock, and winter flounder, Georges Bank cod, and pollock).

Indices of abundance derived from fishery data were included in several of the Northeast groundfish stock assessments until 1994. The Fishery Conservation and Management Act of 1976 established regional fishery management councils and mechanisms to control fishing activities (USDOC, 1976). The New England Fishery Management Council approved the first fishery management plan for the New England groundfish fishery in 1977, which included cod, haddock and yellowtail flounder, and was focused on individual species quotas with individual trip limits (OSB, 1998). In 1982, the Council abandoned the trip limit system under the Interim Groundfish Fishery Management Plan due to inadequate monitoring and enforcement of the trip limit system. The new management system replaced trip limits with minimum fish size and codend mesh size regulations for Georges Bank and the Gulf of Maine (NEFMC, 1993). The Hague Line on Georges Bank was established in 1984, which created a boundary between the US and Canadian Exclusive Economic Zones, and placed the most productive haddock grounds, traditionally fished by US vessels, on the Canadian side of the boundary. The Northeast Multispecies Fishery Management Plan was implemented in 1986 and was the first plan in the world to set biological targets in terms of maximum spawning potential; this plan greatly expanded the number of species included in the management unit (NEFSC, 1993). Between 1986 and 1993 the plan was amended several times to change the minimum landing size and mesh size regulations, establish new spawning closure areas, reduce small mesh fishing in the Gulf of Maine, increase enforcement ability, and include additional species. Although there were several management interventions throughout this period, stock assessments for cod and haddock included standardized commercial CPUE information.

The major management interventions introduced in 1994, including three large areas closed to mobile gear on Georges Bank and restrictions on fishing effort, impacted fishery behavior both spatially and temporally (OSB, 1998). The regulations were designed to reduce fishing effort and fishing mortality, and therefore fundamentally disrupted time series of CPUE indices. The fishery-dependent data collection system also changed in 1994, transitioning from fishermen interviews in a landings intercept program to self-reported logbooks/vessel trip reports (VTRs) to obtain information on fishing effort and location (NEFSC, 1996). Since 1994, there have been a series of significant management changes in the Northeast Multispecies Fishery Management Plan, including effort reductions, gear selectivity modifications, introduction of output controls, and inclusion of leasing options for quota (NEFMC, 2015). The frequent changes in management, switch in the fisheries-dependent data collection system, and the multispecies nature of the fishery have hindered the ability to develop useful indices of abundance from fishery data. These problems have resulted in decisions to exclude CPUE as indices of stock abundance for assessments. Several potential problems associated with the use of commercial catch rate indices have been documented for fisheries globally (e.g. Harley et al., 2001; Maunder et al., 2006). However, it is informative to evaluate CPUE indices to gain a better understanding of commercial catch patterns, even if these indices are not included in the assessment model. Currently none of the groundfish stock assessments include CPUE or landings-per-unit-effort (LPUE) indices in the assessment models. However, several recent analyses of the utility of abundance indices have indicated that further research should be applied to standardize the complexity of factors influencing fishery catch rates, and that such analysis would be best pursued outside the terms of reference for any single stock assessment (NEFSC, 2012c; 2014b; 2015a).

We reviewed recent benchmark stock assessment documents to determine if and how CPUE/LPUE information was considered. The topic has been specifically addressed in some assessments, such as Gulf of Maine haddock, white hake, and pollock, and a dedicated workshop was conducted on the use of CPUE and LPUE for the Gulf of Maine and Georges Bank cod stocks (NEFSC, 2012c). For other species, CPUE and LPUE have not been investigated for utility since 1994. The following sections summarize the use and utility of CPUE and LPUE, as described in recent Stock Assessment Workshop and Review Committee reports for several stocks managed under the Northeast Multispecies Fishery Management Plan.

Cod – Gulf of Maine ***(Summarized from SAW 55; NEFSC, 2013a)***

Trends in commercial landings per unit effort (LPUE) were used in Gulf of Maine cod stock assessments prior to SAW 53 (2012b). LPUE-at-age indices from 1982 to 1993 were calculated based on an otter trawl sub-fleet. The index was not extended beyond 1994 because of major changes occurring in the Gulf of Maine groundfish fishery, including regulatory measures to reduce fishing effort, closed areas, changes in mesh size and trip limits, as well as a change in the fisheries-dependent data collection system. All of these issues affect the comparability of LPUEs estimated from 1994 onward with the earlier time series. These same issues would make standardization of a contemporary catch per unit effort (CPUE) index difficult. The SAW 53 Working Group examined model sensitivity runs to assess the utility of including the LPUE index. Model results were insensitive to the index, and the Working Group decided to remove the index from the SAW 53 assessment.

The disconnect between the increasing CPUE reported by groundfish fishermen and the comparatively limited rebuilding suggested in the SAW 53 assessment led to an NEFSC-sponsored CPUE/LPUE Working Group to review and evaluate the information available on both commercial and recreational CPUE (NEFSC, 2012c). The CPUE/LPUE Working Group concluded that ideally, LPUE indices should be formally considered and vetted as inputs into the assessment model. They made a recommendation that if an LPUE index is determined to be a poor index of fish abundance, the index should be described in the assessment report and explanations put forward describing why the information in the LPUE index may be inconsistent with other assessment tuning indices, even though it may not be formally included as a model input. This recommendation has not been implemented in updated stock assessments for Gulf of Maine cod (Palmer, 2014; NEFSC, 2015b).

The SAW 55 Working Group considered several analyses in an attempt to develop representative indices of Gulf of Maine cod exploitable biomass based on commercial and recreational LPUE. One analysis updated the LPUE index used prior to SAW 53 through 2011 (Palmer, 2012). This index standardized the effects of year, depth, tonnage class, quarter and statistical unit area as factors in a Generalized Linear Model and showed trends that tracked spawning biomass (SSB), as estimated during SAW 53, relatively well up until 2006, after which time LPUE increased much faster than SSB. A hypothesis for the divergence in trends considered by the SAW 55 Working Group was that sand lance abundance, which is a forage species of cod, became abundant in a small region of the western Gulf of Maine (near Stellwagen Bank) between 2006 and 2010 (Richardson et al., 2012), resulting in the aggregation of cod in the area and thus elevated commercial catch rates. Increased observations of sand lance in cod stomachs from the fall Northeast Fisheries Science Center Bottom Trawl Survey in Stellwagen Bank combined with VTR, Vessel Monitoring System (VMS) and observer data indicated that Stellwagen Bank may have become a forage 'hot spot' for cod with highly concentrated fishing effort since the mid-2000s. The Working Group concluded that a large abundance of cod in a region easily exploitable by the day boat fleet was likely responsible for the increase in CPUE reported by the fishing industry between 2006 and 2010 (NEFSC, 2013a).

The Working Group noted that cod appeared to be aggregated in a small area of the Gulf of Maine, which suggests that the catchability (relationship between LPUE and biomass) has changed over the LPUE time series. They mentioned that over the longer term, there have been a number of regulatory changes (e.g. seasonal closures, trip limits, etc.) which challenge the utility of commercial LPUE as an index of Gulf of Maine cod biomass. Based on these concerns, the Working Group recommended that the commercial LPUE index should not be used in the SAW 55 assessment model. An LPUE index was also developed for the recreational fishery (Wood, 2012). However, based on concerns comparable to those of the commercial fishery, the Working Group recommended that the recreational LPUE index also should not be included in the Gulf of Maine cod assessment model.

Cod – Georges Bank *(Summarized from SAW 55; NEFSC, 2013a)*

The LPUE index for Georges Bank cod was last estimated in 1998 (SAW 27; NEFSC, 1998), but was not used as an index of abundance in the assessment or in any subsequent assessments. Effort data after 1994 was no longer considered to be equivalent to the historic 1978-1993 effort series for Georges Bank cod due to increased management restrictions and the change in effort monitoring. The SAW 55 Working Group repeated an analysis first conducted in 1993 (SAW 15; NEFSC, 1993), which used a Generalized Linear Model to estimate standardized US fishing effort and commercial LPUE for Georges Bank cod during 1978-2011. The resulting LPUE index indicated a declining trend from 1980 through 1995, a gradual increase to 2002 with another decline through 2006, then an increasing trend to 2011. The SAW 55 Working Group reviewed the updated analysis and recommended that the standardized LPUE not be used in the SAW 55 assessment model for several reasons. The Working Group noted that LPUE did not represent the entire stock for the entire time series because the index incorporates only the US landings and effort data in the western part of the stock area since 1985, whereas the Canadian fishery contributes about 25% to the overall landings. Additionally, they noted the significant regulatory changes since 1994 and implementation of sector management, which have resulted in spatial shifts in the fishery. The Working Group concluded that the recommendation to not utilize the index was consistent with the findings of the NEFSC-sponsored CPUE/LPUE Working Group (NEFSC, 2012c).

The Working Group also applied a Generalized Linear Model to recreational data to estimate an LPUE index (cod landed/angler hour) for Georges Bank cod during 1994-2011. The Working Group had several concerns with respect to the applicability of the LPUE index, including uncertainty about whether the data reported was in pounds or in numbers, the limited number of party/charter boats involved in the fishery that consistently fished over the time series, and that the fishery was conducted primarily in the westernmost part of the stock area. The Working Group concluded that the recreational LPUE index was not representative of the stock and should not be included in the assessment model.

Haddock – Gulf of Maine *(Summarized from SAW 59; NEFSC, 2014b)*

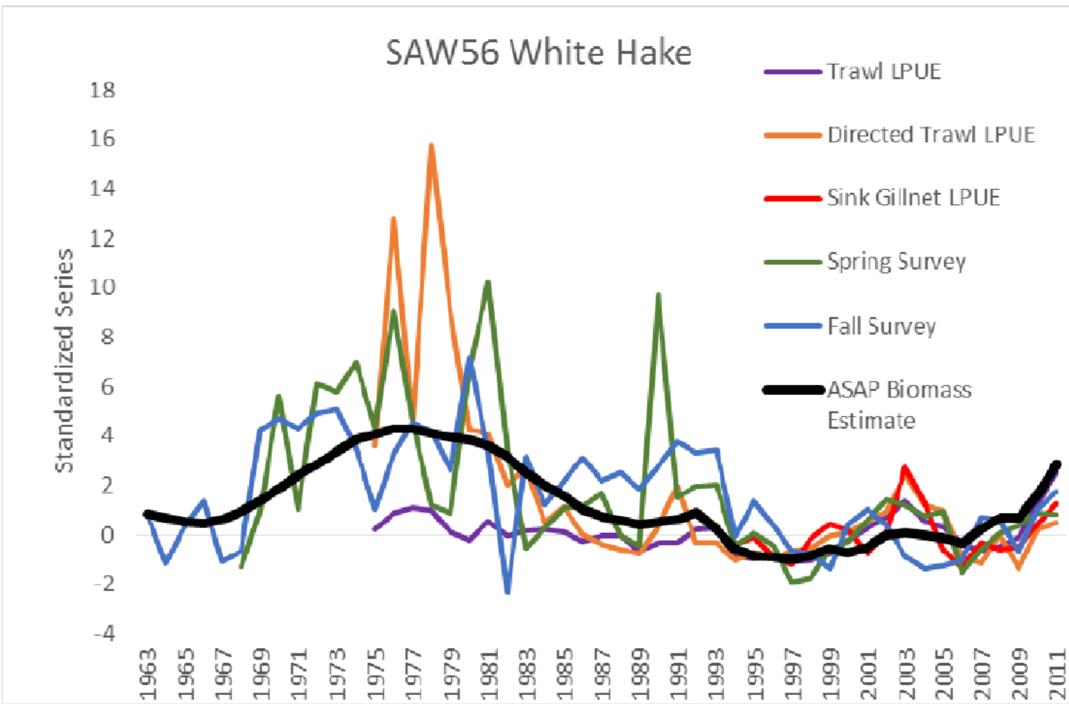
The SAW 59 Working Group for Gulf of Maine haddock analyzed LPUE by generating an analytical dealer data set and applying a Generalized Linear Model (NEFSC, 2014b). The Working Group considered only the trawl fleet data, given that Gulf of Maine haddock landings are dominated by this fleet. They noted that there was no way to accurately identify which trips in the dealer data constitute ‘groundfish’ trips with some probability of encountering haddock and which trips were engaged in other fisheries (e.g., fluke) with virtually no probability of encountering haddock. For that reason, only trips that landed ≥ 1 lb haddock were included in the model. Results for nominal Gulf of Maine haddock commercial trawl LPUE (landings per days fished) showed very little trend since the mid-1980s after declining from a peak in 1980. A comparison of the standardized LPUE index to the spawning stock biomass (SSB) estimates showed close agreement of the two series until 1994. There were several moderate-to-strong recruitment events between 1993 and 1998 leading to a large increase in spawning biomass between 1994 and 2002 (NEFSC, 2012a). The LPUE index, while it increased slightly between 1994 and 2009, did not increase consistent with the rate of increase in estimated stock size. According to the Working Group, there was an apparent shift in relationship between LPUE and stock size in the mid-1990s, such that after the mid-1990s, LPUE is not informative as an index of stock abundance. Based on these results, the Working Group concluded that the commercial LPUE index would not be used in the Gulf of Maine haddock assessment model, and that the recommendation was consistent with the recommendations of other recent assessments (SAW 55; NEFSC, 2013a).

The Working Group conducted sensitivity analyses that included the commercial and recreational LPUE indices separately within the base model assessment. Model fits to both the commercial and recreation LPUE indices exhibited a poor fit with strong residual patterning. The Working Group concluded that the results from these sensitivity analyses suggested that the LPUE indices are not reflective of stock abundance and should not be used for model tuning.

White Hake – Gulf of Maine/ Georges Bank *(Summarized from SAW 56; NEFSC, 2013b)*

The Working Group for Stock Assessment Workshop 56 on Gulf of Maine/Georges Bank white hake analyzed LPUE indices to address one of the assessment terms of reference (TOR), "TOR 2. ...Investigate the utility of commercial or recreational LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data". The Working Group calculated commercial LPUE for otter trawl gear (landings per unit effort in metric tons landed per day fished) indices for white hake using 40% of the landed trip comprised of white hake as the cutoff for standardization for directed trips. Total otter trawl nominal LPUE indices were stable or increased through 1985, generally declined through 1997, and increased to a peak in 2003 depending on the total percentage of landings. The Working Group also analyzed standardized LPUE for all otter trawl trips and for the 40% directed trips. Trends in the standardized LPUE series were similar to the trends in the nominal LPUE indices. They concluded that the standardized effort suggested that overall effort declined since 1992, while the directed effort was higher in the 1980s than in the 1990s and recently increased. Similarly, the Working Group calculated nominal and standardized commercial LPUE for sink gillnet gear. The Working Group noted that the effort data for sink gillnets appeared to be different between 1975-1993 and 1994-2011. The data collection system changed at that time and the way effort was calculated was likely not the same. Therefore, only data from 1994 onwards were used in the standardization. Results showed that all of the sink gillnet LPUE indices generally decreased from 1975 through 1993, increased from 1994-2003, generally declined through 2008, and increased through 2010.

Although not incorporated in the stock assessment (ASAP) model, the results of the LPUE analysis were described and considered in SAW 56 (NEFSC, 2013b). The Working Group noted that the distribution pattern of weighted LPUE (sum of pounds landed in a ten-minute square/sum of days fished in that ten-minute square) in otter trawls had the highest LPUE values occurring in the northeast portion of the Gulf of Maine with lower values of LPUE to the west, and that sink gill net LPUE was higher in the southeast Gulf of Maine with a slight increase from 2008-2011 (NEFSC, 2013b). The trawl and gillnet LPUE series were moderately correlated with the ASAP estimate of stock biomass, and the model estimates of stock biomass were more positively correlated with the standardized directed trawl LPUE series than either survey series, even though the survey series were included in the model.



Pollock ***(Summarized from SAW 50; NEFSC, 2010)***

The 50th Stock Assessment Working Group for pollock in US waters concluded that trends in CPUE have limitations due to regulatory and management changes over time (days-at-sea, area closures, etc.). They also stated that trends in nominal effort (number of trips and/or number of days absent) might be useful for interpretation purposes, but not for direct use in assessment models. Despite these statements, no CPUE/LPUE data were examined in the last assessment for pollock.

Winter Flounder – Gulf of Maine, Georges Bank, Southern New England/Mid-Atlantic ***(Summarized from SAW 52; NEFSC, 2011)***

The winter flounder assessments for all three managed stocks, which were last benchmarked in 2011, do not include any analysis of CPUE or LPUE as indices of stock abundance for commercial or recreational fishing patterns. The Working Group for SAW 52 examined a constant CPUE model to assign trip landings from 2004-2008 for eight species managed under the Northeast Multispecies Fishery Management Plan that are managed as separate stocks, including winter flounder (Palmer and Wigley, 2011). This analysis used VMS data as a proxy for fishing activity in the Northeast Region based on previous studies (e.g., Murawski et al., 2005) to assess the magnitude of misreporting on VTRs, and subsequently the magnitude of misreporting of landings by stock areas. While the analysis noted the caveat that a constant CPUE assumption violates known groundfish distribution patterns, the results of the analysis were used to examine landings of winter flounder by stock area. The analysis showed that since 2005, VMS has provided >80% coverage of winter flounder landings (Palmer and Wigley, 2011). The analysis was not specifically designed to examine trends in abundance for winter flounder stocks, but it provides an example of combining VTR and VMS data to examine CPUE/LPUE trends.

Yellowtail Flounder – Southern New England/Mid-Atlantic *(Summarized from SAW 54; NEFSC, 2012d)*

The Working Group for SAW 52 Southern New England/Mid-Atlantic yellowtail flounder reported an attempt to examine a CPUE index. They noted that there are currently no estimates of CPUE or effort for this species. The Working Group concluded that given the major changes in management, specifically the reduction in allowable days at sea and the regulated 2-for-1 counting of days at sea, as well as the changes in the reporting methodology, CPUE was not likely to be a good indicator of stock status. The Working Group also noted that the fishery has changed from one dominated by a directed fleet that took substantial amounts of yellowtail to a bycatch fishery. They concluded that CPUE/LPUE could not be included in the assessment of the stock.

Other Northeast Multispecies Stocks

Several assessments for stocks managed under the Northeast Multispecies Fishery Management Plan do not incorporate CPUE/LPUE information, and have not considered such information since the major management interventions and monitoring changes of the mid-1990s. The assessment for Georges Bank yellowtail flounder is currently based on an empirical data approach using only survey indices due to previous poor assessment model performance, which precludes use of CPUE/LPUE information. Other stocks have not been subject to benchmark updates in several years (Georges Bank haddock, Cape Cod/Gulf of Maine yellowtail flounder, American plaice, witch flounder, Acadian redfish, Gulf of Maine/Georges Bank and Southern New England/Mid-Atlantic windowpane flounder, Atlantic halibut, ocean pout and Atlantic wolfish).

All of the groundfish stock assessments were updated in 2015 through the Northeast Fisheries Science Center Groundfish Operational Assessments. The operational assessments incorporated updated data (both fishery-independent and dependent), but did not include changes to the reviewed benchmark assessment approaches (NEFSC, 2015d).

EVALUATION OF RATIONALE FOR INCLUSION OR EXCLUSION OF FISHERY-DEPENDENT DATA STREAMS

Through our review of the use of fishery-dependent data streams used in the assessments of the New England groundfish stocks, we examined whether or not the assessment included a rationale for including or excluding various data types, and if there was consistency in the rationale among assessments. Specific data obtained from VTRs, VMS, Dealer reports and the observer program have been used consistently and are well-documented in the assessment reports for the groundfish species. However, there are several data gaps associated with these required data collection systems, which preclude use of certain types of information and confounds assessment analyses. For example, VTR data on discards is notoriously problematic and is not used for assessment purposes. Information on discards is obtained from observer or At-Sea Monitor data, which had a relatively low coverage rate prior to 2005. Total catch is therefore difficult to determine, resulting in confounding trends in CPUE. Another major gap associated with the current fishery-dependent data collection systems is the lack of vessel, operator and gear-specific characteristics. Several assessment reports noted the challenges in using CPUE as an indicator of stock size because of changes in fishery efficiency. While some general knowledge about the effects of increased efficiency resulting from advances in navigational and technological equipment exists, specific information at the individual vessel level is lacking, making it difficult to compare relative catch rates between years.

Recent assessments that have reported CPUE/LPUE information have provided rationale for excluding these data from assessment models. As summarized above, the cod, haddock, white hake, pollock, winter flounder and yellowtail flounder assessments examined the use and utility of CPUE/LPUE information and concluded that the information was not representative of trends in stock size and should not be included in the assessment model. Recent assessments for several stocks in the Northeast Multispecies complex do not include any analysis of CPUE/LPUE, and it is unclear whether or not such information could be used. While there was a long period between 1994 and 2010 when CPUE/LPUE information was not included in the assessments of groundfish stocks, recent benchmark assessments have included an analysis of CPUE/LPUE as a measure of stock abundance in the terms of reference.

Despite the challenges associated with constructing CPUE/LPUE indices for use in the assessments of New England groundfish species, these types of fishery-dependent data can provide useful insights about fleet behavior, population dynamics and environmental conditions. The Gulf of Maine cod assessment report noted that CPUE remained high during a period where cod biomass was declining, possibly due to targeting a foraging ‘hot spot’ on Stellwagen Bank related to an increase in sand lance abundance. While this may be confounding information for producing a stock wide abundance index, it sheds light on a shift in trophic dynamics that has important ramifications for understanding environmental influences on fish stocks. The Gulf of Maine haddock assessment report showed a mismatch of CPUE associated with increasing biomass due to large recruitment events in the late 1990s. Although there may be limited utility of CPUE information as an index of haddock stock size, information about fleet behavior and impacts of management interventions could be examined. Another example of using CPUE information was included in the winter flounder assessment report as a way to assign trip landings by stock area. Despite noted caveats, the information was useful to address misreporting of landings by stock area on VTRs.

Catch per unit of effort is a metric that the fishing fleet understands and relies on to make decisions about where, when and what to target. The uncertainty associated with recent stock assessments, coupled with historic low fishing allocations has triggered a renewed interest by the fishing industry to examine CPUE/LPUE data as a way to reconcile the perceived mismatch of assessment results with on the water observations. Incorporating CPUE/LPUE into assessment models may not be appropriate for many stocks based on the provided rationale in the assessment reports; however examination of the available data to address questions from the fishing industry could reveal novel results related to fine scale spatial and temporal patterns. An immense amount of time and resources have been expended to standardize survey catch data to produce a single time series. Much of this work has been conducted outside of the stock assessment process with results applied to assessments. Similarly, effort could be dedicated to examine methods to standardize CPUE/LPUE indices. The rationale for excluding these data in assessments is largely focused on the challenges associated with standardizing the data due to a variety of influences. While the rationale is sound, it does not preclude additional exploration of possible ways to make CPUE/LPUE information more useful for assessments.

RECOMMENDATIONS FOR FUTURE USE OF FISHERY-DEPENDENT DATA IN STOCK ASSESSMENTS

Use of fishery-dependent data for assessment and management purposes has been reviewed both generally (e.g., Maunder et al., 2006; Maunder and Punt, 2004; Harley et al., 2001) and specific to the Northeast region (e.g., OSB, 1998; NEFSC, 2012c; GMRI, 2014). Several recommendations about the use of CPUE/LPUE have been generated over the last two decades. We summarized the use and utility of CPUE/LPUE information for a small sample of stocks outside of the New England region and the major findings and recommendations specific to New England groundfish CPUE/LPUE data, and included additional recommendations based on our review of assessments of Northeast Multispecies stock assessments, past and current efforts on this topic, and feedback from the fishing industry.

Review of the Use of CPUE/LPUE Information in Assessments of Species in Other Fisheries

Tilefish *(Summarized from SAW 58; NEFSC 2014a)*

A fishery-independent index of abundance does not exist for tilefish. The NEFSC bottom trawl surveys only catch a few tilefish per survey, so the time series is not a useful index of abundance. The assessment relies on fishery-dependent commercial CPUE as an index of abundance. Analyses of catch (landings) and effort data from three different series of longline fishery data were analyzed. CPUE trends were very similar for most vessels that targeted tilefish. Since 1979, the tilefish industry has changed gear configurations. Due to possible changes in catchability associated with the changes in fishing gear, the Working Group considered that it would be best to use the three available CPUE indices separately rather than combined into one or two series. The Working Group suggested that changes in the CPUE were generally explained with evidence of strong incoming year classes that track through the landings size composition over time. Since the 2009 tilefish assessment (SAW 48; NEFSC, 2009) there appeared to be increases in CPUE due to one or two new strong year classes. In general, strong year classes appear to persist longer in the fishery after the implementation of the Fishery Management Plan and after the constant quota management came into effect.

There was some uncertainty associated with the assessment results for tilefish. The Working Group noted that there were unknown effects on CPUE from fishery conflicts with lobster and trawl gear, unfished areas on the south flank of Georges Bank, effects of targeting incoming year classes and avoiding extra-large fish due to marketability, and unknown effects due to competition from increased dogfish abundance. However, the assessment model (ASAP) was able to match the year class dynamics seen in the commercial size distributions and CPUE patterns. The Review Committee recommended developing an industry-based survey to collect more intensive size and catch information on a haul by haul basis to supplement the current CPUE indices (NEFSC, 2014a).

Bluefish *(Summarized from SAW 60; NEFSC, 2015a)*

A standardized bluefish CPUE index from the recreational fishery was evaluated and its utility as an index of abundance was considered by the Stock Assessment Working Group for SAW 60 (NEFSC, 2015a). The Marine Recreational Information Program (MRIP) index covers the entire range of the Atlantic coast stock of bluefish and includes information on older age classes that are poorly sampled by standard fishery-independent surveys, so the Working Group chose to include it as an index of abundance in the assessment model. The MRIP intercept data was used to develop a set of directed bluefish trips, defined as any trip that caught bluefish (regardless of disposition) or where the angler reported targeting bluefish. The MRIP CPUE showed a decline in catch per trip during the 1980s and mid-1990s, before rebounding in the late 1990s to fairly stable levels since 2000 (Figure 1). Sensitivity of the assessment model to individual survey indices was tested by removing each index and re-running the model. The model was fairly insensitive to the removal of all the indices except for the MRIP recreational CPUE index. The MRIP CPUE index was so important because it provides most of the information for model estimates at older ages. When the Working Group removed the MRIP index from the model there was a significant decrease in fishing mortality estimates and an increase in abundance and biomass estimates, which were not considered to be representative of the stock trends.
Figure 1. Bluefish model (solid line) fit to the MRIP CPUE index (open circles; from NEFSC, 2015a).

Scup *(Summarized from SAW 60; NEFSC, 2015a)*

The Stock Assessment Working Group for scup compiled CPUE data and conducted analyses on constructing an index of abundance in 2015 based on fishing industry (both commercial and recreational) comments about the utility of fishery-dependent CPUE. Data sources included: 1) the commercial Dealer reported data for trawl gear; 2) the commercial fishing VTR data for trawl gear; 3) observer program data for trawl gear; 4) the recreational for-hire fishing vessel VTRs for rod-and-reel gear; 5) the Marine Recreational Fishery Statistics Survey / Marine Recreational Information Program (MRFSS/MRIP) data for rod-and-reel gear; and 6) commercial Study Fleet detailed catch per tow information. The Working Group evaluated the utility of CPUE as indices of abundance in the scup stock assessment, and noted generally that: 1) the utility of the fishery-dependent data as the basis for indices of abundance is limited because some reports include only landings, so the resulting LPUE could be biased low relative to the true abundance of fish; 2) the use of only positive trips that catch scup may bias the LPUE or CPUE, and may be influenced by management regulations; and 3) the ratio of catch to effort has generally changed over time due to fish abundance, management regulations, or changes in data reporting systems. The Working Group reported that over the long term, there have been a number of regulatory changes, primarily seasonal trip limits and mesh regulations, which are different in timing and magnitude for each year.

The Working Group continued the analysis by investigating the utility of 'directed scup trips' from the Dealer landings reports as the basis for an index of abundance. They used data from "75% scup trips" LPUE (trips for which scup account for 75% or more of the reported landings), which removed ~200,000 "bycatch" trips for scup. The resulting LPUE series was different than all other survey and CPUE stock indicators (e.g., slight peak in LPUE in mid 1990s). They concluded that further analysis beyond the scope of the assessment was needed to standardize the complexity of factors influencing fishery catch rates, and recommended that a standardized fishery-dependent CPUE of scup targeted tows, from either observer samples or the commercial study fleet, might be considered as an additional index of abundance to complement survey indices in future benchmark assessments.

Atlantic Bluefin Tuna – Western and Eastern Stocks *(Summarized from ICCAT, 2014)*

The International Commission on the Conservation of Atlantic Tunas (ICCAT) conducted a stock assessment for Atlantic Bluefin tuna in 2014. The assessment for the western stock, which used a Virtual Population Analysis (VPA), included relative abundance indices from twelve fleets, including two areas of Canadian rod and reel, tended line and harpoon fisheries, three US rod and reel fisheries, the US Gulf of Mexico pelagic longline fishery, and Japanese longline fishery in the western north Atlantic. The assessment for the eastern stock, also a VPA, included CPUE indices from the Japanese longline fishery in the East Atlantic and Mediterranean (1975-2009, for ages 6+), the Norwegian purse seine fishery (1955-1979, for ages 10+), the Japanese longline fleet in the North East Atlantic (1990-2013, for ages 4+), and the Spanish baitboat fishery. The assessment group noted that there were various problems associated with the eastern stock model results due to the quality of the data. For example, they highlighted the difficulty of the CPUE indices in tracking recent changes in tuna abundance due to management that has directly affected catch, effort and selectivity-at-age in the fisheries. The poor quality of data translates into high sensitivity of the VPA model to minor changes in the CPUE indices. The assessment group concluded that the outputs of the eastern stock VPA remained highly unstable and need to be confirmed by further analyses that would use other modeling approaches than the current VPA. While the CPUE indices were problematic for reasons similar to those in the assessments of Northeast Multispecies stocks (e.g., management interventions and changes in fishery efficiency), the indices are a necessary component of the assessment due to lack of other types of fishery-independent data (ICCAT, 2014).

ICES Stock Assessments

Many assessments for eastern Atlantic stocks that are conducted by the International Council for Exploration of the Sea (ICES) include CPUE/LPUE indices. For example, the North Sea saithe *(Pollachius virens)* assessment includes CPUE information from three commercial fleets as tuning indices, the French demersal trawl fishery and German and Norwegian bottom trawl fisheries, and the North Sea turbot *(Scophthalmus maximus)* assessment includes CPUE information from the Dutch beam trawl fleet (ICES, 2015). No assessment model has been applied to anglerfish *(Lophius piscatorius* and *budegassa)* in the Iberian region, however LPUE from Spanish fleets was used in combination with limited survey information to set catch advice for the 2015 fishing year (ICES, 2014). The assessment for sole *(Solea solea)* in the Bay of Biscay includes CPUE indices from two French trawl fleets, a Belgian beam trawl fleet and inshore and offshore Bay of Biscay trawl fleets (ICES, 2014). All of the ICES example stocks are included in fishery management plans that have changed over time to include effort restrictions, closed areas, and gear modifications.

Prior Recommendations for the Use of CPUE in Northeast Multispecies Stock Assessments

In 1998, a review of Northeast fishery stock assessments was conducted by the Committee on Northeast Fishery Stock Assessments, the Ocean Studies Board, the Commission on Geosciences, Environment and Resources and the National Research Council (OSB, 1998). The review concluded that the skepticism expressed by National Marine Fisheries Service assessment scientists and the Stock Assessment Review Committees about the usefulness of aggregated catch and effort data to construct CPUE series was appropriate due to the quality of logbook data and various management measures that were imposed after 1994. They noted, however, that “fishers have a greater trust in the data that they themselves provide, and therefore an effort should be made to validate and use CPUE data”.

The resulting report from the review, “Review of Northeast Fishery Stock Assessments”, included several recommendations related to use and utility of fishery-dependent data, specifically CPUE information. The report suggested that in order to obtain valid CPUE series, changes in fishing technology, fishing competence and restrictions on effort must be accounted for in the analysis. The report outlined a possible approach of disaggregating the data not only by vessel, but also by captain and management events. The objective of the approach was to focus on periods with constant technology (e.g., same gear, same engine), constant fishing competence (same captain and key crew), and same external conditions (e.g., management regime with respect to closed areas and periods, days at sea limitations, rules for discards and bycatch). The report noted that the resulting catch series from this suggested approach would be highly variable within each period, but could be analyzed together to produce a CPUE series related to relative abundance. As a mechanism to obtain data of sufficient quality for disaggregated CPUE analysis, the report suggested establishment and use of a subset of fishing vessels to provide more detailed logbook data than are recorded in the mandatory VTRs.

The report included several additional recommendations related to the use of fishery-dependent data and fishermen’s knowledge in the stock assessment process. The list below is excerpted from the Recommendations section of the 1998 report, with specific focus on fishery-dependent data use and utility.

- *Improve the collection, analysis, and modeling of stock assessment data. Such improvements could include evaluations of sample size, design, and data collection in the fishery and the surveys; the use of alternative methods for data analysis; consideration of a wider variety of assessment models; and better treatment of uncertainty in forecasting.*
- *Improve relationships and collaborations between NMFS and fishers by providing, for example, an opportunity to involve fishers in the stock assessment process and using fishers to collect and assess disaggregated Catch-Per-Unit-Effort data.*
- *Work toward a comprehensive management model that links stock assessments with ecological, social and economic responses and adaptation for long-term management strategies. This involves input from the social sciences (economics, social and political science, operational research) and from a wider range of natural sciences (ecology, genetics, oceanography) than traditionally is the case in fisheries management.*

In 2012, the Northeast Fisheries Science Center sponsored a Workshop titled, "Utility of Catch and Landings Per Unit of Fishing Effort (CPUE and LPUE) in Gulf of Maine and Georges Bank Cod Stock Assessments", which included fishermen, fisheries scientists and managers (NEFSC, 2012c). The stated objectives of the workshop were to determine the factors of fishery-dependent information that confound the use of CPUE and LPUE, and recommend new ways to mitigate those factors and potentially incorporate their use in the assessments of the Gulf of Maine and Georges Bank cod stocks.

Presentations and discussions during the Workshop noted several challenges to the use of CPUE/LPUE indices in stock assessments, including the previously mentioned management interventions in the New England groundfish fishery, changes in fishery efficiency, market influences on targeted species, lack of reliable catch data, and shifts in trophic dynamics. However, participants generally agreed that there is low public access to and understanding of CPUE/LPUE data or modeling outcomes. The end result from assessments (i.e. stock status and catch level advice for managers) is mostly what is seen by the fishing community. Workshop participants discussed whether or not improving fishery-dependent data to support use of CPUE/LPUE information in stock assessments was worthwhile. Recommendations from the Workshop included:

- *Determine if dealer records are representative of CPUE/LPUE.*
- *Assemble relevant databases using VTRs, observer data and VMS information from specific fishing vessels that may have a more consistent fishing history over a large number of years.*
- *Examine alternative specifications for defining directed cod fishing trips, look at creating more concise categories of fishing gear and modes of deployment that are similar, and analyze these trips for CPUE/LPUE trends.*
- *Examine the use of temporal factors, such as seasonal or monthly time periods as fixed effects in the model using LPUE information.*

New Recommendations for the Use of CPUE in Northeast Multispecies Stock Assessments

Based on our review of the use and utility of CPUE/LPUE information in stock assessments of New England groundfish prior to 1994, as well as in assessments of stocks in the Mid-Atlantic region and ICES and ICCAT assessed stocks, we propose recommendations to reconsider CPUE data in future assessments of the groundfish stocks. These recommendations build upon previous suggestions with an objective of integrating existing information and supplementing current data collection systems.

• Collect the fishery-dependent information needed to identify target species as well as other important factors for standardizing catch rates, such as vessel, operator and gear characteristics, fine scale spatial and temporal fishing behavior and regulatory framework.

NOAA leadership in the Greater Atlantic Region prioritized modernizing fishery-dependent data systems as an opportunity to create efficiencies and improve catch accounting, stock assessments and fine-scale management approaches through timely and accurate data collection and processing. The National Marine Fisheries Service conducted a review of fishery-dependent data collection systems in the Northeast region in 2014, and proposed to implement an improved fishery-dependent data collection system by 2017 (GMRI, 2014). Several Stock Assessment Workshops have noted the lack of fine scale information as a challenge to incorporating fishery-dependent data, specifically CPUE in assessment models. Additionally, changes in technology, efficiency and behavior have been cited as reasons why CPUE information is not informative as an index of stock abundance. Collection of more detailed information about target species, fishing location, and vessel, operator and gear characteristics could enhance our understanding of fishing behavior under changing management scenarios, and provide the necessary level of detail to construct CPUE indices. The opportunity to introduce changes or additions to the current data collection systems is available under NOAA's fishery-dependent data visioning project, and inclusion of target species, vessel, operator and gear characteristics, fine scale spatial and temporal fishing behavior and regulatory framework should be included in the improved data collections system.

• Prioritize the evaluation of standardized CPUE and LPUE for New England groundfish species as a research agenda to be conducted outside of the stock assessment workshop process.

> Fishery-dependent data are currently available for analysis. These data could be examined by assessment, academic or non-government scientists outside of the stock assessment process to determine the utility of including CPUE and LPUE information. Lack of time and resources during stock assessment workshops have been cited as reasons why extensive analyses of CPUE information have not been conducted. Efforts to standardize fishery-independent survey data have been conducted outside of assessments, resulting in availability of reviewed information for use in assessment models. Similar efforts should be applied to fishery-dependent data prior to benchmark assessment for New England groundfish stocks.

• Include the evaluation of standardized CPUE and LPUE as a term of reference in each benchmark stock assessment in Northeast stock assessment workshops for consideration in the stock assessment model.

> The terms of reference for benchmark stock assessments set the scope of topics, analyses and issues to be covered by the assessment Working Group. Formal inclusion of

evaluation of standardized CPUE and LPUE as a term of reference could help to ensure that the topic is addressed, there is opportunity for public comment and input, there is an explanation of the rationale for inclusion or exclusion of the data, all possible uses of the information have been considered, and the use and utility of CPUE and LPUE can be reviewed externally by assessment review committees. This recommendation complements the previous recommendation to examine fishery-dependent data utility outside of the assessment process. Compiling the appropriate data and determining suitable methods for standardizing CPUE should be completed prior to the assessment, so that results can be used to address a specific term of reference for evaluation of the utility of the information for assessment purposes.

• Explore Study Fleet data for the derivation of standardized CPUE and LPUE series.

As noted above, the "Review of Northeast Fishery Stock Assessments" report suggested establishment and use of a subset of fishing vessels to provide more detailed logbook data than are recorded in the mandatory VTRs. The Northeast Fisheries Science Center developed the Study Fleet in 20007 with the objective of assembling a subset of commercial New England vessels capable of providing high resolution (spatial and temporal) self-reported data on catch, effort and environmental conditions while conducting "normal" fishing operations. The program was intended to provide stock assessment scientists with more precise and accurate fishery-dependent data (e.g., more precise estimates of fishing effort, spatially explicit catch, and discard locations) and to improve the understanding of catch rates and species assemblages (NEFSC, 2007). Additionally, it was noted that the collaborative nature of the Study Fleet pilot program could create a channel through which stock assessment scientists and industry members could directly communicate and share information that would serve as the basis for future collaborative research projects (Murawski 2002). The Study Fleet has been active for over 8 years, and has collected a large dataset of fishery-dependent information. A formal review of the utility of the data for the derivation of standardized CPUE and LPUE series should be conducted. The study fleet offers a small sample of the fleet with electronic logbooks. Fleet-wide implementation of electronic logbooks could offer a census of more precise catch location and effort statistics.

• Collaborate with fishermen to identify appropriate index fleets, factors influencing catch rates, and perceptions of trends in catch rates.

The mismatch between fishermen's perceptions of what is occurring on the water and results from recent assessments for several New England groundfish stocks has caused a renewed interest in examining the use and utility of CPUE information in assessments. As previously noted, fishermen generally have a greater trust in the information they collect and a greater understanding of catch and effort statistics than fishery-independent data and model results. Additionally, fishermen may be able to accurately identify trends in catch rates based on historical knowledge of spatial and temporal species distributions, marketability, and business planning. Collaborating with fishermen to identify index fleets and trends in catch rates could enhance efforts to develop standardized CPUE indices. The Sector management system, which has been in place in New England since

2010, includes mechanisms to collect data on target species, influences of management intervention on catch and effort, operating costs, and species marketability. Efforts should be made to work collaboratively with members of the Sector system to extract useful fishery-dependent information and inform the stock assessment process.

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Table 1. Types of fishery-dependent data collected from required reports for the Northeast Multispecies complex.

Data Type	Vessel Trip Report (VTR)	Vessel Monitoring System (VMS)	Dealer Report	Observer Reports (NEFOP)	At-Sea Moinitoring (ASM)	Dockside Monitoring
Vessel Permit	X	X	X			X
Operator Permit	X	X				
Area Fished (statistical area)	X					X
Area Fished (Lat/Lon)		X		X	X	
Time Fished	X	X		X	X	
Landed Species (for sale)	X		X	X	X	X
Landed Species (not sold)				X	X	
Discarded Species	X			X	X	
Species Disposition				X	X	
Landing Date			X	X	X	X
Landing Port			X	X	X	X
Dealer Demographics			X			
Market Category			X			
Landed Species Price			X			
Tow Duration		X		X	X	
Steaming Time		X				
Vessel Characteristics				X	X	
Gear Characteristics				X	X	
Target Species				X	X	
Biological Information				X		

Table 2. Types of collaborative research data collected by fishermen to support stock assessment and management advice.

Data Type	Industry-Based Surveys	Tagging Studies	Mortality Studies
Area Swept Biomass by Species	X		
Biological Samples	X		
Gear Selectivity	X		
Gear Efficiency	X		
Seasonal Distribution by Species	X	X	
Movement Patterns		X	
Stock identification		X	
Abundance Estimates		X	
Spawning Locations		X	
Discard Mortality Estimates (commerical and recreational)		X	X
Post-Release Survival Estimates			X

Table 3. The species and stocks of groundfish managed under the Northeast Multispecies Fishery Management Plan.

Species	Stocks
Cod	Gulf of Maine Georges Bank
Haddock	Gulf of Maine Georges Bank
Yellowtail Flounder	Cape Cod/Gulf of Maine Georges Bank Southern New England/Mid-Atlantic
Winter Flounder	Gulf of Maine Georges Bank Southern New England/Mid-Atlantic
Windowpane Flounder	Gulf of Maine/Georges Bank Southern New England/Mid-Atlantic
American Plaice	Gulf of Maine/Georges Bank
Witch Flounder	Single Stock
Acadian Redfish	Gulf of Maine/Georges Bank
Pollock	Single Stock
White Hake	Gulf of Maine/Georges Bank
Atlantic Halibut	Gulf of Maine/Georges Bank
Ocean Pout	Single Stock
Atlantic Wolffish	Single Stock

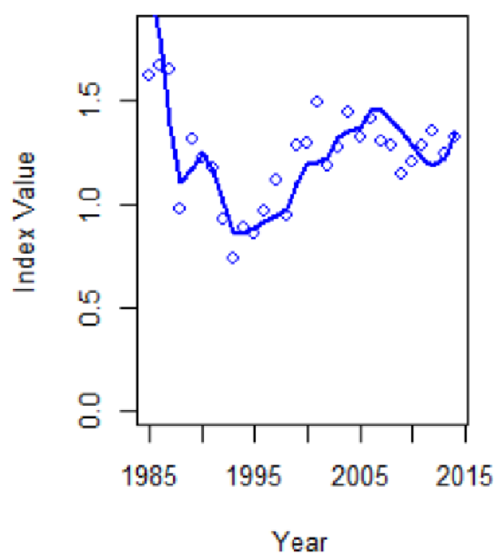


Figure 1. Bluefish model (solid line) fit to the MRIP CPUE index (open circles; from NEFSC, 2015a).

Appendix 4: Introduction of Bias in CPUE from case selection based on relative fraction of target species.

Simple Example in Excel

In many assessments the determination of target species for a trip is done post hoc, using existing data. For example in such an analysis the target species could be defined as the species whose total weight exceeds some fraction of the total weight for the trip. Under this criteria the CPUE index is based on the subset of trips which have target species ratios above the cut point. Table 1 shows the ratios for catches to the target species (an arbitrary range from 0 to 10) compared to the catch of non-target species, also ranging from 0 to 10. Suppose the analyst chose a ratio of 0.5 as the threshold criteria. Table 2 shows in red shading (and the value 1) those trips that would be included in the analysis of CPUE. However it is immediately clear that many trips that caught the target species will be excluded from the analysis.

Table 1 . Ratio of target species to total catch for a two species system. Observations would be excluded when ratio falls below user specified criteria

Catch of non-target species	Catch of Target species: 0	1	2	3	4	5	6	7	8	9	10
0	0	1	1	1	1	1	1	1	1	1	1
1	0	0.5	0.666667	0.75	0.8	0.833333	0.857143	0.875	0.888889	0.9	0.909091
2	0	0.333333	0.5	0.6	0.666667	0.714286	0.75	0.777778	0.8	0.818182	0.833333
3	0	0.25	0.4	0.5	0.571429	0.625	0.666667	0.7	0.727273	0.75	0.769231
4	0	0.2	0.333333	0.428571	0.5	0.555556	0.6	0.636364	0.666667	0.692308	0.714286
5	0	0.166667	0.285714	0.375	0.444444	0.5	0.545455	0.583333	0.615385	0.642857	0.666667
6	0	0.142857	0.25	0.333333	0.4	0.454545	0.5	0.538462	0.571429	0.6	0.625
7	0	0.125	0.222222	0.3	0.363636	0.416667	0.461538	0.5	0.533333	0.5625	0.588235
8	0	0.111111	0.2	0.272727	0.333333	0.384615	0.428571	0.466667	0.5	0.529412	0.555556
9	0	0.1	0.181818	0.25	0.307692	0.357143	0.4	0.4375	0.470588	0.5	0.526316
10	0	0.090909	0.166667	0.230769	0.285714	0.333333	0.375	0.411765	0.444444	0.473684	0.5

Table 2. Cells included incomputations when threshold for percent composition is equal to 0.5

Catch of non-target species	Catch of Target species: 0	1	2	3	4	5	6	7	8	9	10
0	0	1	1	1	1	1	1	1	1	1	1
1	0	1	1	1	1	1	1	1	1	1	1
2	0	0	1	1	1	1	1	1	1	1	1
3	0	0	0	1	1	1	1	1	1	1	1
4	0	0	0	0	1	1	1	1	1	1	1
5	0	0	0	0	0	1	1	1	1	1	1
6	0	0	0	0	0	0	1	1	1	1	1
7	0	0	0	0	0	0	0	1	1	1	1
8	0	0	0	0	0	0	0	0	1	1	1
9	0	0	0	0	0	0	0	0	0	1	1
10	0	0	0	0	0	0	0	0	0	0	1

Thus far we have not considered the probability of observing the catches of target and non-target species. As a simplification, assume that the chances of observing catches of the target species of 0, 1, 2, ...10 are equally probable, i.e, P=1/11. Similarly assume that the non-target species has the same probability (P=1/11). The joint probability is the product of the two independent probabilities or (1/11)*(1/11)= 0.008264 as shown in Table 3. Note that the total probability of all the cells in Table 3 is one. The CPUE index over the entire sample space is simply the value of the target species multiplied by the product of the joint probabilities. When all the data are used the CPUE is 5.5. If however, the threshold criteria of 0.5 is used, the CPUE estimate is higher, because only 53.719% of the observation are used (Table 4). The CPUE estimate based on the truncated sample is 6.77 as shown in Table 5. This is 23% higher than the CPUE estimate over the original set of trips. If the relationship between the target and non-target species were to remain constant over time, then a 23% bias in the CPUE would not be important because the trends would be the same. However, this assumption strains credulity given the dynamics of stocks that constitute the multispecies groundfish fishery. The relative abundances of the typical groundfish species are likely to vary over time, resulting in variable biases over time.

Table 3. Joint probability of occurrence when Target species is between zero and 10 and non-target species is 0 to 10

			Catch of Target species										
			0	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	Value
Catch of non-target species	***value***	***Prob***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	Probability
	0	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	1	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	2	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	3	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	4	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	5	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	6	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	7	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	8	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	9	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	10	0.09091	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
													Total Prob	**1**

Table 4. Probability of occurrence for filtered observations.

			Catch of Target species										
			0	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	Value
Catch of non-target species	***value***	***Prob***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	Probability
	0	0.09091	0	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	1	0.09091	0	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	2	0.09091	0	0	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	3	0.09091	0	0	0	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	4	0.09091	0	0	0	0	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	5	0.09091	0	0	0	0	0	0.008264	0.008264	0.008264	0.008264	0.008264	0.008264	
	6	0.09091	0	0	0	0	0	0	0.008264	0.008264	0.008264	0.008264	0.008264	
	7	0.09091	0	0	0	0	0	0	0	0.008264	0.008264	0.008264	0.008264	
	8	0.09091	0	0	0	0	0	0	0	0	0.008264	0.008264	0.008264	
	9	0.09091	0	0	0	0	0	0	0	0	0	0.008264	0.008264	
	10	0.09091	0	0	0	0	0	0	0	0	0	0	0.008264	
													Total Prob	**0.53719**

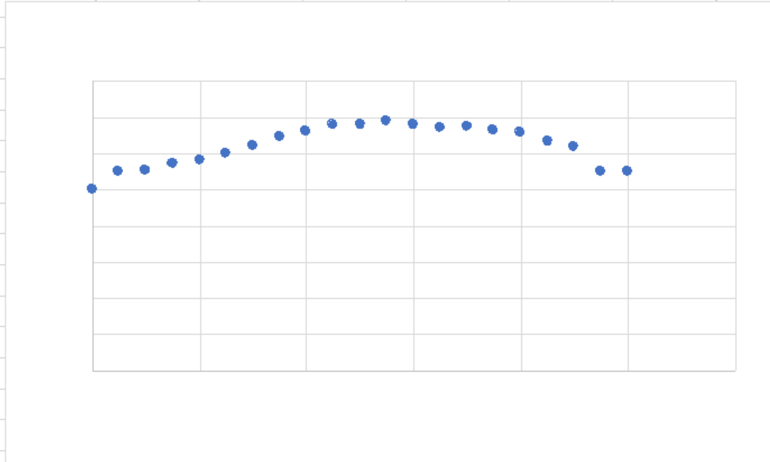
Table 5. Product of Catch value * probability of occurrence for filtered observations.

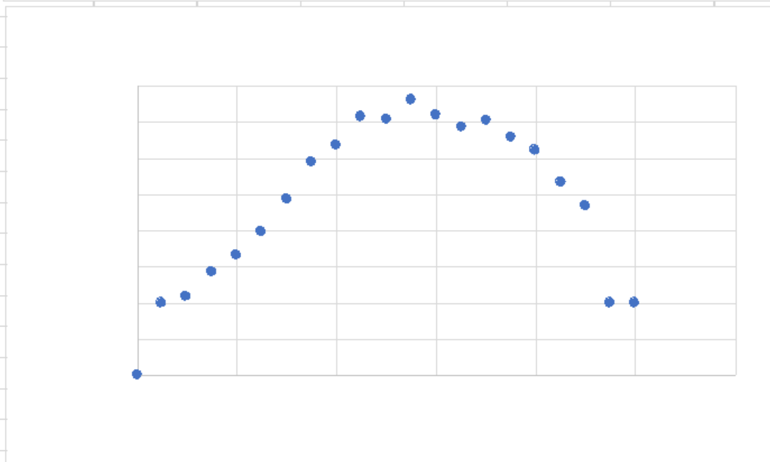
			Catch of Target species										
			0	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	Value
Catch of non-target species	***value***	***Prob***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	***0.09091***	Probability
	0	0.09091	0	0.008264	0.016529	0.024793	0.033058	0.041322	0.049587	0.057851	0.066116	0.07438	0.082645	
	1	0.09091	0	0.008264	0.016529	0.024793	0.033058	0.041322	0.049587	0.057851	0.066116	0.07438	0.082645	
	2	0.09091	0	0	0.016529	0.024793	0.033058	0.041322	0.049587	0.057851	0.066116	0.07438	0.082645	
	3	0.09091	0	0	0	0.024793	0.033058	0.041322	0.049587	0.057851	0.066116	0.07438	0.082645	
	4	0.09091	0	0	0	0	0.033058	0.041322	0.049587	0.057851	0.066116	0.07438	0.082645	
	5	0.09091	0	0	0	0	0	0.041322	0.049587	0.057851	0.066116	0.07438	0.082645	
	6	0.09091	0	0	0	0	0	0	0.049587	0.057851	0.066116	0.07438	0.082645	
	7	0.09091	0	0	0	0	0	0	0	0.057851	0.066116	0.07438	0.082645	
	8	0.09091	0	0	0	0	0	0	0	0	0.066116	0.07438	0.082645	
	9	0.09091	0	0	0	0	0	0	0	0	0	0.07438	0.082645	
	10	0.09091	0	0	0	0	0	0	0	0	0	0	0.082645	
													Total CPUE	**6.769231**

The degree of bias as a function of the threshold criterion was examined for thresholds from 0 to 1 and is shown in the two graphs below. The ratio of the derived estimate to the true CPUE ranges from 1 to 1.36 in this hypothetical example.

Relationship betwee threshold criterion and CPUE estimate

Threshold	CPUE Est	Ratio Est/True
0.000	5	1.0000
0.050	5.5	1.1000
0.100	5.541284	1.1083
0.150	5.714286	1.1429
0.200	5.833333	1.1667
0.250	5.989796	1.1980
0.300	6.217391	1.2435
0.350	6.470588	1.2941
0.400	6.5875	1.3175
0.450	6.785714	1.3571
0.500	6.769231	1.3538
0.550	6.9	1.3800
0.600	6.790698	1.3581
0.650	6.714286	1.3429
0.700	6.758621	1.3517
0.750	6.64	1.3280
0.800	6.55	1.3100
0.850	6.333333	1.2667
0.900	6.166667	1.2333
0.950	5.5	1.1000
1.000	5.5	1.1000





More realistic example in R.

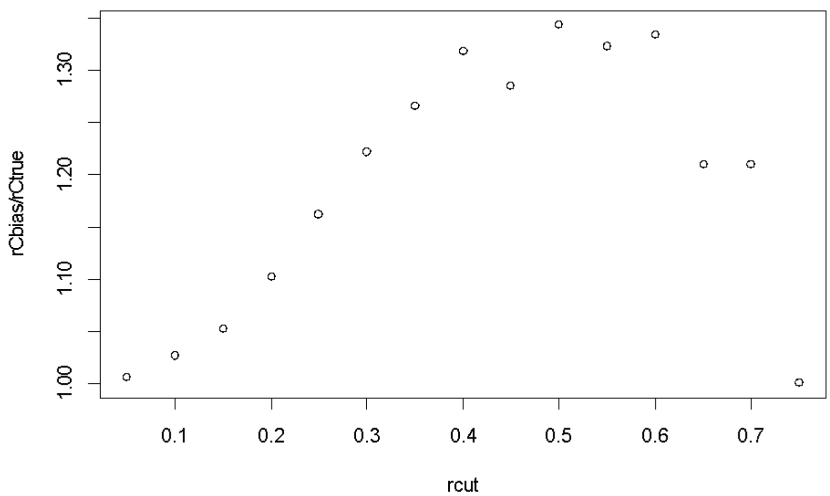
The above "toy" example assumes a uniform distribution of catches in both the species 1 and 2. More realistic simulations can be used to show the effects of alternative distributions of catch and the magnitude of bias induced when the abundance of the target species declines between sampling periods:

R code

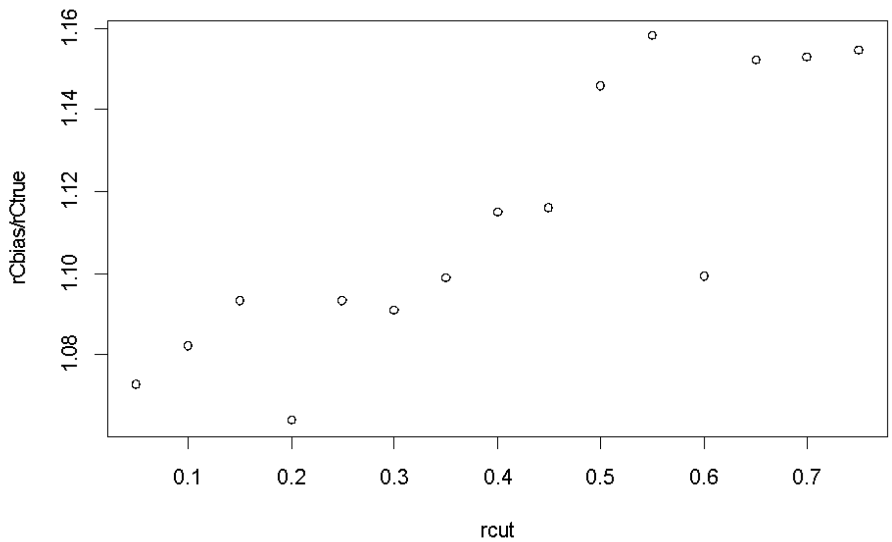
```
# Quick simulation model to demonstrate the bias of defining cpue based on % composition of target species
require(graphics)

B1t1<-10000  # Abundance of species 1 in first time period
B2t1<-10000  # Abundance of species 2 in first time period
B1t2<-5000  # Abundance of species 1 in second time period
B2t2<-10000 # Abundance of species 2 in second time period
```

```
p<-0.001   #Probability of capture for species 1 and 2 per unit of effort
ns<-10000  #Total units of effort in both time period 1 and 2
rcut<-seq(0.05, 0.75, by= 0.05)  #This is the threshold applied to trips to identify targetted trips

for(i in 1:15){
            #Compute the random catches for each unit of effort using binomial distr,
#C1t1<-rbinom(ns,B1t1,p)
#C2t1<-rbinom(ns,B2t1,p)
#C1t2<-rbinom(ns,B1t2,p)
#C2t2<-rbinom(ns,B2t2,p)
            #Compute random catches for each unit of effort using the log normal distribution

C1t1<-rlnorm(ns,meanlog=log(B1t1),sdlog=sqrt(log(B1t1)))
C2t1<-rlnorm(ns,meanlog=log(B2t1),sdlog=sqrt(log(B2t1)))
C1t2<-rlnorm(ns,meanlog=log(B1t2),sdlog=sqrt(log(B1t2)))
C2t2<-rlnorm(ns,meanlog=log(B2t2),sdlog=sqrt(log(B2t2)))

            #Compute the fraction of species 1 in total catch for each time period
f1t1<-C1t1/(C1t1+C2t1)
f1t2<-C1t2/(C1t2+C2t2)
            #Misc intermediate computations
             #max(f1t1)
             #max(f1t2)
             #mean(C1t1)
             #mean(C1t2)
             #mean(C1t1[f1t1>rcut[i]])
             #mean(C1t2[f1t2>rcut[i]])
rBtrue[i]<-B1t2/B1t1   #This is the true ratio of abundance between time periods
rCtrue[i]<-mean(C1t2)/mean(C1t1)  # This the ratio of CPUE using all the data
               # This is the ratio of CPUE truncated by the Fraction of targeting
rCbias[i]<-mean(C1t2[f1t2>rcut[i]])/mean(C1t1[f1t1>rcut[i]])
#ratiobias[i]<-rCbias[i]/rCtrue[i]
}
rcut
rBtrue
rCtrue
rCbias
rCbias/rCtrue    # This is the relative bias induced by the selection criteria for targetting
 plot(rcut,rCbias/rCtrue)
```

Example with binomial distribution



Example with lognormal distribution



The above graphs demonstrate that the degree of bias varies with the cut points selected. In this example the true abundance changes by 50% between sampling events, but the bias can exceed 30%. Thus the bias induced by post hoc determination of target species could obscure the ability to detect reduction in abundance of 50%.

Evaluating the Observer Effect for the Northeast U.S. Groundfish Fishery

Chad Demarest

May 31, 2018

Groundfish Plan Development Team - White Paper

– DRAFT –

Introduction

The commercial component of the Northeast U.S. Multispecies fishery comprises 20 individual fish stocks and 2 management units[1]. Of these, commercial fisherman are allocated quota for 15 stocks, leaving 5 for which retention is prohibited. Fishing quota is allocated to approximately 1,000 permits and actively fished by around 200 participating commercial vessels (NEFMC 2017). The majority of the commercial fishery for groundfish (~98% of landings) is managed under the Sector system whereby individual vessel owners pool stock-level quota into 21 sectors, each operating as a collective, pooling the quota and allocating it to individual member fisherman. Observers are deployed on participating vessels to estimate discarded catch for each of the 22 fish stocks on each trip. Observer coverage levels vary across stocks but in general observers have been onboard trips accounting for between 15-40% of all trips taken in any given fishing year. Actual discards are calculated by dividing the sum of stock-level discards observed for observed tows by the total amount of retained catch on these trips. For trips with no observer coverage, discards are estimated by stratifying the population of fishing trips by broad stock area, sector and fishing gear and applying the annualized real time observed discard rate for each sector's strata. Estimates are applied to the corresponding strata's unobserved trips. Discards count against a sector's quota after adjusting for gear and stock-specific discard mortality rates. Vessels are assessed estimated discards on unobserved trips based on their strata, regardless of whether or not an individual species was reported on that trip. Sectors must have adequate quota reserves for all species in a given stock area prior to any member vessels fishing in that area.

As observer coverage represents only a fraction of the total fishing activity in the sector component of the commercial groundfish fishery, obvious questions arise: Does data generated on observed fishing trips reflect the activities of the whole fleet? Are estimates generated from these data unbiased? Bias may be induced by either a deployment effect, where the assignment of observers to vessels is non-random, or an observer effect, where the fishing activities on observed trips vary in detectable ways from those on unobserved trips (Benoit and Allard 2009). These two effects, deployment and observer, may act separately and in combination to render data collected by on board observers biased. This paper focuses specifically on one component of the the latter effect: do individual vessels alter their behavior in response to the presence of an observer?

Fisherman may alter their fishing behavior when carrying an observer for any one of at least five reasons: (1) people may act differently as a repsonse to simply being watched, an established phenomena referred to as the Hawthorne Effect (McCambridge et al. 2018); (2) fisherman may not want to impart their individual discarding preferences on the other members of their sector, an effect driven primarily by within-strata target

[1] George's Bank is divided into a "west" component for which haddock and cod stocks are assessed exclusively by NOAA fisheries, and an "east" component for which these stocks together with yellowtail flounder are jointly assessed with the Canadian Department of Fisheries and Oceans under a trans-boundary management agreement.

species and fishing practice heterogeneity; (3) observers incur costs associated with slower fish processing and handling times, carrying extra food, and general inconvenience, all of which may incentivize fisherman to make shorter trips when observers are on board; (4) catch of undersized fish varies across space and fishing in areas and at times where undersized fish are relatively less abundant may minimize discard rates, though presumably at a cost in terms of reduced total trip revenues; and (5) binding quota constraints impart strong economic incentives to discard legal-sized fish when an observer is not on board and to avoid these stocks in the presence of an observer, again presumably at a cost in terms of reduced total trip revenues.

This paper employs an exact matching method to determine if vessel performance along several metrics vary in a detectable way when an observer is on board, and when one is not.

Methods

Following a procedure laid out by Benoit and Allard, same-vessel trip sequences are analyzed to test for differences among various metrics. These trip sequences take the form of either: (1) three unobserved trips in a row (UUU), or (2) one observed trip between unobserved trips (UOU). To attenuate the possibility of interpreting seasonal effects as behavioral effects, only trips occurring within 45 days of each other are included. Trips are not repeated in multiple sequences. Vessels with less than two sequences are excluded from the analysis.

Triplet sequences are winnowed to pairs by taking the difference of either the leading or lagging trip with respect to the middle trip. The variable U in equation (1) and U^1 in equation (2), below, are selected randomly as either the leading or trailing trip in the triplet sequence, while the middle trip in the sequence is always the reference trip (O or U^1, below). To mitigate against regulatory changes affecting fishing behavior within trip sequences while maximizing particularly the number of OU pairs for analysis, sequences overlapping the start of a new fishing year change (May 1 of each year) select only the lead or lag pair occurring in the same FY as the reference trip.

Differences are calculated as

$$\Delta O_{yfv} = (O - U/U\acute{})_{yfv} * 100$$

(Equation 1)

$$\Delta U_{yfv} = \left(U^1 - U^2/U\acute{}\right)_{yfv} * 100$$

(Equation 2)

where y is a fishing year, f is fishing vessel and v is any one of the metrics evaluated. $U\acute{}$ is the mean unobserved value for each year, vessel and metric combination.

Metrics evaluated, v, are:

1. Trip duration
2. Kept catch
3. Total revenue
4. Kept groundfish
5. Kept non-groundfish
6. Groundfish average price
7. Non-groundfish average price
8. Number of market categories included in kept catch

The difference between the median values for ΔU's and O's is calculated as

$$(M_{\Delta U-\Delta O})_{yfv} = median(\Delta U)_{yfv} - median(\Delta O)_{yfv}$$

.

(Equation 3)

Differences between observed and unobserved trips are tested in three ways: (1) location differences[2] are observed in $M_{\Delta U-\Delta O}$, with 95% confidence intervals estimated using bootstrap sampling (1,000 replicates) from the U_{yfv} and O_{yfv} values, where a lack of overlap with zero implies a 95% probability that the true median values for each population are significantly different; (2) the Kolmogorov-Smirnov statistic is used to test for general differences in shape of the U_{yfv} and O_{yfv} distributions; and (3) the Kuiper statistic is used to test for differences in the extremities of the distributions.

Multiple hypothesis tests are performed with the Kolmogorov-Smirnov (KSA) and Kuiper (KA) statistics. For these, a p-value of 0.005 is considered to be significant. Statistical significance should be considered in light of the data and research question. All p-values are reported.

Data

Vessel Trip Report (VTR) and Commercial Fishery Dealer (CFDBS) data are combined to construct trip-level data using the Data Matching and Imputation System (DMIS) database [cite needed]. Trips with an Allocation Management System (AMS) declaration code of "NMS" are included in the initial dataset. Only vessels fishing with trawl or gillnet gears are retained. Observer trips are matched by a step-wise algorithm, focusing on permit number, VTR serial number, days-at-sea (DAS) identification number, date and time sailed. For the post-Sector years, both Northeast Fishery Observer Program (NEFOP) and at-sea monitoring (ASM) data are matched.

UUU and UOU triplets are extracted from these data, and annual fishing year data sets are built (May 1 – April 30) with same-vessel two-trip sequences constructed from the UUU and UOU triplets.

Trips in the United States-Canada Resource Sharing Agreement Area (USCA area) are removed from the pre-sector (FY 2007-2009) dataset, as these trips were subject to observer coverage at higher rates than trips outside the area. All trips fishing with extra large mesh (ELM) under the conditions of the 2015 ELM exemption are excluded for all years, as are all trips by vessels enrolled in the Common Pool from 2010-2017. All excluded trips and their corresponding triplets are retained and, to better understand the potential drivers of observer effects, may be analyzed separately in the future.

Results

Results are reported based on two levels of aggregation:

- regulatory regime, as
  - pre-Sector years (FY's 2007-2009),
  - initial Sector years (FY's 2010-2012),
  - intermediate Sector years (FY's 2013-2015),
  - contemporary Sector years (FY's 2016-2017); and
- gear type, distinguishing between trawl and gillnet gears[3].

[2] "Location" refers to the central tendency of the data, in this case the median values, and has no geographic connotation here.

[3] Trawl gears include the Vessel Trip Report (VTR) codes 'OHS','OTB','OTC','OTF','OTM','OTO','OTR','OTS', and 'OTT'. Gillnet gears include the codes 'GNR','GNS', and 'GNT'.

Preliminarily, results at the fishing year (FY) level, dis-aggregated by gillnet and trawl, are included for context. Separate analyses have also been completed for single-day and multi-day trips, as well as a stock-level analysis of kept catch, number of market categories and average price for 15 individual groundfish stocks. The results are still being analyzed and will be integrated in the future.

Tests for differences in central tendency

Equations (1) and (2) are scaled by each vessel's mean annual values and median value differences are represented as percentages. For example, a median value of -0.042 for the kept catch variable implies that vessels catch roughly 4.2% less fish on an observed trip, relative to a neighboring unobserved trip by that same vessel, as measured across all vessels in the dataset. If the bootstrapped 95% confidence intervals fail to overlap with zero, the value is interpreted as significant using the confidence interval test.

Trawl vessels catch less fish when an observer is onboard. In the stanzas after 2009, they fish for less time and land less groundfish in particular. Statistical significance is obtained for kept catch in all four stanzas, and for trip duration, groundfish kept catch and total revenues in the three post-2009 stanzas. Groundfish average prices are statically higher for three of the four stanzas, the exception being the period from 2010-2012, indicating that composition of groundfish catch on observed and unobserved trips is different. Based on the reductions in catch and fishing time on observed trips after 2009, the changes in response to observer presense appear to be related to incentives embedded in catch accountability and the sector management system.

Gillnet vessels consistently made shorter trips, generate less revenue and appear to retain slightly less catch overall in the presence of an observer, but the results are more variable relative to trawl vessels. There is a trend in later stanzas toward more groundfish and less non-groundfish on observed trips for these vessels, indicating a difference in the mix of species landed in response to an observer. The increase in the number of groundfish market categories in the last stanza may indicate differential groundfish targeting, or perhaps high-grading of specific species. Statistically different behavior in response to an observer is equally prevalent for gillnet vessels and trawl vessels, but the magnitude of the effect appears to be slightly smaller for gillnet vessels. This may reflect a truly smaller behavioral response, or it may be due to a smaller number of paired trips, particularly in the later stanzas, or some combination of both. There is a less clear distinction in response before and after the implementation of sectors, where gillnet vessels demonstrated a significant response before sectors and trawl vessels, for the most part, did not.

Tests for differences in distribution shape

TBC

Discussion

Fishing vessels alter their behavior in response to observers. Estimated median paired trip differences are zero for only a handful of the metrics evaluated across stanzas or fishing years. Generally, the most pronounced effects are seen across trip duration, kept catch, kept groundfish and trip revenue. Observer presence has the smallest affect on the number of groundfish market categories and non-groundfish average prices, but even here we see differences.

Incentives to alter fishing behavior have varied across time. Prior to sector implementation discards had no direct cost to fisherman and trip limits required discarding certain species. These factors may have reduced the incentive to alter fishing practices in response to an observer, noting that gillnet vessels did demonstrate a significant behavioral response prior to sectors. After full sector implementation, the accountability of discards and the application of sector/gear specific discard rates to unobserved trips, together with the potential catch of constraining stocks, increased the incentive to change behavior in response to an observer.

There may be off-setting incentives due to quota allocations, fishing preferences or other factors. One vessel may attempt to minimize observed discarding of flatfish at the expense of cod, while another vessel may take the exact opposite approach. Such offsetting behavior could change the central tendency of the distribution of $M_{\Delta U - \Delta O}$ very little, but may affect the shape of the distribution, particularly at the tails. This is where the Kuiper and Kolmogorov-Smirnov (K-S) tests become valuable. The K-S evaluates changes in the overall shape of the distribution, while the Kuiper tests for changes in the the tails.

These analyses point toward a consistent pattern of different fishing behaviors when an observer is on board. The Benoit and Allard method isolates vessel effects by focusing on the differences in behavior in response to an observer *for the same vessel*. The data show a clear trend for three key metrics–in almost all circumstances vessels appear to retain less fish, fish for less time and obtain lower revenues when an observer is on board. Persistent differences such as higher average groundfish prices with an observer on board (trawl vessels) and emerging differences like a greater number of market categories retained with an observer (gillnet vessels) indicate that the composition of catch on observed trips is different. This suggests that data collected by observers are not merely a compressed representation of unobserved fishing practices but, rather, they may be non-representative along critical dimensions such as proportions and quantities of fish discarded and retained.

Tables and figures

Table 1: Stanza 1, 2007-2009

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish		-1.4 %	-0.4 %	0.3 %	21,734	750
Trawl	Number groundfish market categories		0 %	0 %	0 %	21,734	750
Trawl	Groundfish avg price	*	0.9 %	1.4 %	1.9 %	21,734	750
Trawl	Kept catch	*	-4.6 %	-3.5 %	-2.4 %	21,734	750
Trawl	Kept non-groundfish		0 %	0 %	0 %	21,734	750
Trawl	Non-groundfish avg price		0 %	0 %	0 %	21,734	750
Trawl	Total revenue		-1 %	0.2 %	1.4 %	21,734	750
Trawl	Trip duration		-0.1 %	0.4 %	1.2 %	21,734	750
Gillnet	Kept groundfish	*	-2.6 %	-1.9 %	-1.2 %	21,530	532
Gillnet	Number groundfish market categories	*	-3.5 %	-2.1 %	-1 %	21,530	532
Gillnet	Groundfish avg price	*	1 %	1.5 %	2 %	21,530	532
Gillnet	Kept catch	*	-2.7 %	-1.9 %	-1.1 %	21,530	532
Gillnet	Kept non-groundfish	*	-1 %	-0.7 %	-0.4 %	21,530	532
Gillnet	Non-groundfish avg price		-0.3 %	0 %	0 %	21,530	532
Gillnet	Total revenue	*	-4.4 %	-3.5 %	-2.6 %	21,530	532
Gillnet	Trip duration	*	-4.9 %	-4.3 %	-3.9 %	21,530	532

Table 2: Stanza 2, 2010-2012

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	-11.7 %	-9.2 %	-6.8 %	5,756	1,616
Trawl	Number groundfish market categories		-0.9 %	0 %	0 %	5,756	1,616
Trawl	Groundfish avg price		-1.3 %	-0.3 %	0.6 %	5,756	1,616
Trawl	Kept catch	*	-11 %	-8.5 %	-6.2 %	5,756	1,616
Trawl	Kept non-groundfish		-3.6 %	-1.6 %	0 %	5,756	1,616
Trawl	Non-groundfish avg price		-0.2 %	0.5 %	1.8 %	5,756	1,616
Trawl	Total revenue	*	-8.9 %	-6.7 %	-4.4 %	5,756	1,616
Trawl	Trip duration	*	-4.3 %	-3 %	-1.7 %	5,756	1,616
Gillnet	Kept groundfish		-3.3 %	-1 %	1.3 %	5,234	1,365
Gillnet	Number groundfish market categories		0 %	0.8 %	2.9 %	5,234	1,365
Gillnet	Groundfish avg price	*	0.3 %	1.2 %	2 %	5,234	1,365
Gillnet	Kept catch		-3.6 %	-1.6 %	0.5 %	5,234	1,365
Gillnet	Kept non-groundfish		-0.8 %	-0.2 %	0.2 %	5,234	1,365
Gillnet	Non-groundfish avg price		-1 %	-0.1 %	0.5 %	5,234	1,365
Gillnet	Total revenue		-4.3 %	-2.1 %	0 %	5,234	1,365
Gillnet	Trip duration	*	-4 %	-3.2 %	-2.5 %	5,234	1,365

Table 3: Stanza 3, 2013-2015

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	-10.2 %	-7.9 %	-5.4 %	5,944	1,026
Trawl	Number groundfish market categories		0 %	0 %	0 %	5,944	1,026
Trawl	Groundfish avg price	*	0.9 %	1.9 %	3 %	5,944	1,026
Trawl	Kept catch	*	-10.7 %	-8.6 %	-6.1 %	5,944	1,026
Trawl	Kept non-groundfish		-5.1 %	-2.4 %	0.1 %	5,944	1,026
Trawl	Non-groundfish avg price		-1.9 %	-0.3 %	0.9 %	5,944	1,026
Trawl	Total revenue	*	-7.2 %	-5 %	-2.8 %	5,944	1,026
Trawl	Trip duration	*	-4.6 %	-3.3 %	-2.1 %	5,944	1,026
Gillnet	Kept groundfish		-2.2 %	0.8 %	4 %	3,287	447
Gillnet	Number groundfish market categories		0 %	0 %	1.6 %	3,287	447
Gillnet	Groundfish avg price		-0.8 %	0.3 %	1.6 %	3,287	447
Gillnet	Kept catch		-2.1 %	0.7 %	3.3 %	3,287	447
Gillnet	Kept non-groundfish		-3.9 %	-2 %	0.2 %	3,287	447
Gillnet	Non-groundfish avg price	*	0.3 %	2.1 %	4.2 %	3,287	447
Gillnet	Total revenue		-0.1 %	2.7 %	5.3 %	3,287	447
Gillnet	Trip duration	*	-4.4 %	-3.3 %	-2.4 %	3,287	447

Table 4: Stanza 4, 2016-2017

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	-9.5 %	-6.8 %	-4.1 %	3,559	571
Trawl	Number groundfish market categories		0 %	0 %	0 %	3,559	571
Trawl	Groundfish avg price	*	0.9 %	2 %	3.3 %	3,559	571
Trawl	Kept catch	*	-7 %	-4.4 %	-1.5 %	3,559	571
Trawl	Kept non-groundfish		-3.1 %	-0.2 %	2.4 %	3,559	571
Trawl	Non-groundfish avg price		-2.4 %	-0.6 %	1 %	3,559	571
Trawl	Total revenue	*	-5.4 %	-2.8 %	-0.1 %	3,559	571
Trawl	Trip duration	*	-4.3 %	-2.8 %	-1.3 %	3,559	571
Gillnet	Kept groundfish		-1.4 %	4.1 %	10.1 %	996	197
Gillnet	Number groundfish market categories		0 %	5.4 %	9.5 %	996	197
Gillnet	Groundfish avg price		-0.5 %	2.4 %	5.5 %	996	197
Gillnet	Kept catch		-8.1 %	-3.8 %	0.8 %	996	197
Gillnet	Kept non-groundfish	*	-13 %	-8.1 %	-4 %	996	197
Gillnet	Non-groundfish avg price		-1.7 %	0.9 %	3.6 %	996	197
Gillnet	Total revenue		-7.3 %	-3.1 %	1 %	996	197
Gillnet	Trip duration	*	-4.7 %	-3.2 %	-1.3 %	996	197

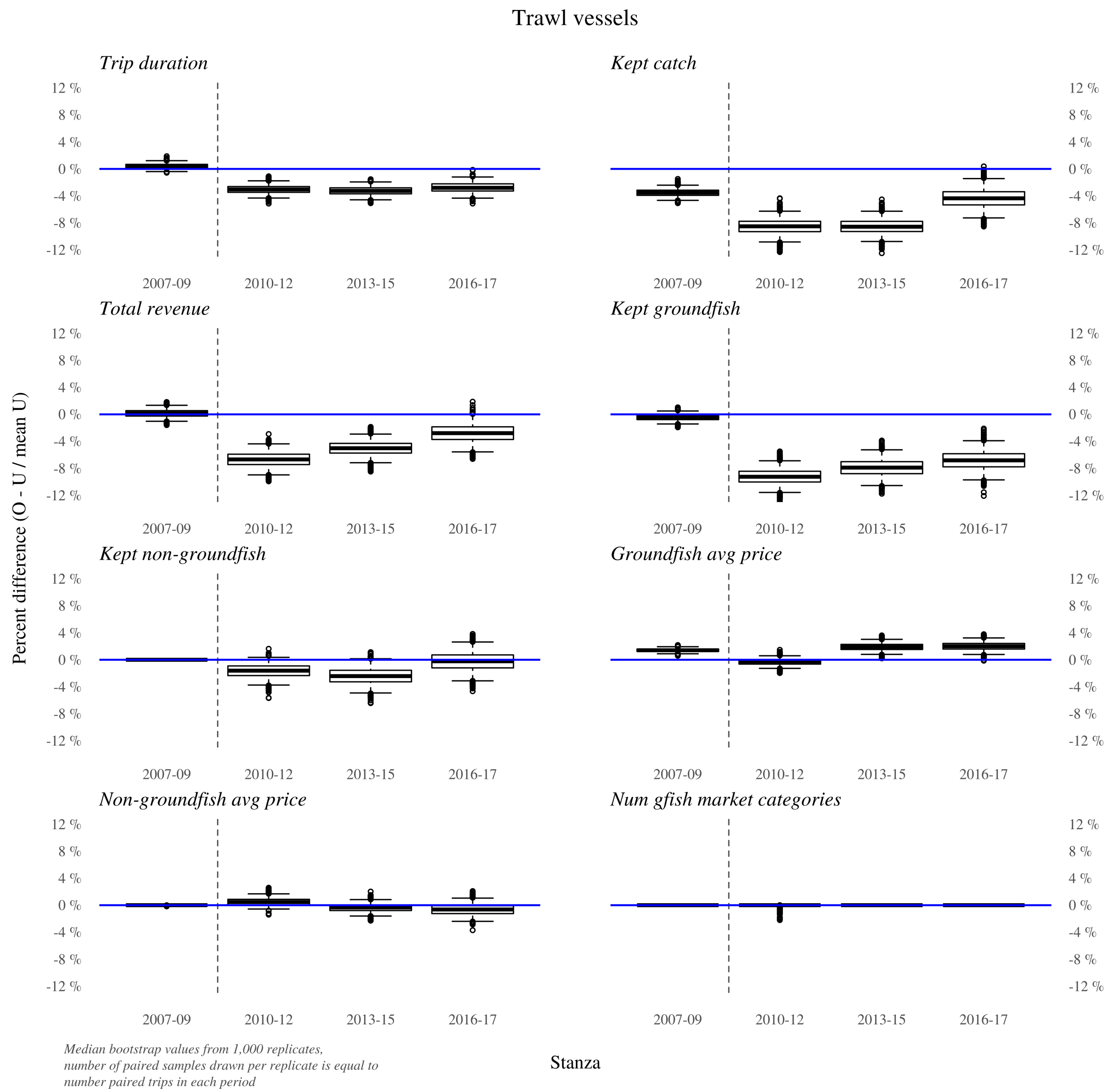


Figure 1: Results of bootstrap analysis, observed and unobserved same-vessel paired trips by stanza

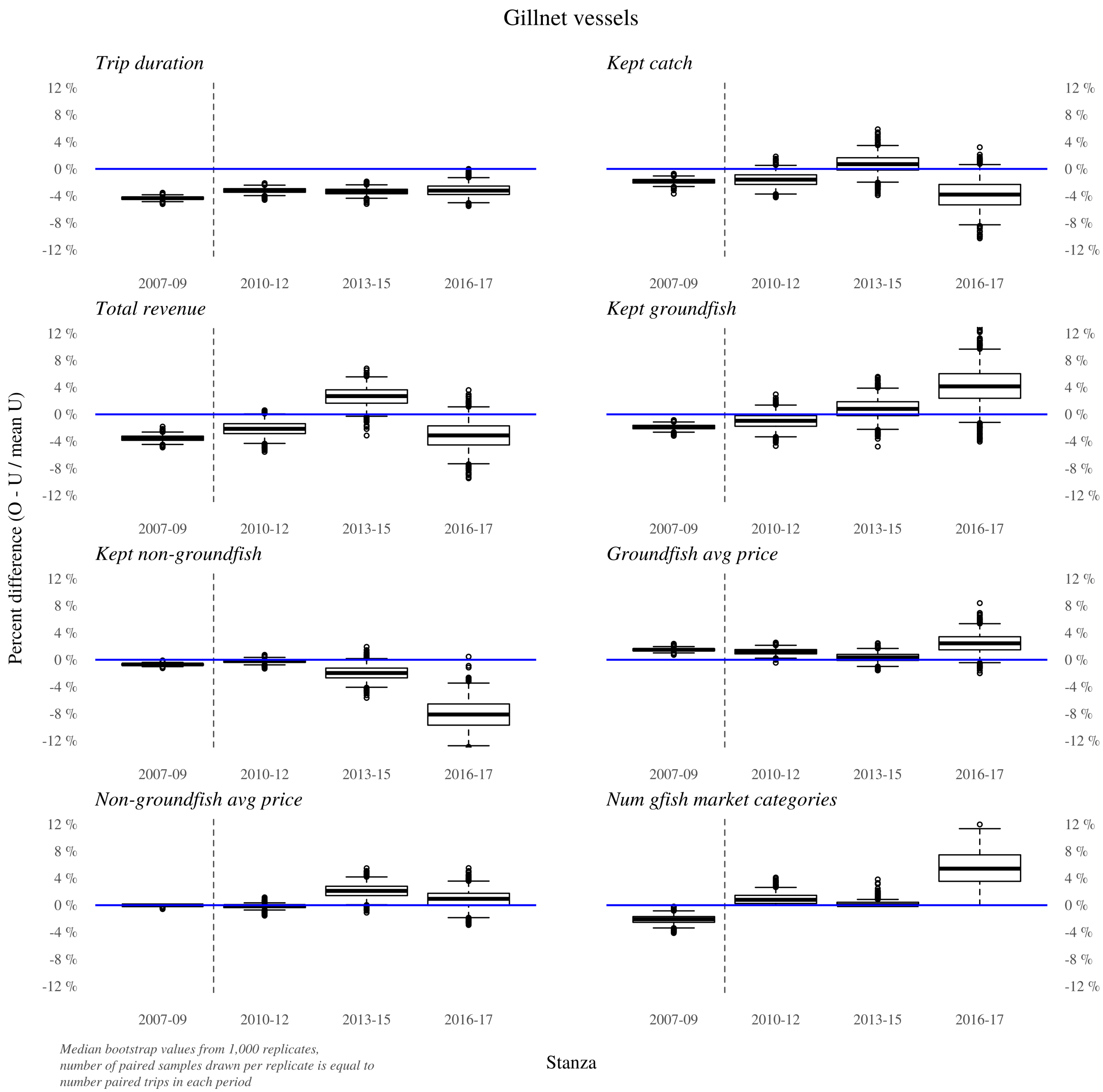


Figure 2: Results of bootstrap analysis, observed and unobserved same-vessel paired trips by stanza

Table 5: Fishing Year 2007

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	-4.7 %	-2.8 %	-0.9 %	8,076	247
Trawl	Number groundfish market categories		0 %	0 %	0 %	8,076	247
Trawl	Groundfish avg price	*	0.3 %	1 %	1.7 %	8,076	247
Trawl	Kept catch	*	-8.1 %	-6.2 %	-4.4 %	8,076	247
Trawl	Kept non-groundfish		-3.8 %	-1.8 %	0 %	8,076	247
Trawl	Non-groundfish avg price		0 %	0 %	0.1 %	8,076	247
Trawl	Total revenue		-3.2 %	-1.4 %	0.6 %	8,076	247
Trawl	Trip duration		-2.1 %	-0.9 %	0 %	8,076	247
Gillnet	Kept groundfish	*	-4.7 %	-2.9 %	-1.3 %	6,172	154
Gillnet	Number groundfish market categories	*	-6.7 %	-4.2 %	-1.9 %	6,172	154
Gillnet	Groundfish avg price		-0.3 %	0.5 %	1.3 %	6,172	154
Gillnet	Kept catch		-1.5 %	0 %	1.5 %	6,172	154
Gillnet	Kept non-groundfish		-0.6 %	0 %	0 %	6,172	154
Gillnet	Non-groundfish avg price		0 %	0 %	0 %	6,172	154
Gillnet	Total revenue	*	-4.1 %	-2.5 %	-0.9 %	6,172	154
Gillnet	Trip duration	*	-4.2 %	-3.2 %	-2.3 %	6,172	154

Table 6: Fishing Year 2008

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish		-3.1 %	-1.2 %	0.5 %	7,348	303
Trawl	Number groundfish market categories		0 %	0 %	0 %	7,348	303
Trawl	Groundfish avg price	*	1.2 %	2.2 %	3.2 %	7,348	303
Trawl	Kept catch	*	-7.6 %	-5.7 %	-3.6 %	7,348	303
Trawl	Kept non-groundfish		0 %	0 %	0 %	7,348	303
Trawl	Non-groundfish avg price		-0.6 %	0 %	0 %	7,348	303
Trawl	Total revenue	*	-5.7 %	-3.4 %	-1.3 %	7,348	303
Trawl	Trip duration		-2.1 %	-0.8 %	0.3 %	7,348	303
Gillnet	Kept groundfish	*	-6.4 %	-4.8 %	-3.3 %	6,903	180
Gillnet	Number groundfish market categories		-2 %	-0.2 %	0 %	6,903	180
Gillnet	Groundfish avg price	*	2.5 %	3.4 %	4.3 %	6,903	180
Gillnet	Kept catch	*	-6.3 %	-4.9 %	-3.5 %	6,903	180
Gillnet	Kept non-groundfish	*	-2.4 %	-1.9 %	-1.3 %	6,903	180
Gillnet	Non-groundfish avg price	*	-2.4 %	-1.3 %	-0.5 %	6,903	180
Gillnet	Total revenue	*	-5.4 %	-3.7 %	-2.1 %	6,903	180
Gillnet	Trip duration	*	-4.4 %	-3.6 %	-2.7 %	6,903	180

Table 7: Fishing Year 2009

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	0.6 %	1.7 %	3 %	6,310	200
Trawl	Number groundfish market categories		0 %	0 %	2.1 %	6,310	200
Trawl	Groundfish avg price	*	0.1 %	0.9 %	1.9 %	6,310	200
Trawl	Kept catch		0 %	1.8 %	3.5 %	6,310	200
Trawl	Kept non-groundfish	*	0.6 %	2 %	3.7 %	6,310	200
Trawl	Non-groundfish avg price		-0.3 %	0 %	0 %	6,310	200
Trawl	Total revenue	*	5.1 %	7.1 %	9.1 %	6,310	200
Trawl	Trip duration	*	3.5 %	5 %	6.6 %	6,310	200
Gillnet	Kept groundfish		-0.4 %	0 %	0.5 %	8,455	198
Gillnet	Number groundfish market categories	*	-5.4 %	-2.5 %	-0.1 %	8,455	198
Gillnet	Groundfish avg price		-0.2 %	0.5 %	1.4 %	8,455	198
Gillnet	Kept catch		-1.7 %	-0.5 %	0.3 %	8,455	198
Gillnet	Kept non-groundfish		-0.7 %	-0.4 %	0 %	8,455	198
Gillnet	Non-groundfish avg price		-0.1 %	0 %	0 %	8,455	198
Gillnet	Total revenue	*	-5.5 %	-4.2 %	-2.7 %	8,455	198
Gillnet	Trip duration	*	-6.9 %	-6 %	-5.2 %	8,455	198

Table 8: Fishing Year 2010

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	-19.1 %	-14.2 %	-8.8 %	1,226	456
Trawl	Number groundfish market categories		-5.2 %	-1.2 %	0 %	1,226	456
Trawl	Groundfish avg price		-2.2 %	0.1 %	2 %	1,226	456
Trawl	Kept catch	*	-15.2 %	-10.4 %	-5.5 %	1,226	456
Trawl	Kept non-groundfish	*	-10.4 %	-5.5 %	-0.7 %	1,226	456
Trawl	Non-groundfish avg price		-0.6 %	1 %	3.6 %	1,226	456
Trawl	Total revenue	*	-15.2 %	-10.5 %	-5.4 %	1,226	456
Trawl	Trip duration	*	-9.4 %	-6.1 %	-2.4 %	1,226	456
Gillnet	Kept groundfish	*	-12.2 %	-7.5 %	-2.6 %	1,385	460
Gillnet	Number groundfish market categories		0 %	0.7 %	6.3 %	1,385	460
Gillnet	Groundfish avg price	*	0.3 %	2 %	3.6 %	1,385	460
Gillnet	Kept catch		-6.7 %	-2.1 %	2.2 %	1,385	460
Gillnet	Kept non-groundfish		-0.6 %	0 %	0.4 %	1,385	460
Gillnet	Non-groundfish avg price		-2.4 %	-0.1 %	0.9 %	1,385	460
Gillnet	Total revenue		-6.7 %	-2.4 %	2.4 %	1,385	460
Gillnet	Trip duration	*	-6 %	-4.5 %	-2.7 %	1,385	460

Table 9: Fishing Year 2011

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	-11 %	-6.6 %	-1.9 %	1,826	606
Trawl	Number groundfish market categories		-1.1 %	0 %	0 %	1,826	606
Trawl	Groundfish avg price		-1.8 %	-0.1 %	1.4 %	1,826	606
Trawl	Kept catch	*	-9.6 %	-5.8 %	-1.8 %	1,826	606
Trawl	Kept non-groundfish		-5 %	-1.4 %	1.3 %	1,826	606
Trawl	Non-groundfish avg price		-0.5 %	1.1 %	3.4 %	1,826	606
Trawl	Total revenue		-7.3 %	-3.3 %	0.8 %	1,826	606
Trawl	Trip duration	*	-5.4 %	-3.3 %	-1.2 %	1,826	606
Gillnet	Kept groundfish	*	1.6 %	4.9 %	8.4 %	1,775	545
Gillnet	Number groundfish market categories	*	0.4 %	3 %	6.6 %	1,775	545
Gillnet	Groundfish avg price		-0.4 %	0.8 %	2 %	1,775	545
Gillnet	Kept catch		-2.6 %	0.7 %	4 %	1,775	545
Gillnet	Kept non-groundfish		-1.8 %	-0.8 %	0 %	1,775	545
Gillnet	Non-groundfish avg price		-2.2 %	-0.3 %	1.1 %	1,775	545
Gillnet	Total revenue		-3.1 %	0.2 %	3.5 %	1,775	545
Gillnet	Trip duration	*	-2.7 %	-1.6 %	-0.2 %	1,775	545

Table 10: Fishing Year 2012

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	-12 %	-8.1 %	-4.6 %	2,704	554
Trawl	Number groundfish market categories		-1.4 %	0 %	0 %	2,704	554
Trawl	Groundfish avg price		-2.7 %	-1.1 %	0.4 %	2,704	554
Trawl	Kept catch	*	-13.9 %	-10.5 %	-6.9 %	2,704	554
Trawl	Kept non-groundfish		-2 %	0.6 %	4 %	2,704	554
Trawl	Non-groundfish avg price		-3 %	-0.5 %	1.5 %	2,704	554
Trawl	Total revenue	*	-11.2 %	-7.8 %	-4.3 %	2,704	554
Trawl	Trip duration		-2.9 %	-1 %	0.6 %	2,704	554
Gillnet	Kept groundfish		-5.2 %	-1.4 %	2.1 %	2,074	360
Gillnet	Number groundfish market categories		0 %	0 %	0.1 %	2,074	360
Gillnet	Groundfish avg price		-1.1 %	0.4 %	2 %	2,074	360
Gillnet	Kept catch		-6 %	-2.9 %	0.4 %	2,074	360
Gillnet	Kept non-groundfish		-1.7 %	0.2 %	2.1 %	2,074	360
Gillnet	Non-groundfish avg price		-1.7 %	0 %	1.6 %	2,074	360
Gillnet	Total revenue	*	-8.8 %	-5.2 %	-2 %	2,074	360
Gillnet	Trip duration	*	-5.5 %	-4.5 %	-3.2 %	2,074	360

Table 11: Fishing Year 2013

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	-16.7 %	-12.8 %	-8.9 %	2,294	320
Trawl	Number groundfish market categories		0 %	0 %	0.8 %	2,294	320
Trawl	Groundfish avg price	*	1.1 %	2.9 %	4.9 %	2,294	320
Trawl	Kept catch	*	-13.9 %	-10.2 %	-6.6 %	2,294	320
Trawl	Kept non-groundfish		-1.6 %	2.7 %	7.2 %	2,294	320
Trawl	Non-groundfish avg price		-3.2 %	-1.3 %	0.4 %	2,294	320
Trawl	Total revenue	*	-7.4 %	-3.8 %	-0.5 %	2,294	320
Trawl	Trip duration	*	-5.6 %	-3.5 %	-1.5 %	2,294	320
Gillnet	Kept groundfish		-3 %	1.4 %	6.1 %	1,521	167
Gillnet	Number groundfish market categories		-3.1 %	-0.3 %	0 %	1,521	167
Gillnet	Groundfish avg price		-1.6 %	0.2 %	1.8 %	1,521	167
Gillnet	Kept catch		-3.7 %	0.7 %	5.2 %	1,521	167
Gillnet	Kept non-groundfish		-3.3 %	-0.2 %	2.6 %	1,521	167
Gillnet	Non-groundfish avg price		-3.2 %	-0.6 %	1.7 %	1,521	167
Gillnet	Total revenue		-2.4 %	1.8 %	6.4 %	1,521	167
Gillnet	Trip duration	*	-6.5 %	-5.1 %	-3.8 %	1,521	167

Table 12: Fishing Year 2014

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish		-7.4 %	-3.3 %	0.6 %	1,683	342
Trawl	Number groundfish market categories		0 %	0 %	1.5 %	1,683	342
Trawl	Groundfish avg price		-0.2 %	1.7 %	4 %	1,683	342
Trawl	Kept catch	*	-12.5 %	-8.2 %	-3.8 %	1,683	342
Trawl	Kept non-groundfish	*	-9.7 %	-5.1 %	-0.3 %	1,683	342
Trawl	Non-groundfish avg price		-2.3 %	0.3 %	3.2 %	1,683	342
Trawl	Total revenue	*	-9.9 %	-6.2 %	-2.2 %	1,683	342
Trawl	Trip duration	*	-7.1 %	-4.8 %	-2.4 %	1,683	342
Gillnet	Kept groundfish		-4.2 %	1.1 %	7.4 %	1,119	176
Gillnet	Number groundfish market categories		0 %	2.4 %	7.4 %	1,119	176
Gillnet	Groundfish avg price		-2 %	0.1 %	2.1 %	1,119	176
Gillnet	Kept catch		-0.2 %	4 %	8.4 %	1,119	176
Gillnet	Kept non-groundfish		-5 %	-1.1 %	2.6 %	1,119	176
Gillnet	Non-groundfish avg price		-0.9 %	3 %	7.2 %	1,119	176
Gillnet	Total revenue	*	2.4 %	6.7 %	11.1 %	1,119	176
Gillnet	Trip duration		-2 %	0 %	1.6 %	1,119	176

Table 13: Fishing Year 2015

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	-11.4 %	-7 %	-2.8 %	1,967	364
Trawl	Number groundfish market categories		-1.8 %	0 %	0 %	1,967	364
Trawl	Groundfish avg price		-0.3 %	1.3 %	2.9 %	1,967	364
Trawl	Kept catch	*	-11.1 %	-7 %	-3.2 %	1,967	364
Trawl	Kept non-groundfish	*	-8.6 %	-4.1 %	-0.3 %	1,967	364
Trawl	Non-groundfish avg price		-2.1 %	0.1 %	2.7 %	1,967	364
Trawl	Total revenue	*	-8.7 %	-5.2 %	-1.6 %	1,967	364
Trawl	Trip duration		-3.9 %	-1.9 %	0.1 %	1,967	364
Gillnet	Kept groundfish		-6.7 %	-0.4 %	6.9 %	647	104
Gillnet	Number groundfish market categories		0 %	0.3 %	7.3 %	647	104
Gillnet	Groundfish avg price		-2.3 %	1.3 %	4.6 %	647	104
Gillnet	Kept catch		-9.5 %	-4.8 %	0.4 %	647	104
Gillnet	Kept non-groundfish	*	-10.6 %	-5.7 %	-1.6 %	647	104
Gillnet	Non-groundfish avg price	*	2.4 %	6.5 %	11.3 %	647	104
Gillnet	Total revenue		-7.6 %	-2.3 %	2.7 %	647	104
Gillnet	Trip duration	*	-7.8 %	-5.5 %	-3.6 %	647	104

Table 14: Fishing Year 2016

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish		-8.3 %	-4.1 %	0 %	1,951	280
Trawl	Number groundfish market categories		0 %	0 %	0 %	1,951	280
Trawl	Groundfish avg price		-0.6 %	0.8 %	2.4 %	1,951	280
Trawl	Kept catch	*	-10.1 %	-6.5 %	-2.8 %	1,951	280
Trawl	Kept non-groundfish		-5.6 %	-1.4 %	2.6 %	1,951	280
Trawl	Non-groundfish avg price		-1.4 %	0.9 %	3.3 %	1,951	280
Trawl	Total revenue		-6.6 %	-2.9 %	0.9 %	1,951	280
Trawl	Trip duration	*	-5.2 %	-3 %	-0.9 %	1,951	280
Gillnet	Kept groundfish		-6.6 %	1.4 %	10 %	494	112
Gillnet	Number groundfish market categories		0 %	3.8 %	9.7 %	494	112
Gillnet	Groundfish avg price		-0.4 %	3.4 %	6.7 %	494	112
Gillnet	Kept catch		-11 %	-3.6 %	2.7 %	494	112
Gillnet	Kept non-groundfish	*	-14.2 %	-7.6 %	-0.8 %	494	112
Gillnet	Non-groundfish avg price		-3.6 %	0.3 %	4.5 %	494	112
Gillnet	Total revenue		-8.4 %	-2.3 %	3.4 %	494	112
Gillnet	Trip duration	*	-6.9 %	-4.4 %	-2.2 %	494	112

Table 15: Fishing Year 2017

Gear	Variable	CIs <> 0	95% CI, low	Median	95% CI, high	n Unobserved	n Observed
Trawl	Kept groundfish	*	-13.2 %	-8.9 %	-5.2 %	1,608	291
Trawl	Number groundfish market categories		0 %	0 %	0 %	1,608	291
Trawl	Groundfish avg price	*	1.5 %	3.3 %	5.1 %	1,608	291
Trawl	Kept catch		-6.3 %	-2.1 %	1.9 %	1,608	291
Trawl	Kept non-groundfish		-2.9 %	1.3 %	5.3 %	1,608	291
Trawl	Non-groundfish avg price		-4.7 %	-2.2 %	0.2 %	1,608	291
Trawl	Total revenue		-6.9 %	-2.9 %	0.7 %	1,608	291
Trawl	Trip duration	*	-4.5 %	-2.4 %	-0.2 %	1,608	291
Gillnet	Kept groundfish	*	0.8 %	8.3 %	15.7 %	502	85
Gillnet	Number groundfish market categories		0 %	8 %	13.6 %	502	85
Gillnet	Groundfish avg price		-3.7 %	1.5 %	6.2 %	502	85
Gillnet	Kept catch		-9.4 %	-3.3 %	2.1 %	502	85
Gillnet	Kept non-groundfish	*	-15 %	-8.8 %	-2.6 %	502	85
Gillnet	Non-groundfish avg price		-1.6 %	1.7 %	5.2 %	502	85
Gillnet	Total revenue		-9.5 %	-3.8 %	1.5 %	502	85
Gillnet	Trip duration		-3.8 %	-1.5 %	1.1 %	502	85

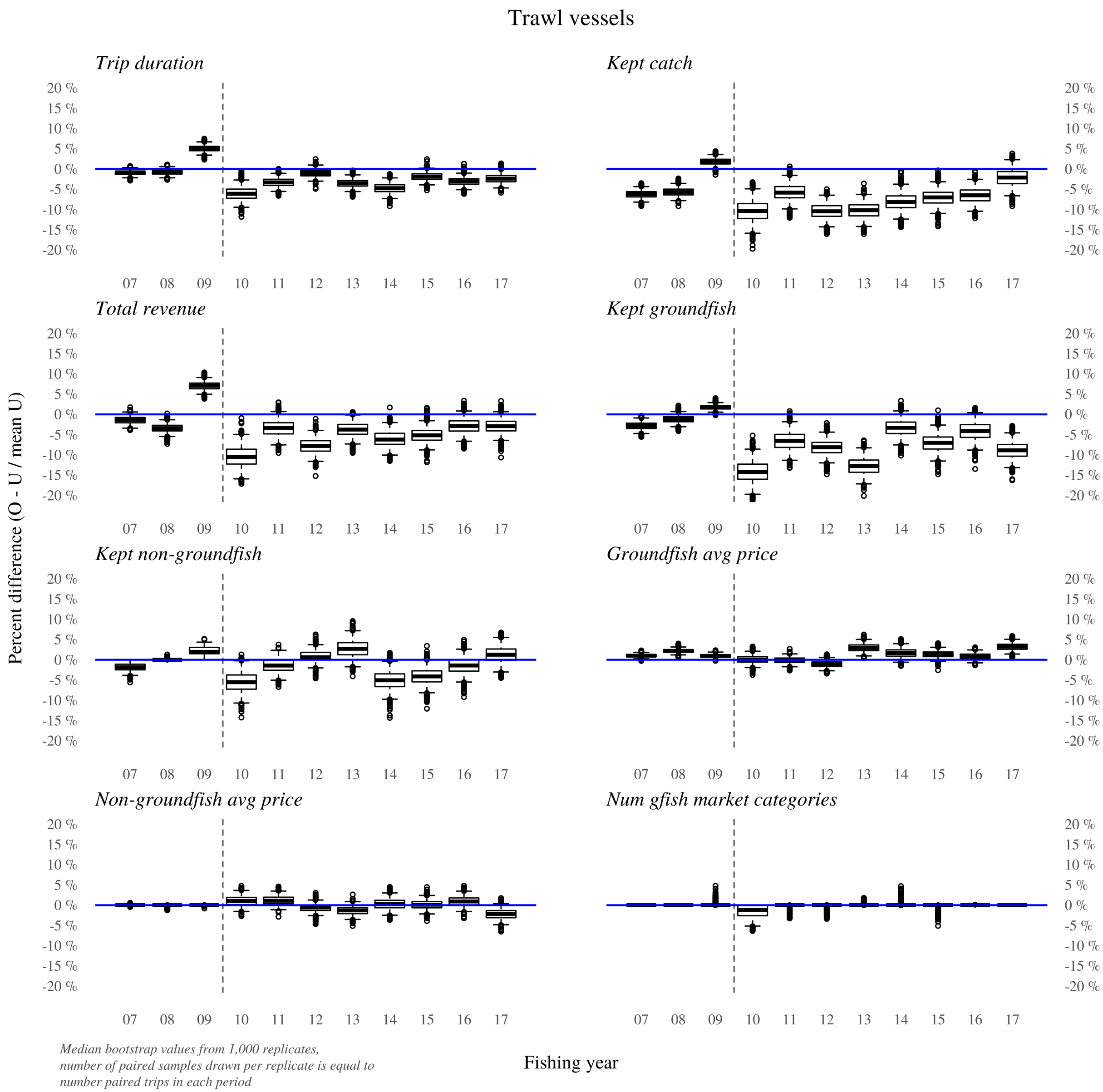


Figure 3: Results of bootstrap analysis, observed and unobserved same-vessel paired trips by fishing year

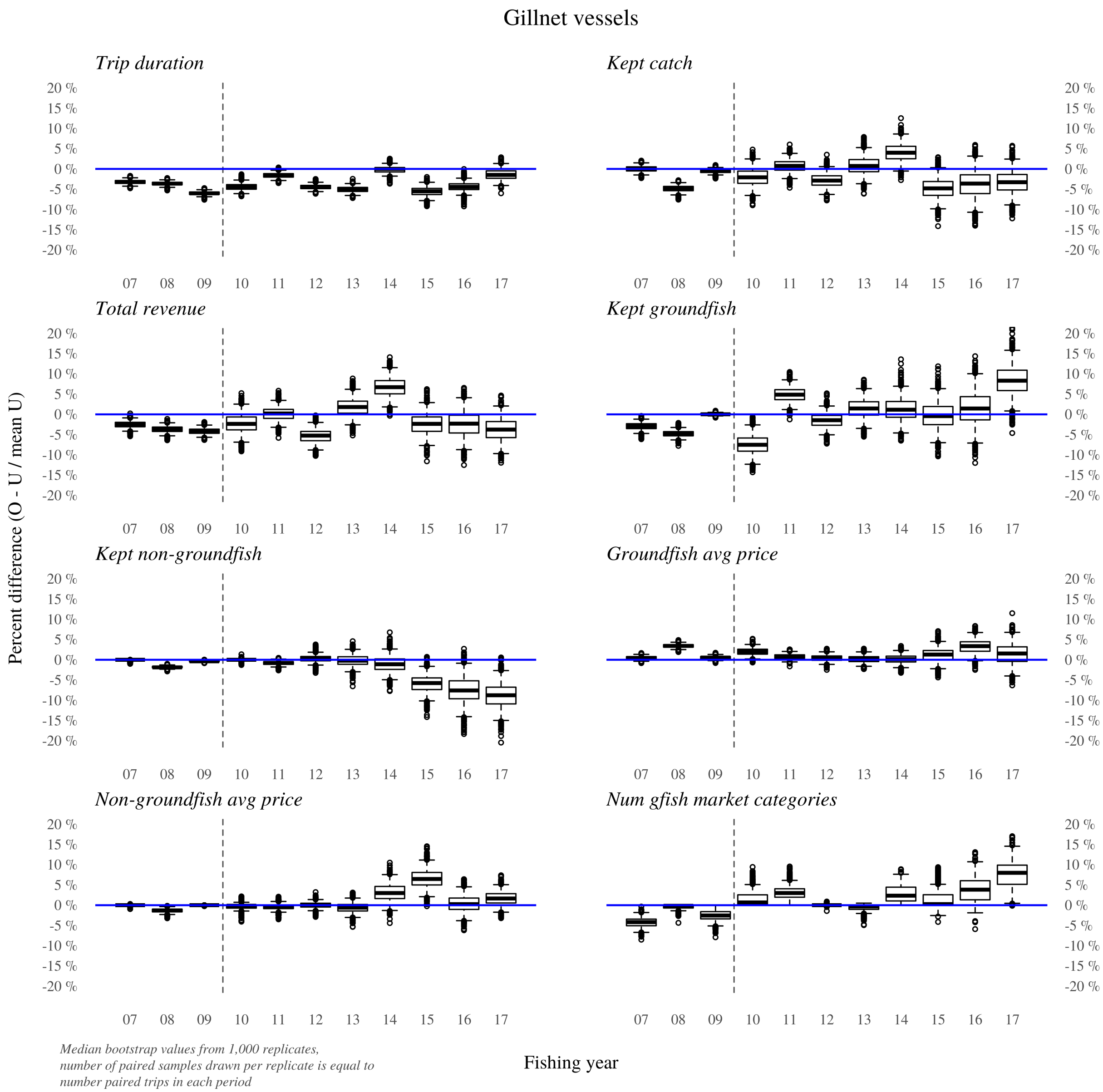


Figure 4: Results of bootstrap analysis, observed and unobserved same-vessel paired trips by fishing year

References

Benoît H. P., Allard J. Can the data from at-sea observer surveys be used to make general inferences about catch composition and discards? Canadian Journal of Aquatic Sciences 2009; 66:2025-2039.

Faunce C. H., Barbeaux S. J. The frequency and quantity of Alaskan groundfish catcher-vessel landings made with and without an observer. ICES Journal of Marine Science 2011; 68 (8): 1757-1763.

McCambridge, Jim, John Witton, and Diana R. Elbourne. "Systematic Review of the Hawthorne Effect: New Concepts Are Needed to Study Research Participation Effects." Journal of Clinical Epidemiology 67.3 (2014): 267–277. PMC. Web. 30 Apr. 2018.

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Appendix 6: Use of Fishermen's Questionaires in ICES Assessments.

2011 Survey of North Sea Stocks - as an example fishermen's questionaire:

A survey of North Sea fishermen in five countries - Belgium, Denmark, England, the Netherlands, and Scotland - has been carried out annually since 2003 (following a pilot in 2002) with the aim of making their knowledge of the state of fish stocks available to fisheries scientists and fisheries managers. Results of the survey are provided to the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). Below is a blank copy of the 2011 survey, provided as an example of the types of questions asked of fishermen, which include questions about fishermen's perceptions of changes in their economic circumstances and in the state of selected fish stocks from the previous year to the current year.

2014 Fishers' North Sea Stock Survey Results:

As described above, a questionaire is distributed annually to North Sea fishermen, with the purpose of ensuring that fishermen's knowledge of the state of fish stocks is considered during the development of TACs. The results of the survey are provided to the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). Below is a summary of the 2014 Fisher's North Sea Stock Survey results, provided as an example. Included is a summary of fishermen's responses on perceptions of economic circumstances, which fall under the following categories: Difficulty of Getting/Retaining Crew, Operating Costs, Profits, and Optimism for the Future. Fishermen's responses on perceptions of stock abundance are also summarized for each stock (cod, haddock, whiting, saithe, monkfish, *Nephrops* (Norway lobster), common sole, and plaice), and include perceptions on Stock Abundance, Size Class, Discards, and Recruitment. The fishermen's perceptions of changes in the abundance of fish (from the responses to the survey) were compared with ICES assessments of changes in their abundance. A comparison of the index of abundance derived from the fishers' survey responses (the methodology for deriving this index is described in the Survey Results) and the ICES abundance estimate is provided for each stock.

2011 Survey of North Sea Stocks

The purpose of this questionnaire is to ensure that fishermen's knowledge of the state of fish stocks is considered during the development of TACs.

The questionnaire should be completed by **comparing conditions in January - June this year with conditions in January - June last year.**

All information will remain strictly confidential. Data will be pooled before presentation to the Advisory Committee on Fisheries Management. To ensure complete confidentiality please *do not* write your name, or the name of your vessel, on this questionnaire.

Instructions

1. The questionnaire refers to the **North Sea only**.

2. The questionnaire is in four sections that will help us use the data
   1. Vessel size and gear type
   2. Information on the eight main species
   3. Your financial status compared to last year
   4. Any other information you may wish us to know

3. Questions should be answered by putting a tick in the appropriate box (see example below).

EXAMPLE

Question 1	Answer 1	√	Answer 2		Answer 3	

4. **Please return your completed questionnaire to [national coordinator] by Friday 15th July 2011**

SECTION 1

VESSEL & GEAR										
Size	Under 15m			15-24m				Over 24m		

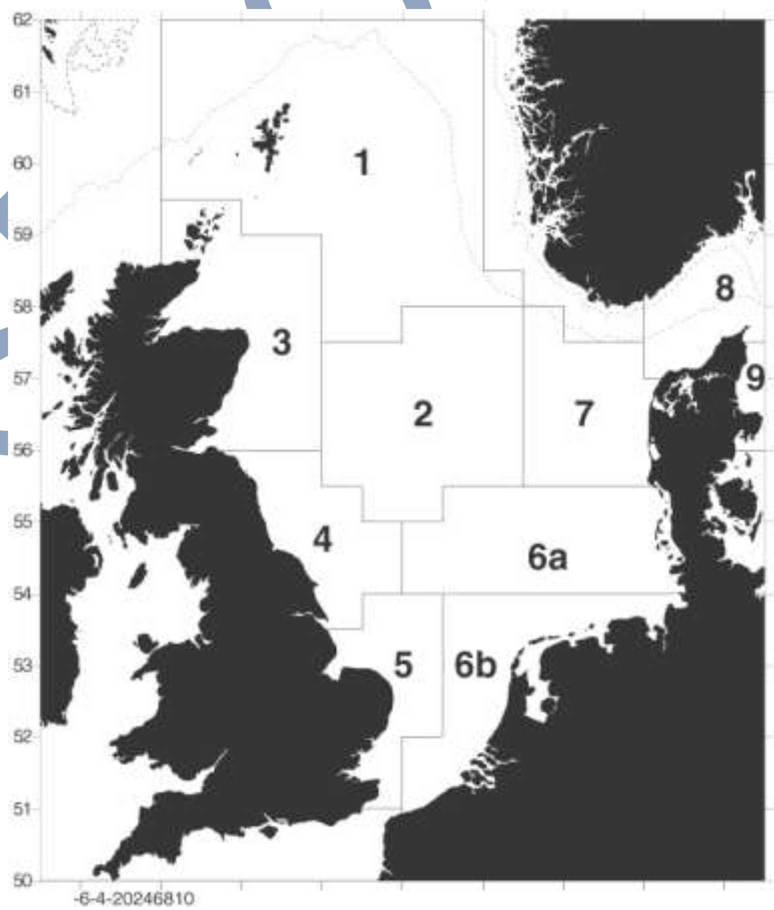
*Main fishing method **last** year*	Trawl		*Nephrops* Trawl		Beam Trawl		Gill Net		Seine*	
	*Seine = Scottish Seine, Pair Seine, or Danish Seine (please indicate which)									
	Other (please specify)									

*Main fishing method **this** year*	Trawl		*Nephrops* Trawl		Beam Trawl		Gill Net		Seine*	
	*Seine = Scottish Seine, Pair Seine, or Danish Seine (please indicate which)									
	Other (please specify)									

SECTION 2

When completing the question on fishing area in this section, reference should be made to the numbered boxes on the map below.

Information on abundance should be provided on the basis of **catch** not landings



COD

Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of cod changed since last year? No ☐ Yes ☐

If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of cod discarding changed since last year? No ☐ Yes ☐

If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

HADDOCK

Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of haddock changed since last year? No ☐ Yes ☐

If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of haddock discarding changed since last year? No ☐ Yes ☐

If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

WHITING										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of whiting changed since last year? No ☐ Yes ☐

If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of whiting discarding changed since last year? No ☐ Yes ☐

If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

SAITHE										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of saithe changed since last year? No ☐ Yes ☐

If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of saithe discarding changed since last year? No ☐ Yes ☐

If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

MONKFISH

Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of monkfish changed since last year? No ☐ Yes ☐

If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of monkfish discarding changed since last year? No ☐ Yes ☐

If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

NEPHROPS

Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of Nephrops changed since last year? No ☐ Yes ☐

If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of Nephrops discarding changed since last year? No ☐ Yes ☐

If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

COMMON (DOVER) SOLE

Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of sole changed since last year? No ☐ Yes ☐

If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of sole discarding changed since last year? No ☐ Yes ☐

If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

PLAICE

Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of plaice changed since last year? No ☐ Yes ☐

If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of plaice discarding changed since last year? No ☐ Yes ☐

If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

SECTION 3

ECONOMIC CIRCUMSTANCES

Have your economic circumstances changed since last year?

Difficulties in obtaining or retaining crew	Much less		Less		Same		More		Much more	
Operating costs	Much less		Less		Same		More		Much more	
Profits	Much less		Less		Same		More		Much more	
Are you more or less optimistic about the future?	Much less		Less		Same		More		Much more	

SECTION 4

Have you any additional information on the fisheries?

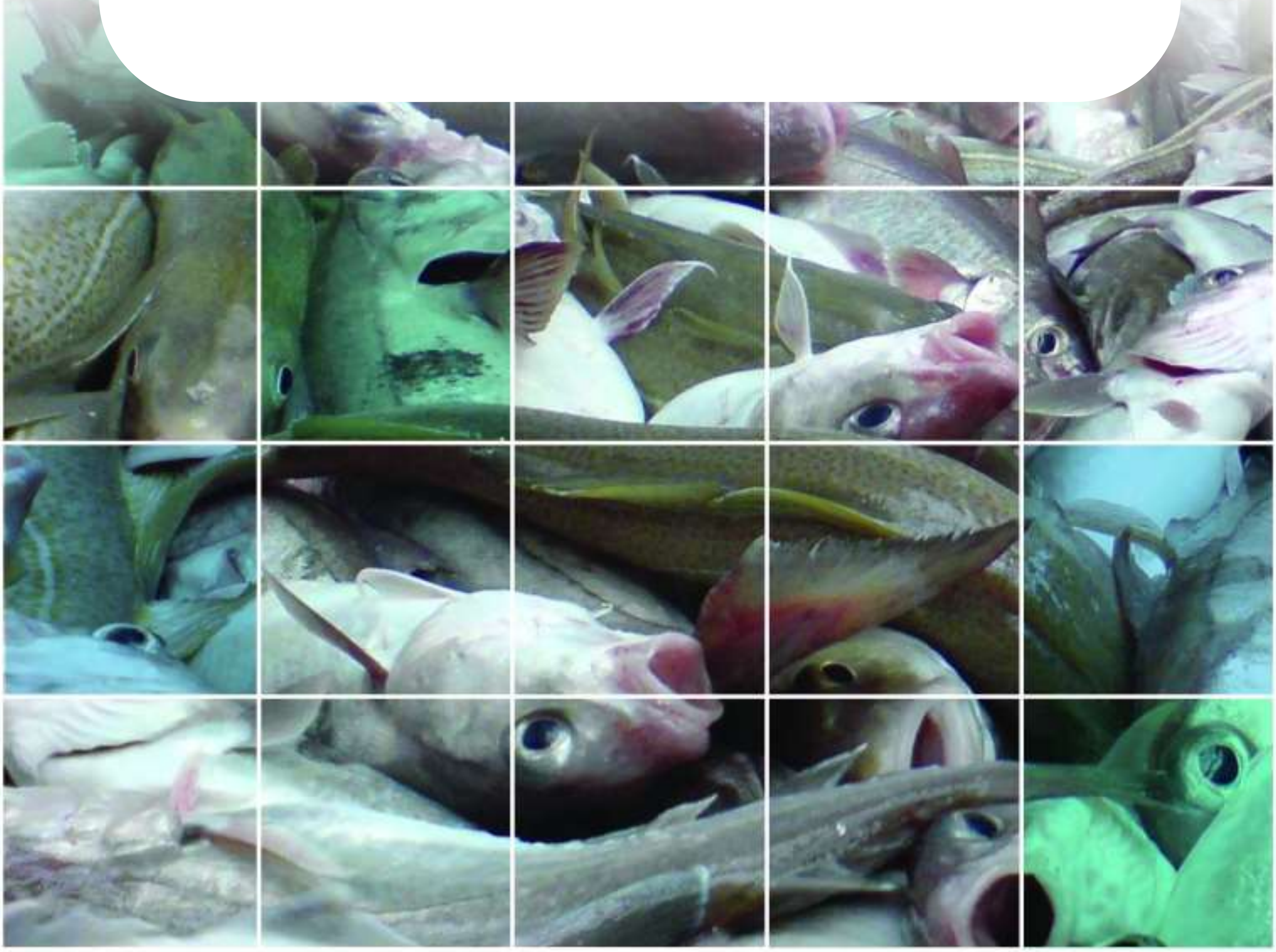
Thank you for your contribution.

Appendix 6

NAFC Marine Centre
University of the Highlands and Islands

Fishers' North Sea Stock Survey 2014

November 2014



Fishers' North Sea Stock Survey 2014

November 2014

Author: **Ian R. Napier**

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Acknowledgements

The cooperation and assistance of the national coordinators (see p. 13), without whom this survey would not have been possible, is gratefully acknowledged, as is the contribution of the individual fishermen who completed questionnaires.

Thanks are also due to John Clayton for maintaining the survey website and providing IT support.

The data analysis and preparation of this report was funded by the survey partners.

Disclaimer

The contents of this report reflect the perceptions and opinions of the respondents to the survey. They do not reflect the views or opinions of the NAFC Marine Centre, the author, or the sponsoring or coordinating organisations.

Data Ownership

The data collected through the Fishers' North Sea Stock Survey are collated and analysed by the NAFC Marine Centre and used to prepare this report, but ownership of the raw data remains with the national coordinating organisations responsible for their collection.

Table of Contents

Summary

<u>Given the non-quantitative and subjective nature of this survey the results contained in this report should be interpreted and used with caution</u>.

This report presents the results of an analysis of the data collected through the Fishers' North Sea Stock Survey in 2014. As in previous years, the survey was carried out using a questionnaire circulated to North Sea fishermen in five countries; Belgium, Denmark, England, the Netherlands, and Scotland. Fishermen were asked to record their perceptions of changes in their economic circumstances and in the state of selected fish stocks from 2013 to 2014.

A total of 196 completed questionnaires were returned in 2014, of which 177 were included in the analysis. The number of questionnaires returned was higher than in 2013, but still below that in 2012.

The results of the analysis of economic perceptions are summarised in Table 1 and, in somewhat more detail, in Table 2. Overall, the economic perceptions were fairly negative with most responses reporting higher costs, lower profits and lower optimism, although most responses reported no change in the level of difficulty of getting crew.

The results of the analysis of perceptions of the state of fish stocks are summarised in Table 3 and Table 4. The overall picture appears fairly optimistic: the majority of responses reported the same or higher levels of abundance for all eight species; all sizes of fish, the same level of discards and moderate or high levels of recruitment for all eight.

Table 1 Summary of perceptions and trends in relation to economic circumstances in responses to the Fishers' North Sea Stock Survey:
Top: *Perceptions*; response category with largest proportion of responses.
Bottom: *Trends*: response category with largest increase from last year to this year in proportion of responses. (It should be borne in mind that the category with the largest increase may still only account for a small proportion of responses. See Table 2 for more details.)

	Crew	Costs	Profits	Optimism
Perception	same	more	less	less
Trend	same	same	same	more

Table 2 Summary of perceptions of economic circumstances from the Fishers' North Sea Stock Survey: proportions of responses in each category, and the change in proportions from last year to this year (+/- %). The largest proportion for each parameter and the category with the largest increase are highlighted.

	'Less'	Same	'More'
Crew	10% -0%	**71%** **+1%**	19% **-0%**
Costs	7% -3%	40% **+10%**	**53%** -7%
Profits	**51%** -12%	35% **+12%**	14% +1%
Optimism	**46%** -16%	34% +5%	20% **+11%**

Table 3 Summary of perceptions and trends in relation to the state of fish stocks in responses to the Fishers' North Sea Stock Survey:
Top: *Perceptions*; response category with largest proportion of responses.
Bottom: *Trends*: response category with largest change from last year to this year in proportion of responses. (It should be borne in mind that the category with the largest change may still only account for a small proportion of responses. See Table 4 for more details.)

Perception	Abundance	Size Range	Discards	Recruitment
Cod	more	all	same	moderate
Haddock	same	all	same	moderate
Whiting	same	all	same	moderate
Saithe	same	all	same	mod./high
Monkfish	same	all	same	moderate
Nephrops	more	all	same	moderate
Sole	more	all	same	high
Plaice	more	all	same	high

Trend	Abundance	Size Range	Discards	Recruitment
Cod	more	small	more	high
Haddock	more	all	same	high
Whiting	less	small	less	mod'
Saithe	same	all	same	high
Monkfish	more	large	more	high
Nephrops	more	large	more	high
Sole	more	small	same	high
Plaice	same	small	more	high

Table 4 Summary of perceptions of the state of fish stocks from the Fishers' North Sea Stock Survey: Proportions of responses in each category and the change in proportions from last year to this year (+/- %). The largest proportion for each parameter and the category with the largest increase are highlighted for each species. (Continued overleaf.)

	Abundance			Fish Size		
	'Less'	No Change	'More'	Mostly Small	All Sizes	Mostly Large
Cod	13% -14%	27% -4%	**60%** **+19%**	13% **+2%**	**82%** +1%	4% -3%
Haddock	14% -13%	**44%** **+12%**	42% +1%	13% +1%	**87%** **+6%**	0% -8%
Whiting	21% -7%	**57%** **+26%**	22% -19%	21% **+9%**	**78%** -3%	1% -7%
Saithe	12% -16%	**52%** **+21%**	37% -5%	21% **+10%**	**71%** -10%	7% -0%
Monkfish	9% -19%	**54%** **+22%**	38% -3%	16% **+4%**	**79%** -2%	5% -2%
Nephrops	13% -15%	17% -14%	**70%** **+29%**	16% +5%	**69%** -12%	15% **+7%**
Sole	24% -4%	29% -2%	**47%** **+6%**	31% **+20%**	**65%** -16%	3% -4%
Plaice	14% -13%	27% -4%	**59%** **+17%**	27% **+15%**	**65%** -15%	7% -0%

cont./

Table 4 cont.

	Discards			Recruitment		
	'Less'	No Change	'More'	Low	Moderate	High
Cod	17% -9%	**53%** +1%	29% **+9%**	14% -1%	**47%** -2%	40% **+3%**
Haddock	13% -13%	**78%** **+26%**	8% -12%	15% +1%	**52%** **+3%**	32% -4%
Whiting	19% -8%	**66%** **+13%**	16% -5%	19% +5%	**56%** **+7%**	24% -12%
Saithe	10% -17%	**67%** **+15%**	23% +2%	5% -9%	**47%** -2%	**47%** **+11%**
Monkfish	11% -16%	**83%** **+30%**	6% -14%	12% -2%	**55%** **+6%**	33% -4%
Nephrops	20% -7%	**62%** **+9%**	18% -2%	2% -12%	**80%** **+31%**	17% -19%
Sole	20% -6%	**58%** **+6%**	21% +0%	13% -1%	42% -8%	**45%** **+9%**
Plaice	12% -15%	**62%** **+9%**	26% +5%	3% -11%	42% -7%	**55%** **+19%**

Introduction

This report presents the results of an analysis of the data collected through the Fishers' North Sea Stock Survey in 2014.

Given the non-quantitative and subjective nature of this survey the results contained in this report should be interpreted and used with caution.

Background

A survey of North Sea fishermen in five countries - Belgium, Denmark, England, the Netherlands, and Scotland - has been carried out annually since 2003 (following a pilot in 2002) with the aim of making their knowledge of the state of fish stocks available to fisheries scientists and fisheries managers. The results of the survey are provided to the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK).

The questionnaire-based survey collects information on vessel size and fishing gear type, on the status of key fish species, and on the fishermen's economic circumstances (further information on the survey is provided below) across 10 areas of the North Sea (Figure 1). These areas are based on the standard roundfish sampling areas defined by ICES[1], with their area 6 divided into two parts (6a & 6b).

The survey was repeated in 2014, with funding for the collation and analysis of the data provided by the project participants under the auspices of the North Sea Advisory Council.

Reviews of the Survey by ICES

The survey was reviewed by ICES in 2006[2] and was discussed by the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) in 2012[3]. The working group comments are summarised in the report of the 2012 Fishers' North Sea Stock Survey.

[1] See ICES Manual for the International Bottom Trawl Surveys, Fig. 6.2 (p 45). Available online at: datras.ices.dk/Documents/Manuals/Addendum_1_Manual_for_the_IBTS_Revision_VIII.pdf

[2] Report of the Review Group on Fisheries Surveys of North Sea Stocks (RGFS). ICES CM 2006 / ACFM:38. Available at: www.ices.dk/products/CMdocs/2006/ACFM/ACFM3806.pdf

[3] Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 27 April - 3 May 2012. Section 1.6, pp. 16-18. Available at: www.ices.dk/reports/ACOM/2012/WGNSSK/Sec 01 General.pdf

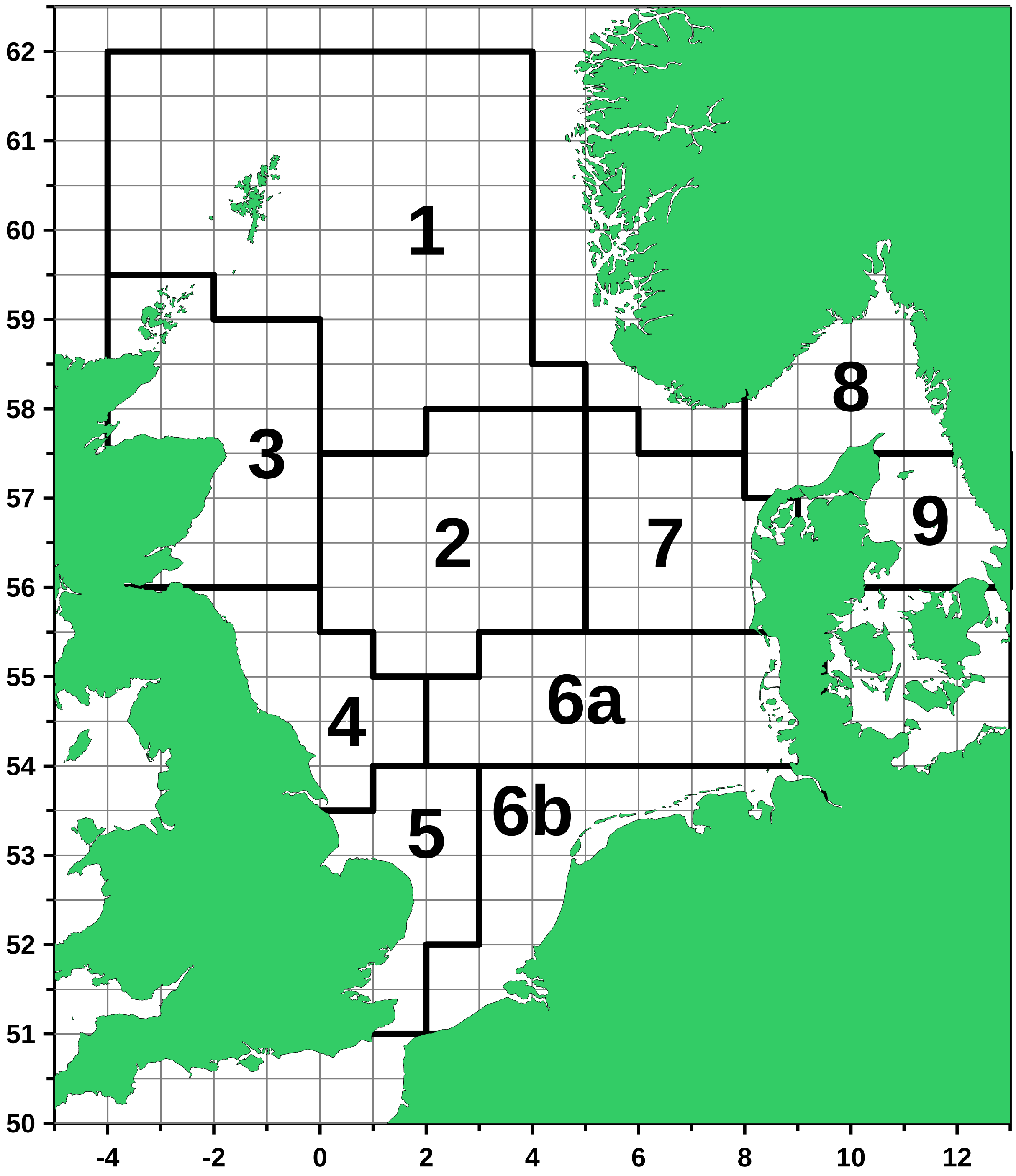

Figure 1 The areas of the North Sea used in the survey. Based on the ICES standard roundfish sampling areas with area 6 divided into two parts.

Methodology

The methodology of the survey in 2014 was largely unchanged from the previous years. Questionnaires[1] were translated and circulated to North Sea fishermen by coordinators in the five participating countries (Table 5).

As in previous years the questionnaire asked fishermen for three types of information:

- the size of their fishing vessel and the fishing gear used (Table 6).
- their perceptions of changes from 2013 to 2014 in the abundance, level of discards, size range, and level of recruitment of eight species of fish (Table 7) in each of 10 areas of the North Sea (Figure 1).
- their perceptions of changes from 2013 to 2014 in the difficulty in obtaining or retaining crew, their operating costs and profits, and their degree of optimism about the future.

In each case, respondents were asked to compare the first half of 2014 (January to June) with the same period of 2013. The questionnaire is not quantitative but asks respondents to select from response categories, e.g. for abundance: ‘much less’, ‘less’, ‘no change’, ‘more’ or ‘much more’. Respondents could also provide any additional information or comments that they wished to.

Fishermen in each country returned the completed questionnaires to their national coordinators, who entered the information provided into a single central database via a web-based data entry system. The analysis of these data and the preparation of this report were undertaken by the NAFC Marine Centre.

Nephrops

In 2012 an additional question was included that asked fishermen to record their perceptions of *Nephrops* in relation to the areas of the Functional Units (FUs) used by ICES in their assessment of the North Sea *Nephrops* stock. (No responses to this question were received in 2014.)

Pulse Trawl[2]

In recent years a number of Dutch respondents have reported using ‘Pulse’ Trawls (Pulskor). Previously these responses were excluded from the analyses, as this was

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[1] A specimen questionnaire can be downloaded from the Fishers’ North Sea Stock Survey website at: www.nsss.eu .

[2] Pulse trawls resemble beam trawls, but use electric currents rather than tickler chains to disturb flatfish lying on the sea-bed (see: britishseafishing.co.uk/pulse-trawling/). Pulse trawling is permitted in EU waters on an experimental basis.

not one of the gear types covered by the survey. The decision was taken to add this fishing gear category to the analysis of the 2013 data, and it was added to the questionnaire in 2014.

Table 5 Countries participating in the North Sea Stock Survey and the coordinating organisation and principle coordinators in each.

Country	Coordinating Organisation	Coordinators
Belgium	Rederscentrale (Belgian Fishing Vessel Owners Association and Producers Organisation)	Céline Van den bosch
Denmark	Danmarks Fiskeriforening (Danish Fishermen's Association)	Michael Andersen
England	National Federation of Fishermen's Organisations	Joanna Lenehan Dale Rodmell
Netherlands	Coöperatieve Visserij Organisatie (Co-operative Fisheries Organisation)	Inger Wilms
Scotland	Scottish Fishermen's Federation	Kenny Coull Fiona Lord

Table 6 The fishing gears covered by the survey.

Trawl (Otter Trawl)
Beam Trawl
Pulse Trawl (Electric Beam Trawl) - *added 2013*
***Nephrops* Trawl**
Gill Nets
Seine Net (Scottish seining / fly-dragging)

Table 7 The species covered by the survey.

Cod	*Gadus morhua*
Haddock	*Melanogrammus aeglefinus*
Whiting	*Merlangius merlangus*
Saithe	*Pollachius virens*
Monkfish	*Lophius piscatorius*
Nephrops	*Nephrops norvegicus*
Common (Dover) Sole	*Solea solea*
Plaice	*Pleuronectes platessa*

Data Analysis

Times Series Index

Although the results are not quantitative, an index of abundance is calculated for each species in each area by assigning scores to the response categories as follows: 'much less' = -1; 'less' = -0.5; 'no change' = 0; 'more' = 0.5; and 'much more' = 1. A weighted score is then calculated for each species in each area by multiplying the percentage of responses in each category by the score for that category and summing the results:

$$Index = \sum score_{category} \times percentage\ of\ responses_{category}$$

A time series has been generated from previous survey results by assigning a value of zero to 2001 and cumulatively summing the annual indices for each species in each area since then. These indices were updated in 2014.

Comparison with ICES Abundance Estimates

Following the method developed by Henrik Sparholt of ICES following the 2009 Fishers' North Sea Stock Survey[1], the fishermen's perceptions of changes in the abundance of fish (from this survey) were compared with ICES assessments of changes in their abundance.

An annual index of abundance for each species each year was calculated from the Fishers' North Sea Stock Survey data as follows (illustrated in Table 8):

1) The percentages of responses in each of the abundance categories were calculated for each species and area.
2) These percentages were multiplied by a weighting factor (-2, -1, 0, 1, 2).
3) The resulting values were added to give a single index for each species and area.
4) Finally, the indices for each species were averaged to give an overall annual North Sea index for each species which could be compared with the annual ICES abundance estimates.

These overall indices - which reflect fishermen's perceptions of changes in the abundance of fish - were compared to changes in the ICES estimates of spawning stock biomass (SSB) in the North Sea. (It should be noted that the areas for which ICES provides biomass estimates may not correspond exactly with the area covered

[1] For further details of Sparholt's methods and analysis see the report of the 2010 Fishers' North Sea Stock Survey, pp. 89-93 & Appendix 2. Available online at: www.nsss.eu .

by the Fishers' North Sea Stock Survey. For example, the NSSS survey area includes the Kattegat which is generally not included in the ICES North Sea Area.)

To compensate for the fact that ICES estimates the SSB on the 1st of January each year while the Fishers' North Sea Stock Survey covers the period from mid-year to mid-year, the SSB in the middle of each year was estimated as the average of the SSB at the start of that year and at the start of the following year. The percentage changes between these estimated mid-year SSBs were calculated and compared to the Fishers' North Sea Stock Survey indices.

To provide a mid-year SSB estimate for 2014 the predicted SSB for 2015 was used. (All SSB data, including the predicted 2015 values, were taken from the latest ICES Advice[1].)

Table 8 Illustration of Sparholt's method of calculating an abundance index from Fishers' North Sea Stock Survey data for one species in one area. In the final step (not shown) these area indices are averaged to give an overall index for each species for the North Sea. See text for full explanation.

	(1)		(2)		
Category	**No. of Responses**	**% of Responses**	**Weighting Factor**	**% × Factor**	
'Much Less'	2	4%	-2	-0.08	
'Less'	10	19%	-1	-0.19	
'No Change'	22	42%	0	0.00	
'More'	15	29%	1	0.29	
'Much More'	3	6%	2	0.12	
TOTAL	52			**index = 0.13**	**(3)**

Comparison of Areas

Indices of abundance were calculated for each area to provide a means of comparing trends in perceptions of changes in abundance across different areas of the North Sea. The method used followed steps 1 to 3 described above for the calculation of indices for comparison with ICES abundance estimates.

However, in the final step the individual species-area indices were averaged across all species in each area, thus giving a single index for each area. Broadly speaking,

[1] Available online at: www.ices.dk/community/advisory-process/Pages/Latest-Advice.aspx

a higher index indicates that a greater proportion of responses from that area perceived that abundances of fish were higher in that area in 2013.

Similar indices were calculated for perceptions of changes in the size range of fish (using weighting factors -1, 0 & 1 for the three categories of response for that parameter), discards (-2, -1, 0, 1 & 2) and recruitment (1, 2 & 3).

Similar indices were also calculated for perceptions of changes in the economic parameters surveyed: difficulty of getting/obtaining crew (using weighting factors (2, 1, 0, -1 & -2); costs (2, 1, 0, -1 & -2); optimism (-2, -1, 0, 1 & 2); and profits (-2, -1, 0, 1 & 2). The weighting factors were adjusted for each parameter to give negative values to more 'negative' responses, e.g. low costs would be perceived as 'good' so received a positive weighting factor (1 or 2) while low profits would be perceived as 'bad' and so received a negative weighting factor (-1 or -2). An overall economic index was calculated by averaging the individual economic indices for each area.

As an additional overall measure of changes in perceptions of abundance the percentage changes in the time series indices (see above) for all species in each area were averaged.

General Results

A total of 196 completed questionnaires were returned in 2014 (Figure 2). This was substantially (39%) more than in 2013 (141), but was still lower than the number received in 2012 and the second lowest since the survey started. Nineteen questionnaires (10%) were omitted for various reasons, including: major changes in fishing gear used from 2013 to 2014; not specifying the fishing gear used; not providing information on any of the species or areas covered by the survey; or using fishing gears other than those covered by the survey.

This left 177 questionnaires that were included in the analyses: 8 from Belgium, 73 from Denmark, 14 from England, 56 from the Netherlands, and 26 from Scotland. (Unlike some previous years there were no returns from Netherlands 'flagships'.)

There were increases in the numbers of responses from all countries, except Belgium (Figure 3), and all areas, except Area 5 (Figure 4). The balance of responses between the different species remained roughly in line with that of the last few years (Figure 5), with increases in the numbers of responses for all species.

Figure 6 shows a breakdown of the valid questionnaires received in 2014 by nationality, area fished, fishing gear used, and size of fishing vessel. Overall, rather more responses were received for the southern and eastern North Sea (areas 6b, 7 & 8), and for gill nets and otter trawls. Numbers of responses were fairly evenly split by vessel size class. As may be seen from Figure 6 there were marked variations in all the parameters between the different countries.

The number of questionnaires received (both total and 'valid') was substantially greater than in 2013, but still less than in 2012 and continuing a downwards trend seen for a number of years. Anecdotal information from at least some national coordinators suggests that, as in previous years, fishermen may be 'losing faith' in the survey as they do not perceive that the results have any influence on assessments of fish stocks or on management decisions.

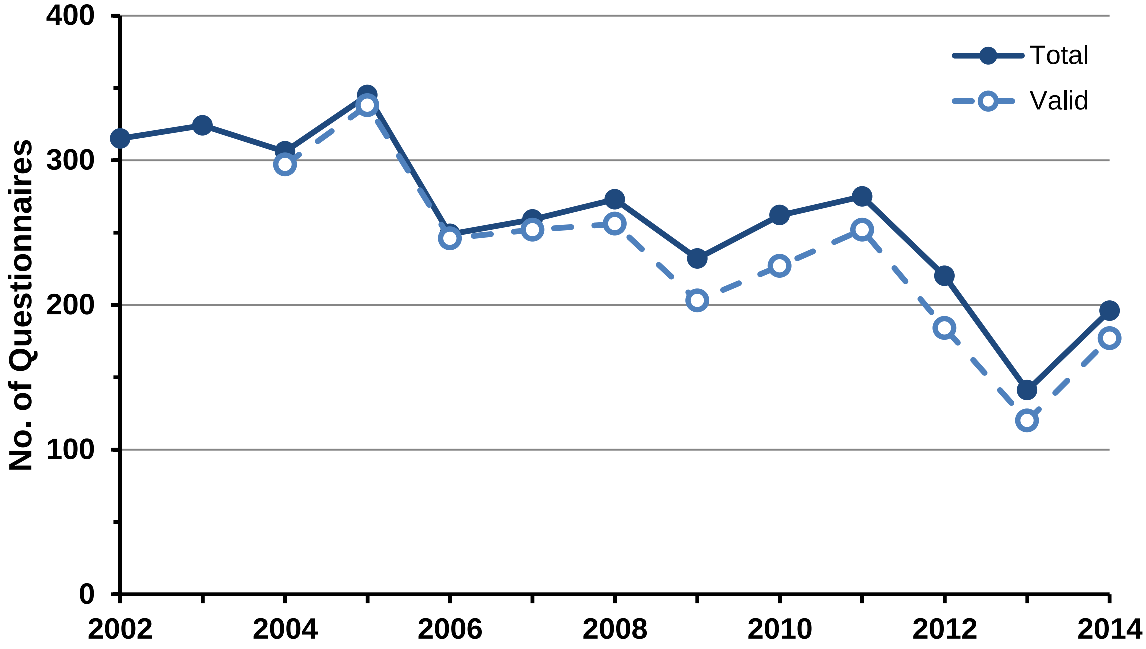


Figure 2 The total number of questionnaires returned each year, and the number of valid questionnaires included in the analysis.

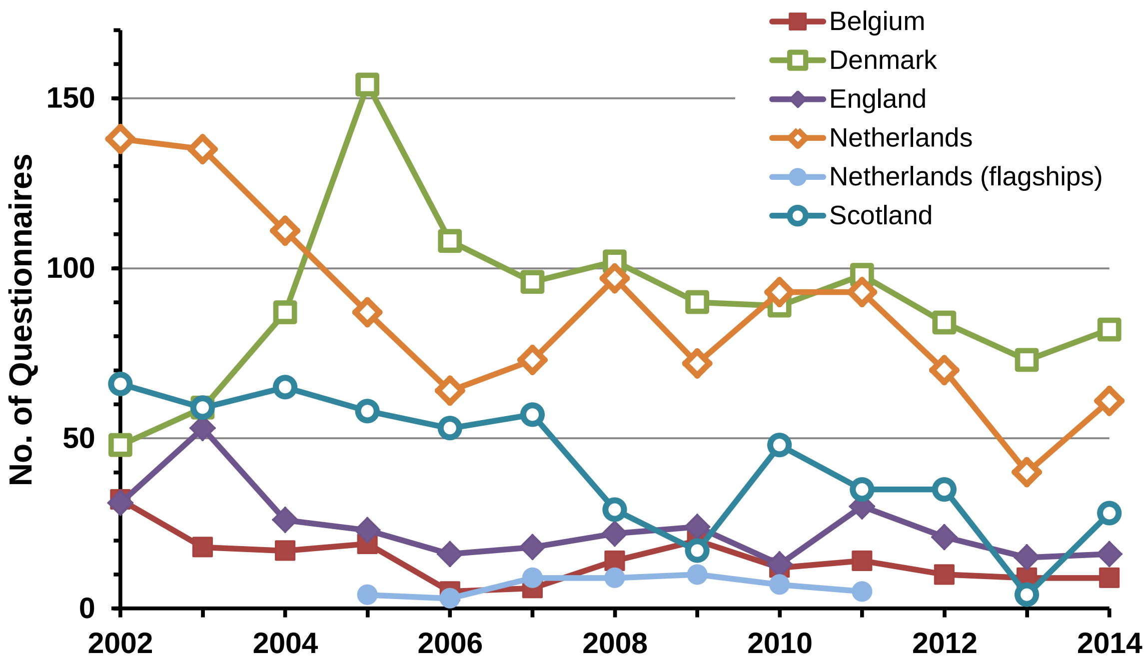


Figure 3 The total number of questionnaires returned each year, by country (all responses).

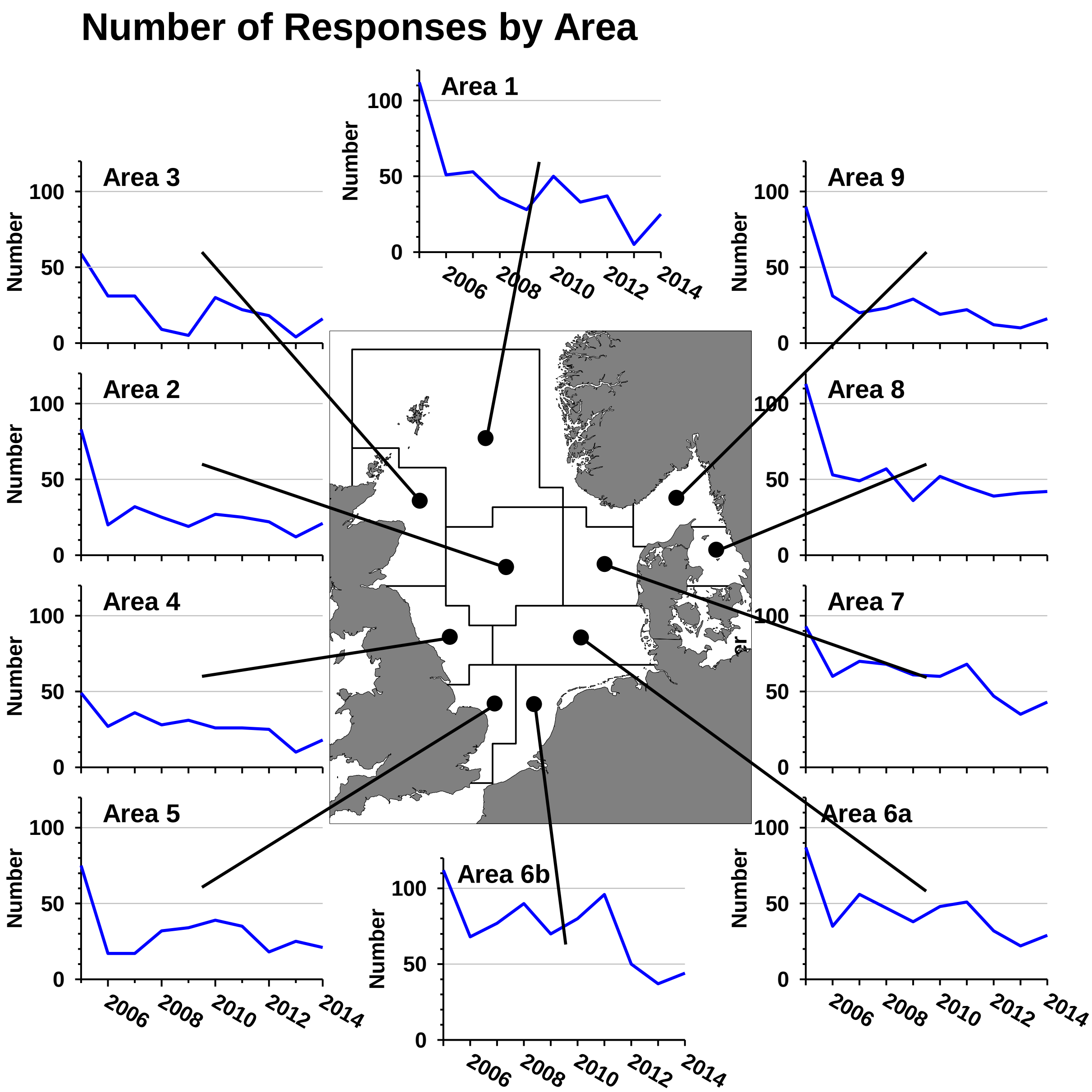


Figure 4 The number of valid questionnaires returned each year, by area. Number of responses providing information on at least one species in each area.

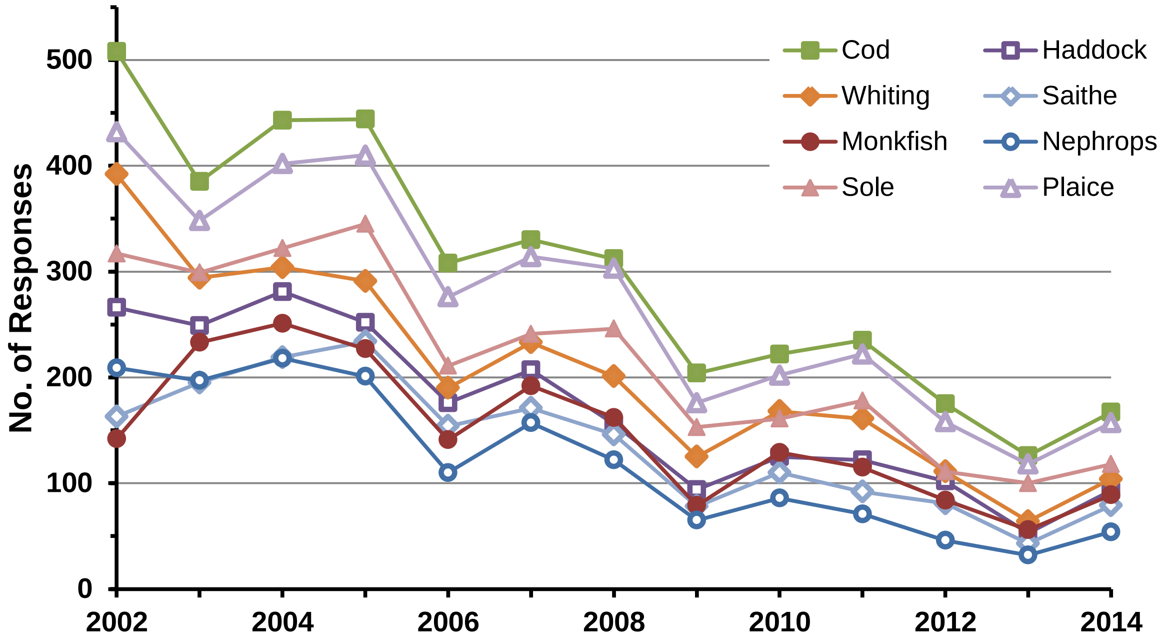


Figure 5 The number of valid questionnaires returned each year giving information for each species (most responses give information for more than one species).

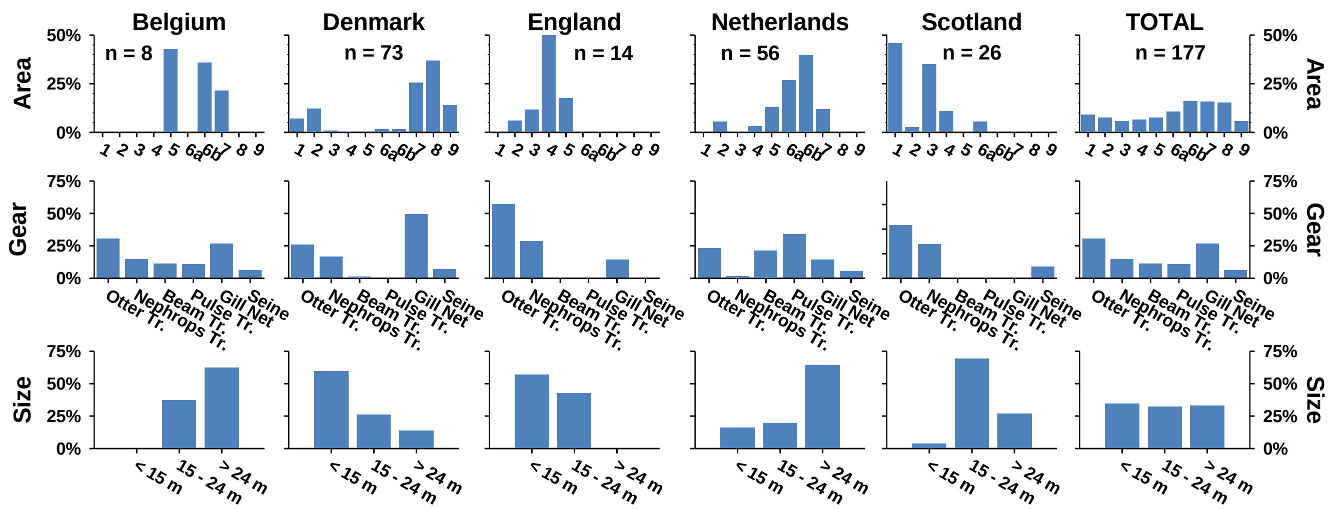


Figure 6 Breakdown of valid questionnaires received in 2014 by country, area fished, fishing gear, and vessel size. Numbers displayed on top row of charts ('n = X') are total numbers of valid questionnaires for that country.

Economic Circumstances

Most of the 177 valid questionnaires received provided information on perceptions of economic circumstances. These responses are summarised in Table 9 and Table 10, and in Figure 7 to Figure 9.

Table 9 Summary of perceptions of economic circumstances this year and last year: Difficulty of obtaining/retaining crew; operating costs; profits; and optimism about the future. Proportion of responses in each category for all areas combined this year and last year, and change in proportions (+/-).

Crew	2013	2014	+/-	Costs	2013	2014	+/-
'Less' [1]	11%	10%	-0%	'Less' [1]	11%	7%	-3%
Same	70%	71%	+1%	Same	29%	40%	+10%
'More' [2]	19%	19%	-0%	'More' [2]	60%	53%	-7%
Profits	**2013**	**2014**	**+/-**	**Optimism**	**2013**	**2014**	**+/-**
'Less' [1]	64%	51%	-12%	'Less' [1]	62%	46%	-16%
Same	23%	35%	+12%	Same	29%	34%	+5%
'More' [2]	13%	14%	+1%	'More' [2]	9%	20%	+11%

[1] 'Less' = sum of 'Less' and 'Much Less' responses.
[2] 'More' = sum of 'More' and 'Much More' responses.

Difficulty of Getting / Retaining Crew

Overall, just under three-quarters of respondents reported the same level of difficulty in getting or retaining crew in 2014 (Table 9), almost unchanged from 2013. Of the remaining responses more (19%) reported more difficulty, again almost unchanged from 2013.

The picture was broadly similar whether the responses were broken down by area (Figure 7), species (Figure 8), fishing gear type (Figure 9) or vessel size (Figure 10), with the majority of responses in each case reporting the 'same' level of difficulty in getting or retaining crew. No clear patterns were apparent in the balance of the remaining responses between lower and higher levels of difficulty.

Operating Costs

Just over half of responses reported that their operating costs were higher in 2014, somewhat less than in 2013 (Table 9). Most of the balance reported the same costs, more than in 2013. The proportion of responses reporting lower costs fell slightly and remained relatively small.

The picture was broadly similar across individual areas (Figure 7) and species (Figure 8). By fishing gear type, otter trawls, *Nephrops* trawls and gill nets were more likely than the other gear types to report higher costs (Figure 9), as were smaller vessels (Figure 10).

Profits

About half of responses reported lower profits in 2014 (Table 9), less than in 2013. About one-third of responses reported the same level of profits, more than in 2013, while the (small) proportion reporting greater profits was almost unchanged.

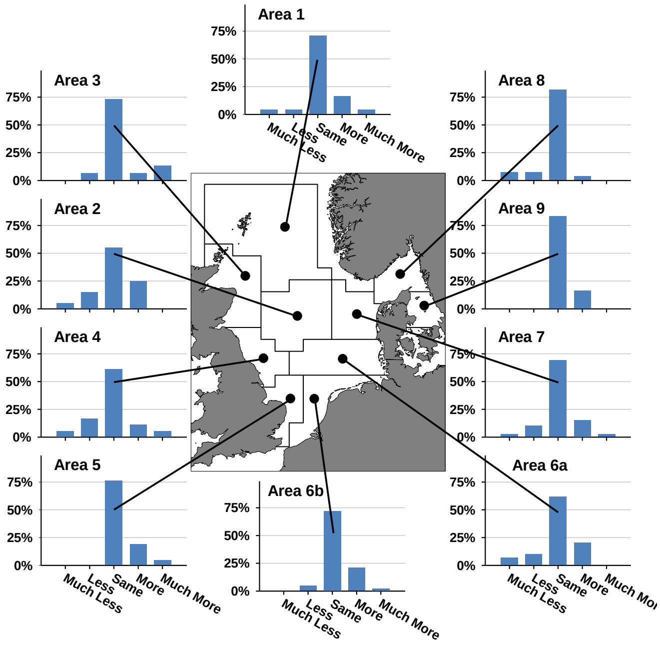
The picture was broadly similar across individual areas (Figure 7), species (Figure 8) and vessel sizes (Figure 10). By fishing gear type, beam trawlers and pulse trawlers were more likely than the other gear types to report the same level of profits (Figure 9).

Optimism for the Future

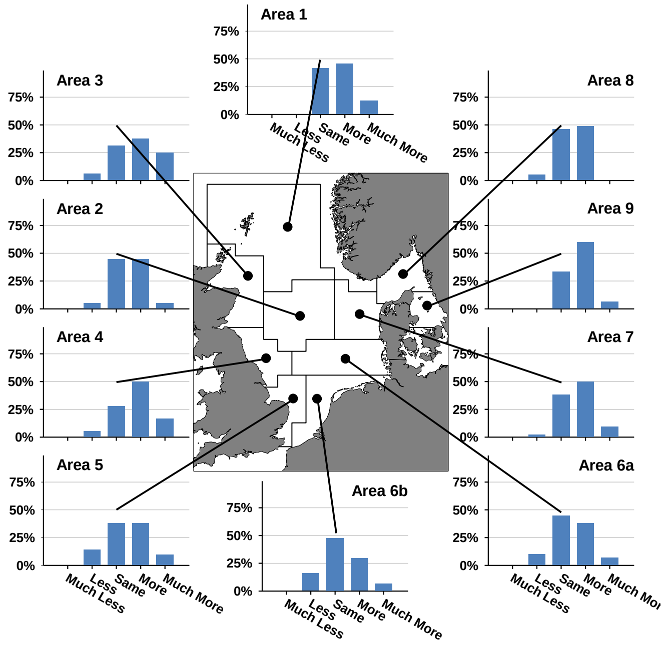
Levels of optimism in 2014 were generally higher than in 2013 (Table 9), with just over half of responses reporting the same or higher levels of optimism and a fairly large fall in the proportion reporting less optimism.

The picture was broadly similar across individual areas (Figure 7), species (Figure 8) and vessel sizes (Figure 10). By fishing gear type, otter trawls, *Nephrops* trawls and gill nets were most likely to report lower levels of optimism (Figure 9).

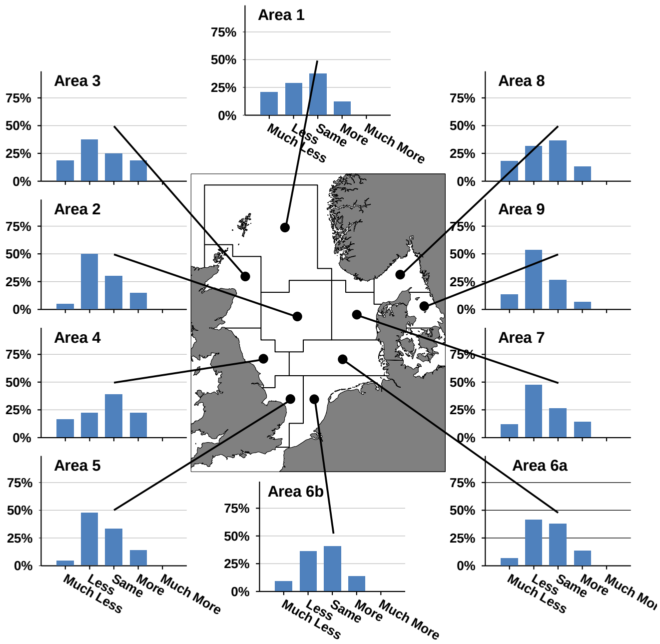
Difficulty of Getting / Retaining Crew



Operating Costs



Profits



Optimism for the Future

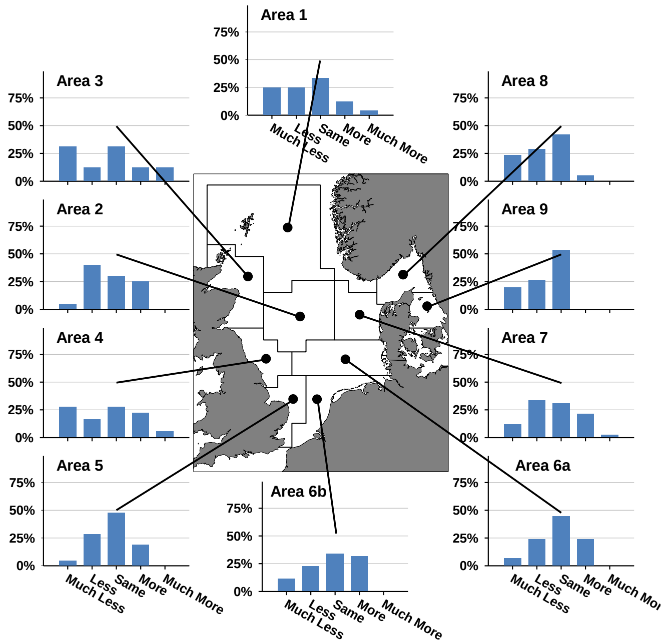


Figure 7 Breakdown by area of perceptions of changes in the difficulty of getting or retaining crew; of operating costs; of profit levels; and of optimism for the future. Percentage of responses from each area in each category.

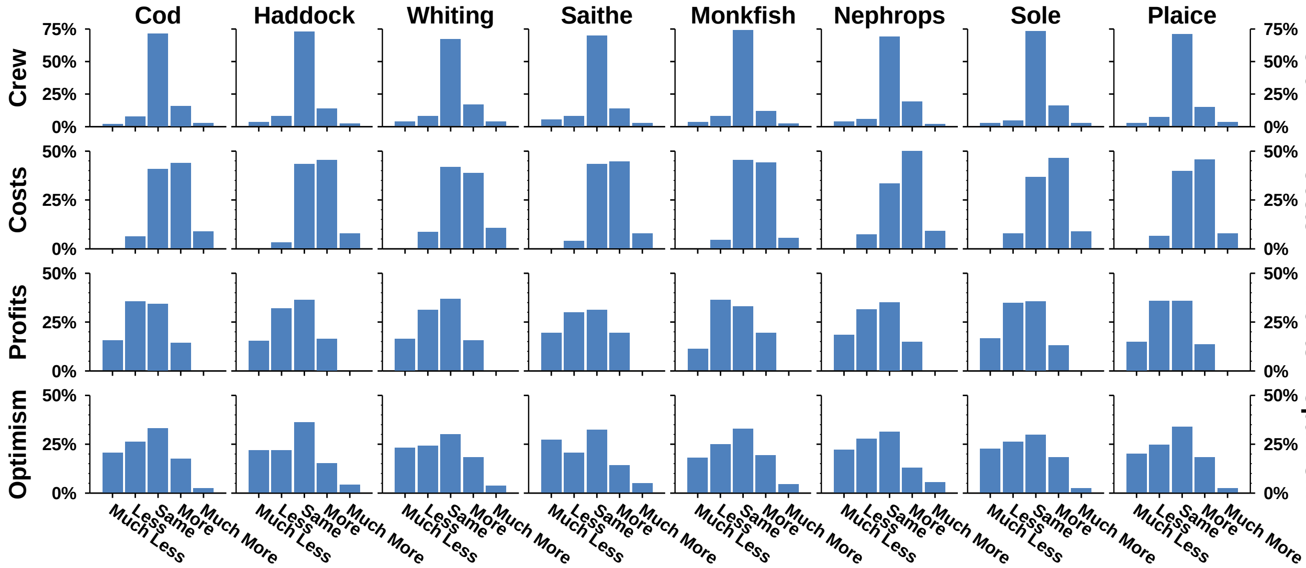


Figure 8 Breakdown of economic perceptions by species: difficulty of obtaining/retaining crew, operating costs, profits, and optimism about the future. Percentage of responses for each species in each category.

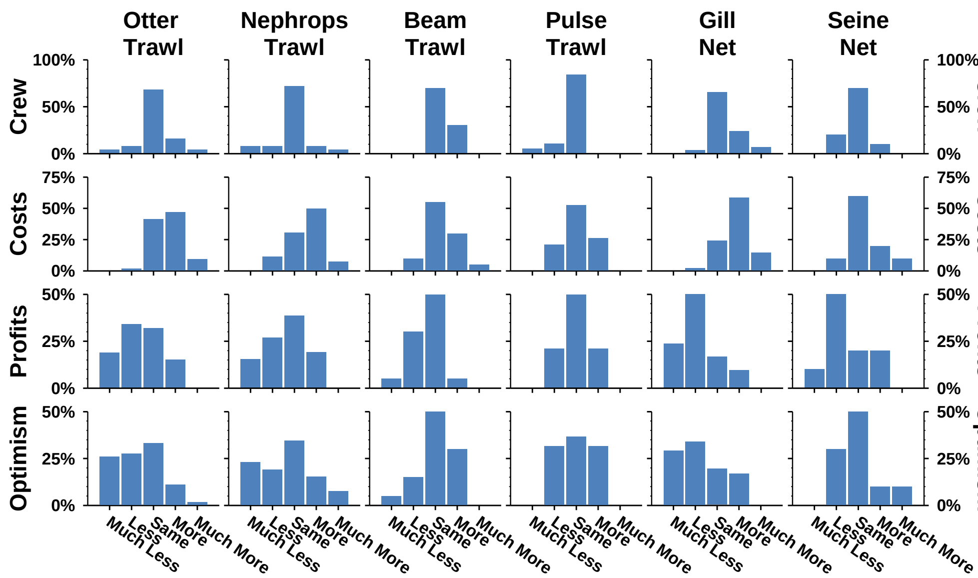


Figure 9 Breakdown of economic perceptions by fishing gear type: difficulty of obtaining/retaining crew, operating costs, profits, and optimism about the future. Percentage of responses in each category for all responses for each gear type.

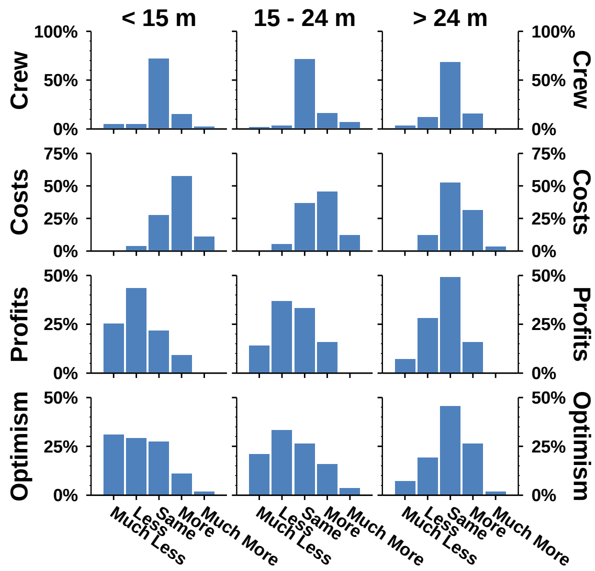


Figure 10 Breakdown of economic perceptions by fishing vessel size: difficulty of obtaining/retaining crew, operating costs, profits, and optimism about the future. Percentage of responses in each category for all responses for each vessel size.

Table 10 Numbers of responses per category by area, species, gear type (otter trawl, *Nephrops* trawl, beam trawl, pulse trawl, gill nets and seine net) and vessel size for perceptions of difficulty of obtaining/retaining crew, operating costs, profits, and optimism about the future.

		Crew						Costs						Profits						Optimism						
		Much Less	Less	Same	More	Much More	No Answer	Much Less	Less	Same	More	Much More	No Answer	Much Less	Less	Same	More	Much More	No Answer	Much Less	Less	Same	More	Much More	No Answer	TOTAL
Area	1	1	1	17	4	1	1	0	0	10	11	3	1	5	7	9	3	0	1	6	6	8	3	1	1	25
	2	1	3	11	5	0	1	0	1	9	9	1	1	1	10	6	3	0	1	1	8	6	5	0	1	21
	3	0	1	11	1	2	1	0	1	5	6	4	0	3	6	4	3	0	0	5	2	5	2	2	0	16
	4	1	3	11	2	1	0	0	1	5	9	3	0	3	4	7	4	0	0	5	3	5	4	1	0	18
	5	0	0	16	4	1	0	0	3	8	8	2	0	1	10	7	3	0	0	1	6	10	4	0	0	21
	6a	2	3	18	6	0	0	0	3	13	11	2	0	2	12	11	4	0	0	2	7	13	7	0	0	29
	6b	0	2	31	9	1	1	0	7	21	13	3	0	4	16	18	6	0	0	5	10	15	14	0	0	44
	7	1	4	27	6	1	4	0	1	16	21	4	1	5	20	11	6	0	1	5	14	13	9	1	1	43
	8	2	2	22	1	0	15	0	2	17	18	0	5	7	12	14	5	0	4	9	11	16	2	0	4	42
	9	0	0	10	2	0	4	0	0	5	9	1	1	2	8	4	1	0	1	3	4	8	0	0	1	16
Species	Cod	3	11	103	23	4	23	0	10	65	70	14	8	25	57	55	23	0	7	33	42	53	28	4	7	167
	Haddock	3	7	64	12	2	5	0	3	39	41	7	3	14	29	33	15	0	2	20	20	33	14	4	2	93
	Whiting	4	8	67	17	4	4	0	9	43	40	11	1	17	32	38	16	0	1	24	25	31	19	4	1	104
	Saithe	4	6	51	10	2	6	0	3	33	34	6	3	15	23	24	15	0	2	21	16	25	11	4	2	79
	Monkfish	3	7	63	10	2	4	0	4	40	39	5	1	10	32	29	17	0	1	16	22	29	17	4	1	89
	Nephrops	2	3	36	10	1	2	0	4	18	27	5	0	10	17	19	8	0	0	12	15	17	7	3	0	54
	Sole	3	5	77	17	3	13	0	9	42	53	10	4	19	40	41	15	0	3	26	30	34	21	3	4	118
	Plaice	4	10	98	21	5	19	0	10	61	70	12	4	23	55	55	21	0	3	31	38	52	28	4	4	157
Gear	Otter Tr.	2	4	34	8	2	4	0	1	22	25	5	1	10	18	17	8	0	1	14	15	18	6	1	0	54
	Neph. Tr.	2	2	18	2	1	1	0	3	8	13	2	0	4	7	10	5	0	0	6	5	9	4	2	0	26
	Beam Tr.	0	0	14	6	0	0	0	2	11	6	1	0	1	6	12	1	0	0	1	3	10	6	0	0	20
	Pulse Tr.	1	2	16	0	0	0	0	4	10	5	0	0	0	4	11	4	0	0	0	6	7	6	0	0	19
	Gill Nets	0	1	19	7	2	18	0	1	10	24	6	6	10	21	7	4	0	5	12	14	8	7	0	6	47
	Seine	0	2	7	1	0	1	0	1	6	2	1	1	1	5	2	2	0	1	0	3	5	1	1	1	11
Size	<15m	2	2	28	6	1	22	0	2	15	31	6	7	14	24	12	5	0	6	17	16	15	6	1	6	61
	15-24m	1	2	40	9	4	1	0	3	21	26	7	0	8	21	19	9	0	0	12	19	15	9	2	0	57
	>24m	2	7	39	9	0	1	0	7	30	18	2	1	4	16	28	9	0	1	4	11	26	15	1	1	58
	Not Stat.	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1

Species Accounts

One hundred and seventy seven (177) valid responses were received that provided information on at least one species in at least one area. Most responses provided information on several species, but most responses provided information on just one or two areas (Figure 11).

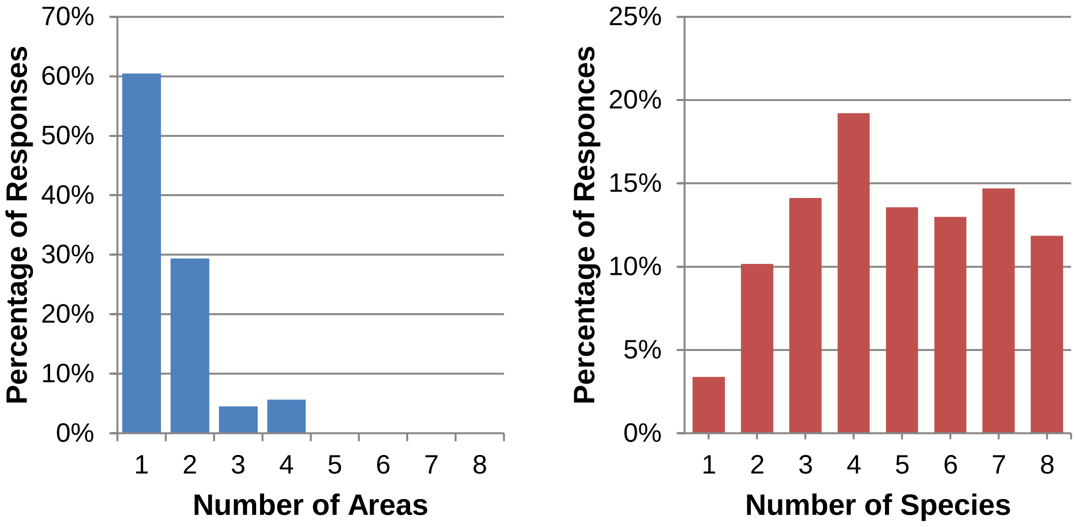


Figure 11 The proportions of responses providing information on different numbers of areas (left) and species (right).

A more detailed breakdown of responses by species and areas is provided in Table 11. Eight species and 10 areas provides a total of 80 possible species-area combinations. The number of responses per species-area combination varied from one to 40, with an average of 14. To reduce the potential for small numbers of responses to markedly skew the results, species-area combinations with less than three responses were omitted from the analyses. This affected five of the 80 species-area combinations in 2014 (Table 11), substantially fewer than in 2013. No area had more than one species with fewer than three responses, and saithe and common sole were the only species to have fewer than three responses in more than one area.

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Table 11 The numbers of responses by area and species. Species-areas combinations with less than three responses (bracketed) were omitted from the analyses.

	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6a	Area 6b	Area 7	Area 8	Area 9	TOTAL
Number of responses for each species from each area:											
Cod	25	16	14	15	13	11	34	36	38	15	167
Haddock	23	11	15	16	5	(2)	3	19	24	6	93
Whiting	20	9	13	17	15	10	30	5	12	3	104
Saithe	24	13	10	9	(2)	4	(1)	19	21	3	79
Monkfish	21	14	10	14	8	7	3	18	19	3	89
Nephrops	5	4	8	13	3	7	3	9	14	5	54
Common Sole	(2)	(2)	4	11	18	11	40	13	21	13	118
Plaice	17	16	9	14	13	25	29	40	34	9	157
TOTAL	25	21	16	18	21	29	44	43	42	16	275
% of responses from each area for each species:											
Cod	100%	76%	88%	83%	62%	38%	77%	84%	90%	94%	79%
Haddock	92%	52%	94%	89%	24%	7%	7%	44%	57%	38%	45%
Whiting	80%	43%	81%	94%	71%	34%	68%	12%	29%	19%	49%
Saithe	96%	62%	63%	50%	10%	14%	2%	44%	50%	19%	39%
Monkfish	84%	67%	63%	78%	38%	24%	7%	42%	45%	19%	43%
Nephrops	20%	19%	50%	72%	14%	24%	7%	21%	33%	31%	26%
Common Sole	8%	10%	25%	61%	86%	38%	91%	30%	50%	81%	49%
Plaice	68%	76%	56%	78%	62%	86%	66%	93%	81%	56%	75%
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% of responses for each species from each area:											
Cod	12%	7%	6%	7%	6%	5%	16%	17%	18%	7%	100%
Haddock	19%	9%	12%	13%	4%	2%	2%	15%	19%	5%	100%
Whiting	15%	7%	10%	13%	11%	7%	22%	4%	9%	2%	100%
Saithe	23%	12%	9%	8%	2%	4%	1%	18%	20%	3%	100%
Monkfish	18%	12%	9%	12%	7%	6%	3%	15%	16%	3%	100%
Nephrops	7%	6%	11%	18%	4%	10%	4%	13%	20%	7%	100%
Common Sole	1%	1%	3%	8%	13%	8%	30%	10%	16%	10%	100%
Plaice	8%	8%	4%	7%	6%	12%	14%	19%	17%	4%	100%
TOTAL	9%	8%	6%	7%	8%	11%	16%	16%	15%	6%	100%

Cod

Of the 177 valid responses received, 167 (94%) provided information on cod. The proportion of responses providing information on cod was lowest – at 38% – in the south-eastern North Sea (area 6a), but relatively high throughout most of the area covered by the survey (Figure 12).

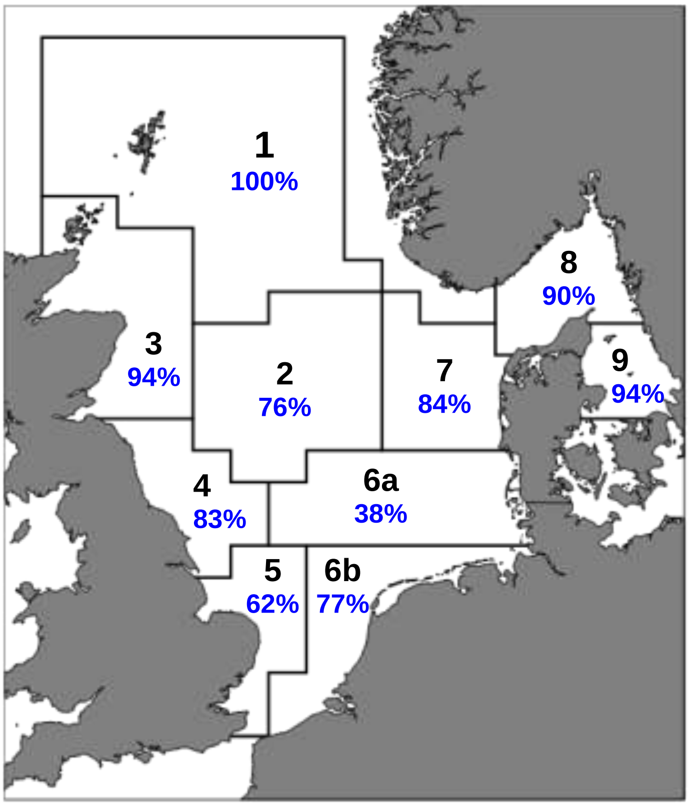

Figure 12 The proportions of responses from each area that provided information on cod.

Table 12 shows the responses broken down by fishing gear and vessel size class. Responses were roughly equally split between the three vessel size classes. Of the fishing gears, the otter trawl accounted for almost one-third of responses and gill nets about one quarter. Figure 13 and Figure 14 provide a more detailed breakdown of the responses for cod by vessel size and fishing gear.

Table 12 Numbers of responses for cod by fishing gear type and vessel size class. Percentages show % of vessels in each size class using each gear type (at right), and % of vessels using each gear type in each size class (at bottom). (Excludes vessels that did not provide information on fishing gear and/or vessel size class.)

FISHING GEAR		Numbers <15m	Numbers 15-24m	Numbers >24m	Numbers ALL	% by Gear Type <15m	% by Gear Type 15-24m	% by Gear Type >24m	% by Gear Type ALL
Numbers	Otter Trawl	13	20	19	**52**	22%	38%	36%	31%
	Nephrops Trawl	8	16	1	**25**	13%	30%	2%	15%
	Beam Trawl	0	6	13	**19**	0%	11%	25%	11%
	Pulse Trawl	0	1	14	**15**	0%	2%	26%	9%
	Gill Net	39	5	0	**44**	65%	9%	0%	27%
	Seine Net	0	5	6	**11**	0%	9%	11%	7%
	ALL	**60**	**53**	**53**	**166**	100%	100%	100%	100%
% by Size	Otter Trawl	25%	38%	37%	100%				
	Nephrops Trawl	32%	64%	4%	100%				
	Beam Trawl	0%	32%	68%	100%				
	Pulse Trawl	0%	7%	93%	100%				
	Gill Net	89%	11%	0%	100%				
	Seine Net	0%	45%	55%	100%				
	ALL	36%	32%	32%	100%				

Table 13 Summary of perceptions of the abundance, size, level of discarding and level of recruitment of cod this year and last year. Proportion of responses in each category for all areas combined this year and last year, and change in proportions (+/-).

Abundance	2013	2014	+/-	Fish Size	2013	2014	+/-
'Less' [1]	27%	13%	-14%	Mostly Small	12%	13%	+2%
No Change	31%	27%	-4%	All Sizes	81%	82%	+1%
'More' [2]	41%	60%	+19%	Mostly Large	8%	4%	-3%
Discards	**2013**	**2014**	**+/-**	**Recruitment**	**2013**	**2014**	**+/-**
'Less' [1]	27%	17%	-9%	Low	15%	14%	-1%
No Change	53%	53%	+1%	Moderate	49%	47%	-2%
'More' [2]	21%	29%	+9%	High	36%	40%	+3%

[1] 'Less' = sum of 'Less' and 'Much Less' responses.
[2] 'More' = sum of 'More' and 'Much More' responses.

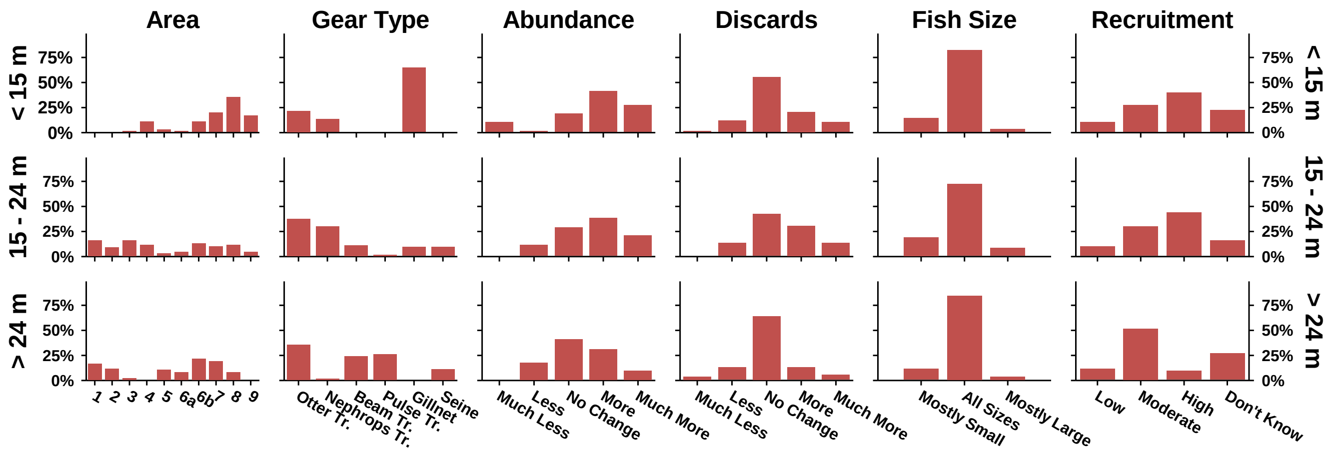

Figure 13 Breakdown of responses for cod by fishing vessel size class. Percentage of responses for each size class in each category.

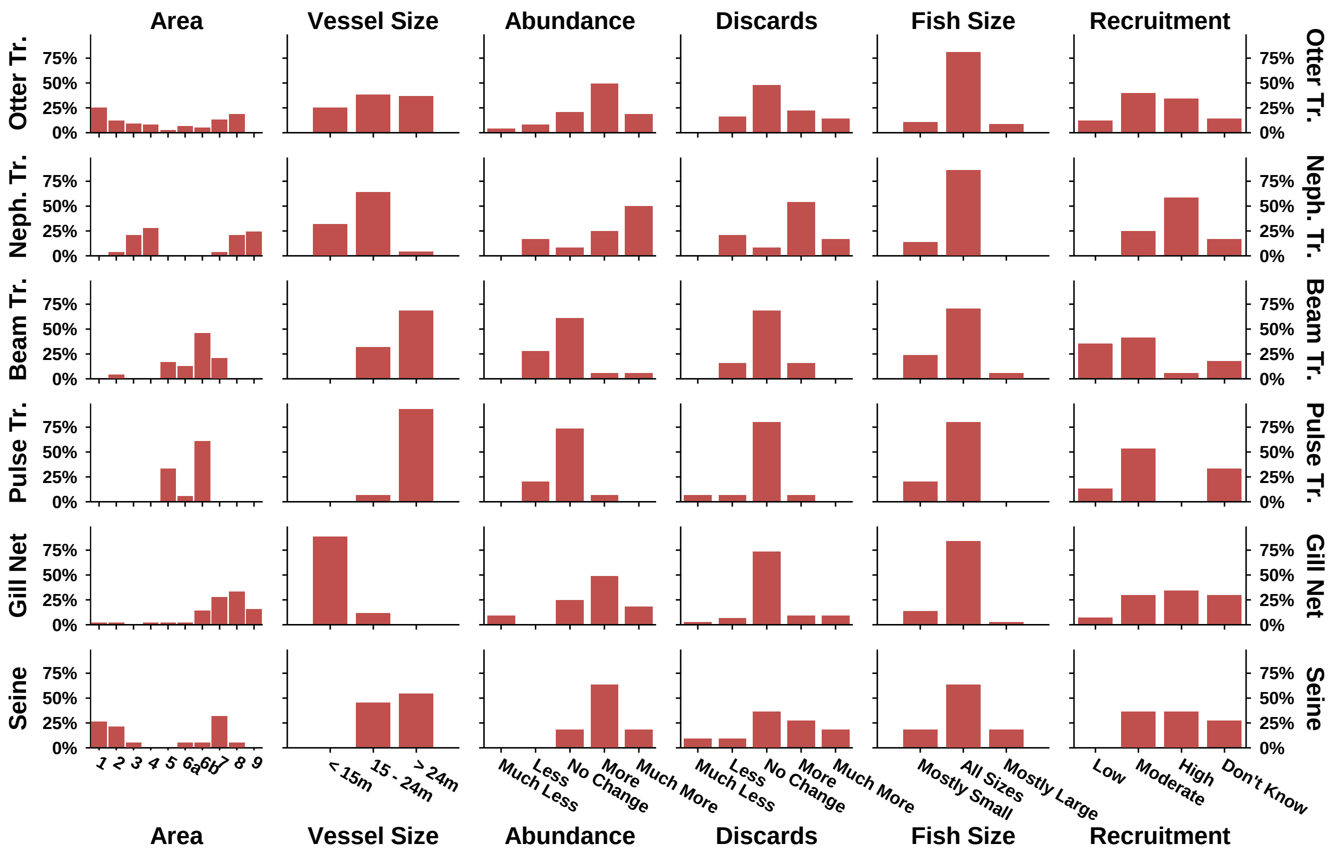

Figure 14 Breakdown of responses for cod by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

Abundance

Overall, 60% of responses reported that cod were more abundant in 2014 (Table 13), a substantial increase from 2013. More than one-quarter reported no change in the abundance of cod in 2014, slightly less than in 2013, while there was a fairly large fall in the proportion reporting less cod.

By area, the proportions reporting greater abundances of cod were highest in the north and east (areas 1, 8 & 9) while the proportions reporting lower abundances were highest in the south and east (areas 4 & 6b) (Figure 16).

The cumulative index of perceptions of the abundance of cod increased in most areas (Figure 17), except the south and east (areas 4 & 6b).

Size Range

Perceptions of the size range of cod in 2014 were similar to those in 2013, with the majority reporting catching all sizes (Table 13). Most of the balance reported catching mostly small cod, a small increase from 2013, while there was a small decrease in the proportion reporting mostly large cod.

The picture was broadly similar across all areas, with the majority of responses in each reporting all sizes of cod (Figure 16). The biggest proportions reporting mostly small cod were in the south west (areas 4, 5 & 6b).

Discards

About half of responses reported no change in the level of discarding of cod in 2014 (Table 13), almost unchanged from 2013. Of the balance, more responses reported a higher level of discards, with a marked increase from 2013, while there was a comparable fall in the proportion reporting lower levels of cod discarding in 2014.

Across individual areas the proportions reporting no change in the levels of discards of cod tend to be highest in the central and south eastern North Sea (areas 2, 5, 6a, 6b, 7 & 8) (Figure 16), while the proportions reporting higher levels of discards tended to be highest in the north and west (areas 1 & 3), and the Kattegat (area 9).

Recruitment

Almost half of responses reported moderate levels of recruitment of cod in 2014 while a somewhat smaller proportion reported high levels of recruitment (Table 13). These levels of response were little changed from 2013.

No clear patterns was apparent in the responses across individual areas (Figure 16).

Comparison with ICES Stock Assessment

There was some agreement between the cod abundance index derived from the Fishers' North Sea Stock Survey and the ICES estimates of the North Sea cod spawning stock biomass, but the relationship was statistically weak (Figure 15).

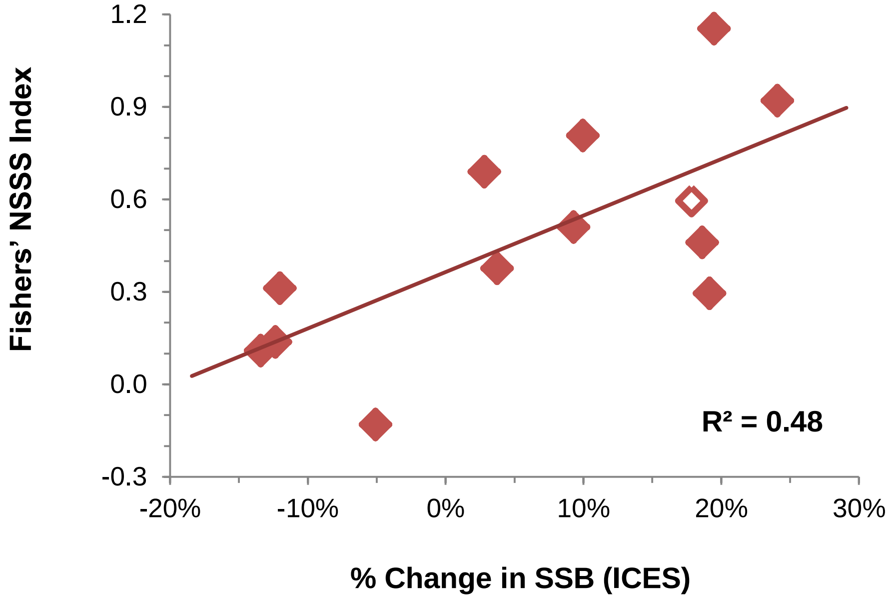

Figure 15 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea cod spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination (R^2; values closer to 1 indicate a better agreement.) The unshaded point is based on the predicted year SSB for 2015.

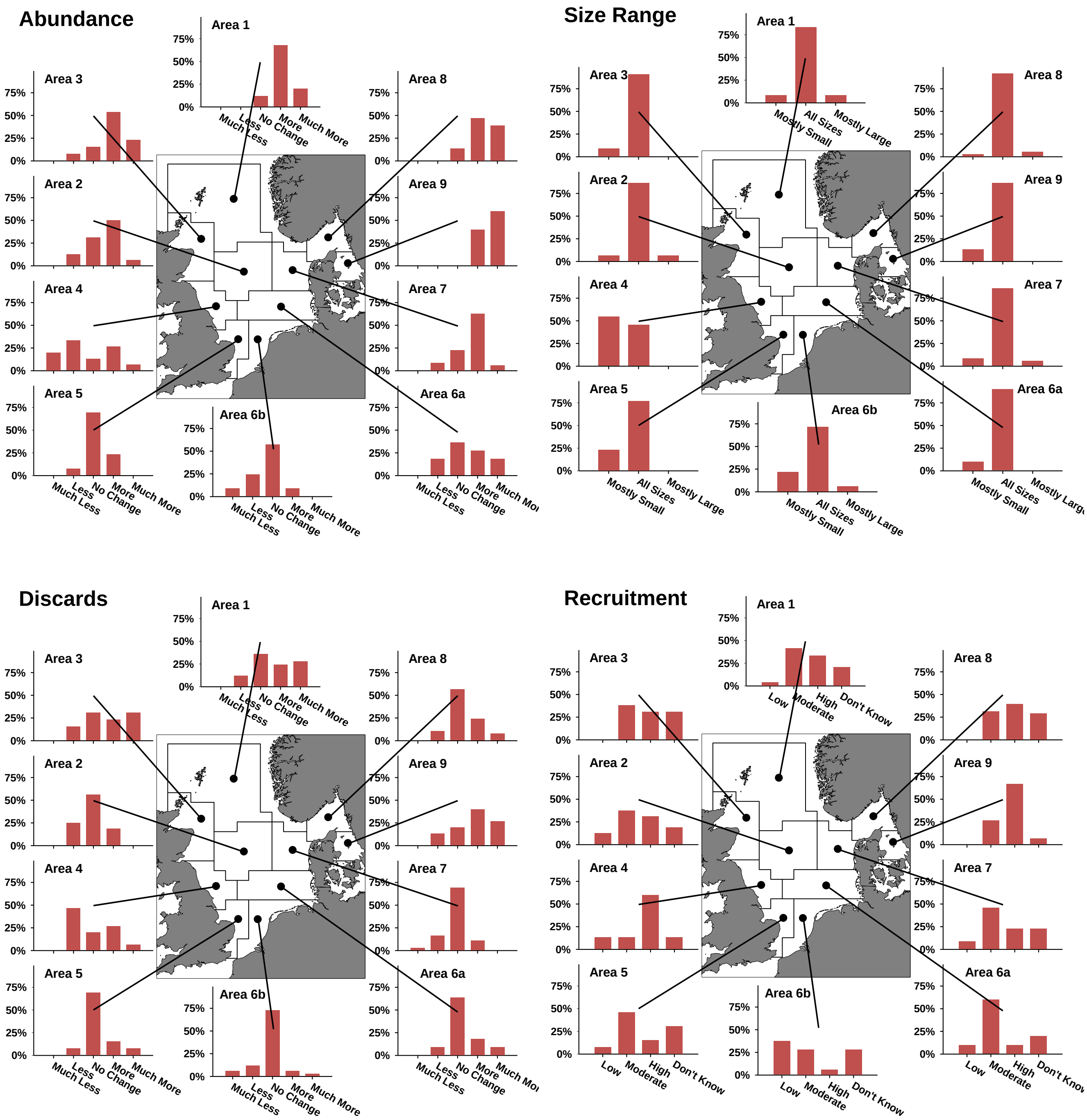

Figure 16 Perceptions of the abundance and size range of cod, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category.

Abundance Index

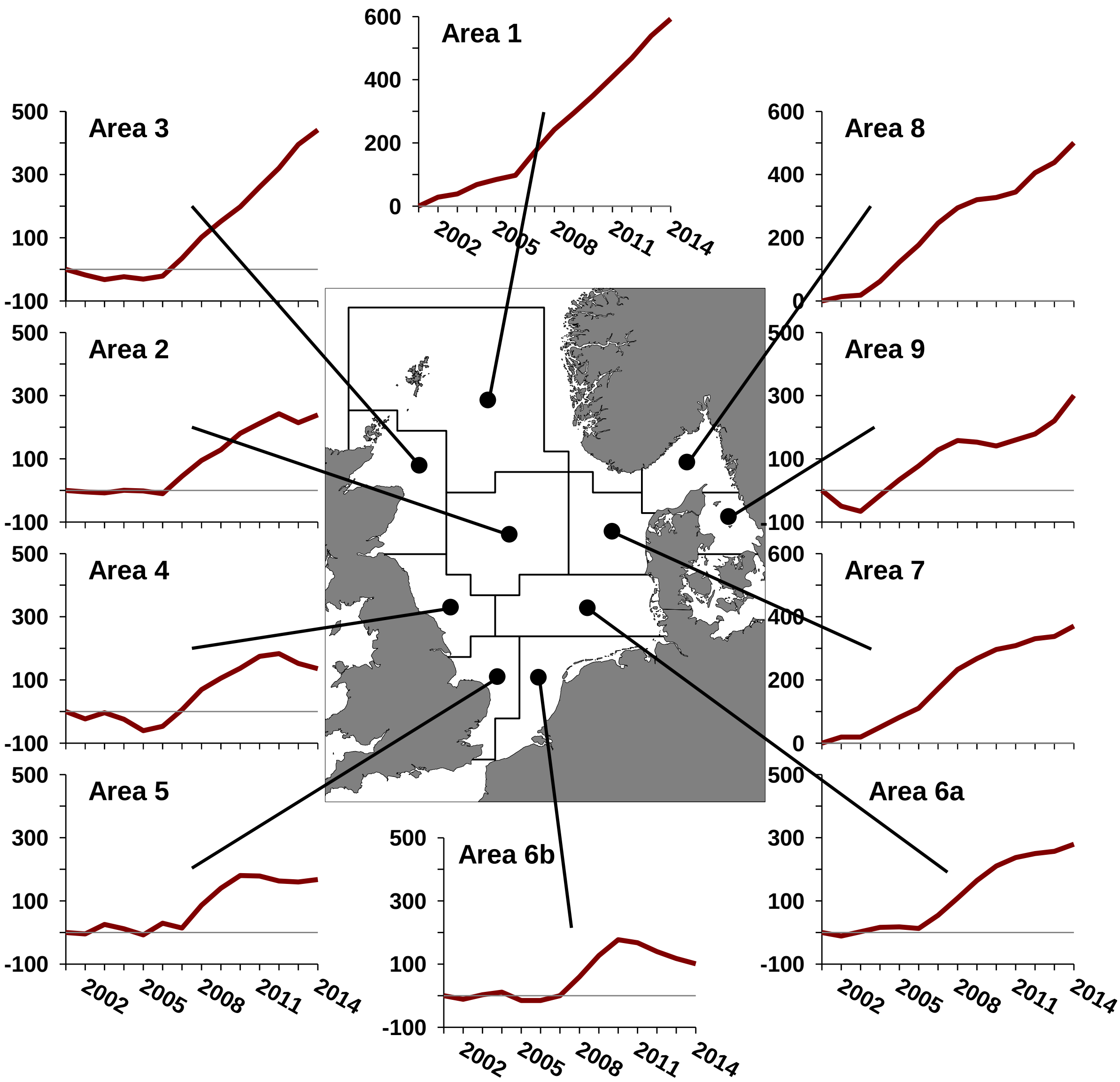

Figure 17 Cumulative time series of index of perceptions of abundance of cod, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

Table 14 Numbers of responses by area and category for perceptions of the abundance, size, level of discarding and level of recruitment of cod.

	Area									
	1	**2**	**3**	**4**	**5**	**6a**	**6b**	**7**	**8**	**9**
Number	25	16	14	15	13	11	34	36	38	15
Abundance										
Much Less	0	0	0	3	0	0	3	0	0	0
Less	0	2	1	5	1	2	8	3	0	0
No Change	3	5	2	2	9	4	19	8	5	0
More	17	8	7	4	3	3	3	22	17	6
Much More	5	1	3	1	0	2	0	2	14	9
No Answer	0	0	1	0	0	0	1	1	2	0
Size										
Mostly Small	2	1	1	6	3	1	7	3	1	2
All Sizes	20	13	10	5	10	9	23	30	34	13
Mostly Large	2	1	0	0	0	0	2	2	2	0
No Answer	1	1	3	4	0	1	2	1	1	0
Discards										
Much Less	0	0	0	0	0	0	2	1	0	0
Less	3	4	2	7	1	1	4	6	4	2
No Change	9	9	4	3	9	7	24	25	21	3
More	6	3	3	4	2	2	2	4	9	6
Much More	7	0	4	1	1	1	1	0	3	4
No Answer	0	0	1	0	0	0	1	0	1	0
Recruitment										
Low	1	2	0	2	1	1	12	3	0	0
Moderate	10	6	5	2	6	6	9	16	12	4
High	8	5	4	9	2	1	2	8	15	10
Don't Know	5	3	4	2	4	2	9	8	11	1
No Answer	1	0	1	0	0	1	2	1	0	0

Haddock

Of the 177 valid responses received, 93 (53%) provided information on haddock. The proportion of responses providing information on haddock was lowest in the south-eastern North Sea (areas 6a & 6b), and highest in the north and west (areas 1, 3 & 4) (Figure 18).

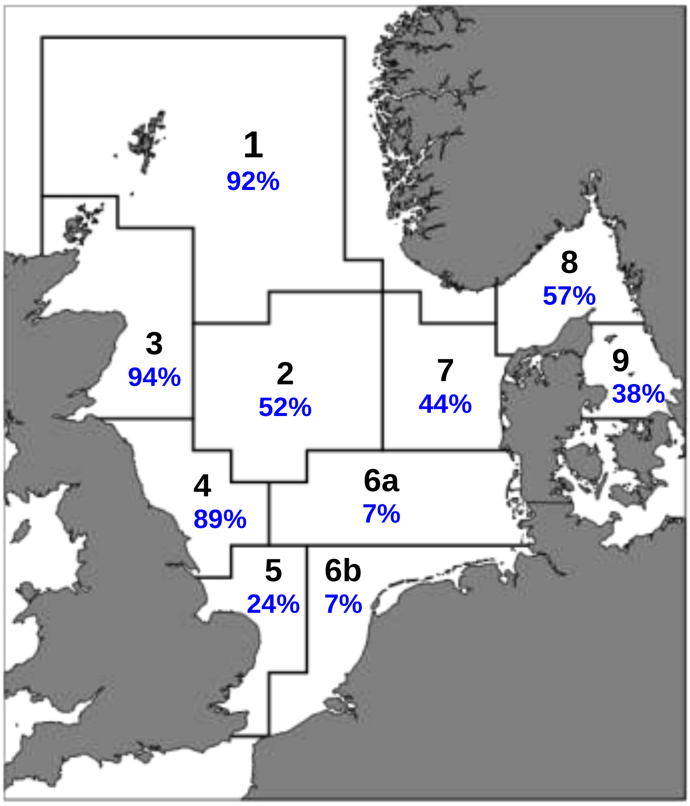

Figure 18 The proportions of responses from each area that provided information on haddock.

Table 15 shows the responses broken down by fishing gear and vessel size class. The largest proportion of responses was from medium-sized (15-24m) fishing vessels, and the smallest proportion from small (<15m) vessels. Of the fishing gears, the otter trawl accounted for the largest proportion of the responses followed by the *Nephrops* trawl, and the beam trawl and pulse trawl least.

Figure 19 and Figure 20 provide a more detailed breakdown of the responses for haddock by vessel size and fishing gear.

Table 15 Numbers of responses for haddock by fishing gear type and vessel size class. Percentages show % of vessels in each size class using each gear type (at right), and % of vessels using each gear type in each size class (at bottom). (Excludes vessels that did not provide information on fishing gear and/or vessel size class.)

FISHING GEAR		VESSEL SIZE CLASS: Numbers <15m	15-24m	>24m	ALL	% by Gear Type <15m	15-24m	>24m	ALL
Numbers	Otter Trawl	6	16	16	**38**	26%	41%	53%	41%
	***Nephrops* Trawl**	8	15	0	**23**	35%	38%	0%	25%
	Beam Trawl	0	1	7	**8**	0%	3%	23%	9%
	Pulse Trawl	0	1	2	**3**	0%	3%	7%	3%
	Gill Net	9	1	0	**10**	39%	3%	0%	11%
	Seine Net	0	5	5	**10**	0%	13%	17%	11%
	ALL	**23**	**39**	**30**	**92**	100%	100%	100%	100%
% by Size	**Otter Trawl**	16%	42%	42%	100%				
	***Nephrops* Trawl**	35%	65%	0%	100%				
	Beam Trawl	0%	13%	88%	100%				
	Pulse Trawl	0%	33%	67%	100%				
	Gill Net	90%	10%	0%	100%				
	Seine Net	0%	50%	50%	100%				
	ALL	25%	42%	33%	100%				

Table 16 Summary of perceptions of the abundance, size, level of discarding and level of recruitment of haddock this year and last year. Proportion of responses in each category for all areas combined this year and last year, and change in proportions (+/-).

Abundance	**2013**	**2014**	**+/-**	**Fish Size**	**2013**	**2014**	**+/-**
'Less' [1]	23%	14%	-9%	**Mostly Small**	22%	13%	-9%
No Change	42%	44%	+2%	**All Sizes**	72%	87%	+15%
'More' [2]	35%	42%	+7%	**Mostly Large**	6%	0%	-6%
Discards	**2013**	**2014**	**+/-**	**Recruitment**	**2013**	**2014**	**+/-**
'Less' [1]	25%	13%	-11%	**Low**	23%	15%	-7%
No Change	65%	78%	+14%	**Moderate**	51%	52%	+1%
'More' [2]	11%	8%	-2%	**High**	26%	32%	+7%

[1] 'Less' = sum of 'Less' and 'Much Less' responses.
[2] 'More' = sum of 'More' and 'Much More' responses.

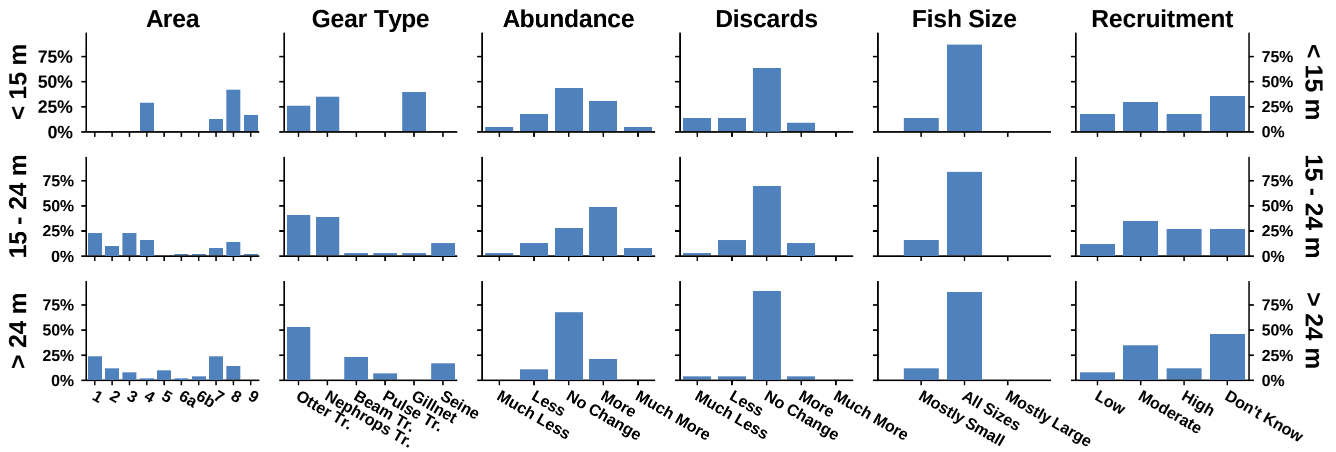

Figure 19 Breakdown of responses for haddock by fishing vessel size class. Percentage of responses for each size class in each category.

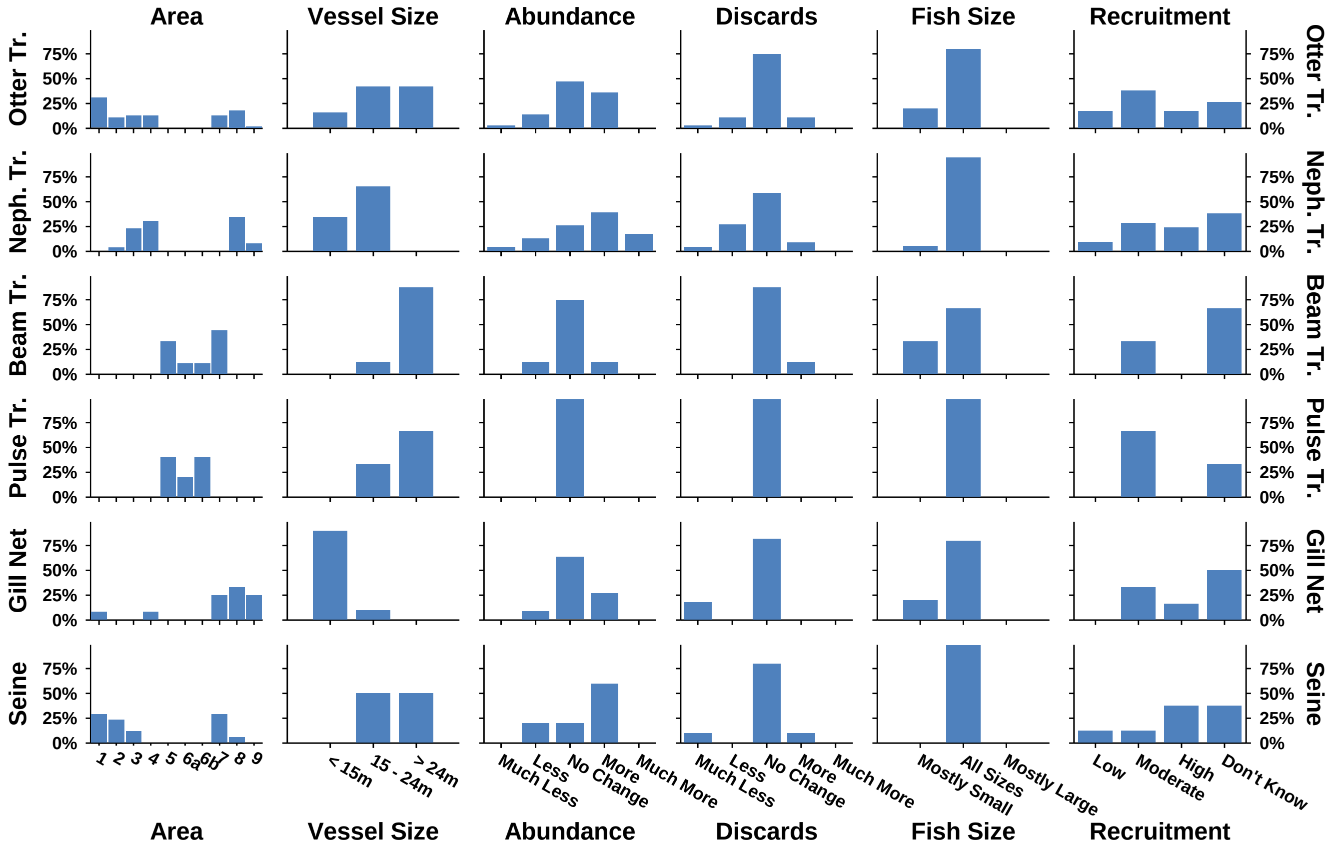

Figure 20 Breakdown of responses for haddock by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

Abundance

Roughly equal proportions of responses reported no change and an increase in the abundance of haddock in 2014 (Table 16), with small increases in both from 2013, especially in the proportion reporting more haddock. There was a similar fall from 2013 in the proportion reporting less haddock.

The proportions reporting a greater abundance of haddock tended to be highest in the northern part of the North Sea (including areas 1, 2, 3, 8 & 9; Figure 22). The highest proportion reporting a lower abundance was in the west (area 4) while no change was most commonly reported in the south.

The cumulative index of perceptions of the abundance of haddock increased in most areas (Figure 23), the exceptions being in the west (area 4) where it declined, and the south (areas 6a & 6b) where it remained unchanged.

Size Range

Well over three-quarters of responses reported catching all sizes of haddock in 2014 (Table 16), a marked increase from 2013. All the remaining responses reported catching mostly small haddock, although this proportion was less than in 2013.

Most responses reported catching all sizes of haddock in most areas (Figure 22).

Discards

More than three-quarters of responses reported no change in the level of discarding of haddock in 2014 (Table 16), a marked increase from 2013. Of the remainder, slightly more reported lower levels of discards, a marked decrease from 2013.

Across most areas the majority of responses reported no change in levels of discarding of haddock (Figure 22). The highest proportions reporting lower levels of discarding of haddock were in the extreme west and east (areas 4 & 9), while the highest proportion reporting higher levels was in the central North Sea (area 2).

Recruitment

Half of all responses reported moderate levels of recruitment of haddock in 2014, and one-third reported high levels (Table 16), with a small increase in the latter from 2013. There was a small fall in the proportion reporting low levels of recruitment

In general, the proportion of responses reporting high levels of recruitment tended to be greatest in the north (areas 1, 2, 3 & 8).

Comparison with ICES Stock Assessment

There was little agreement between the haddock abundance index derived from the Fishers' North Sea Stock Survey and the ICES estimates of the North Sea haddock spawning stock biomass (Figure 21).

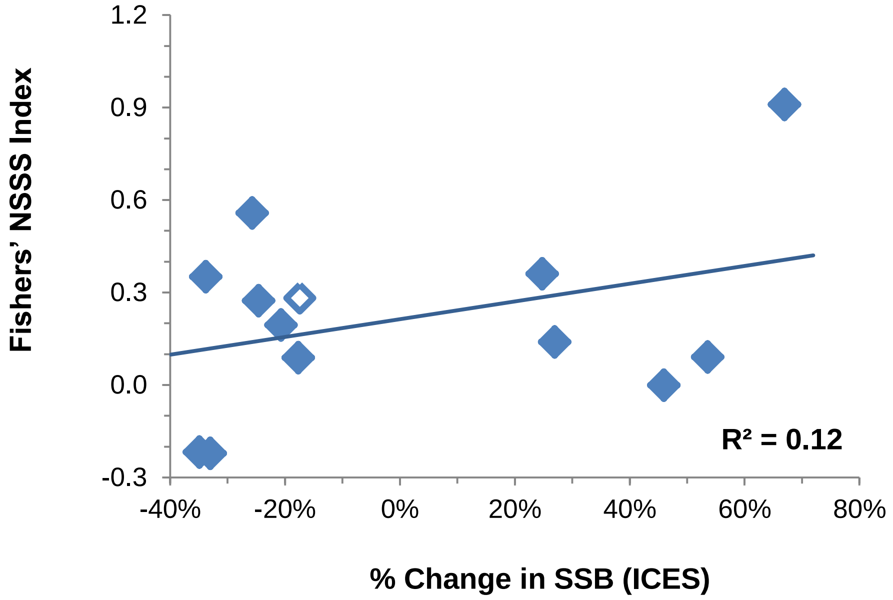

Figure 21 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea haddock spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination (R^2; values closer to 1 indicate a better agreement). The unshaded point is based on the predicted SSB for 2015.

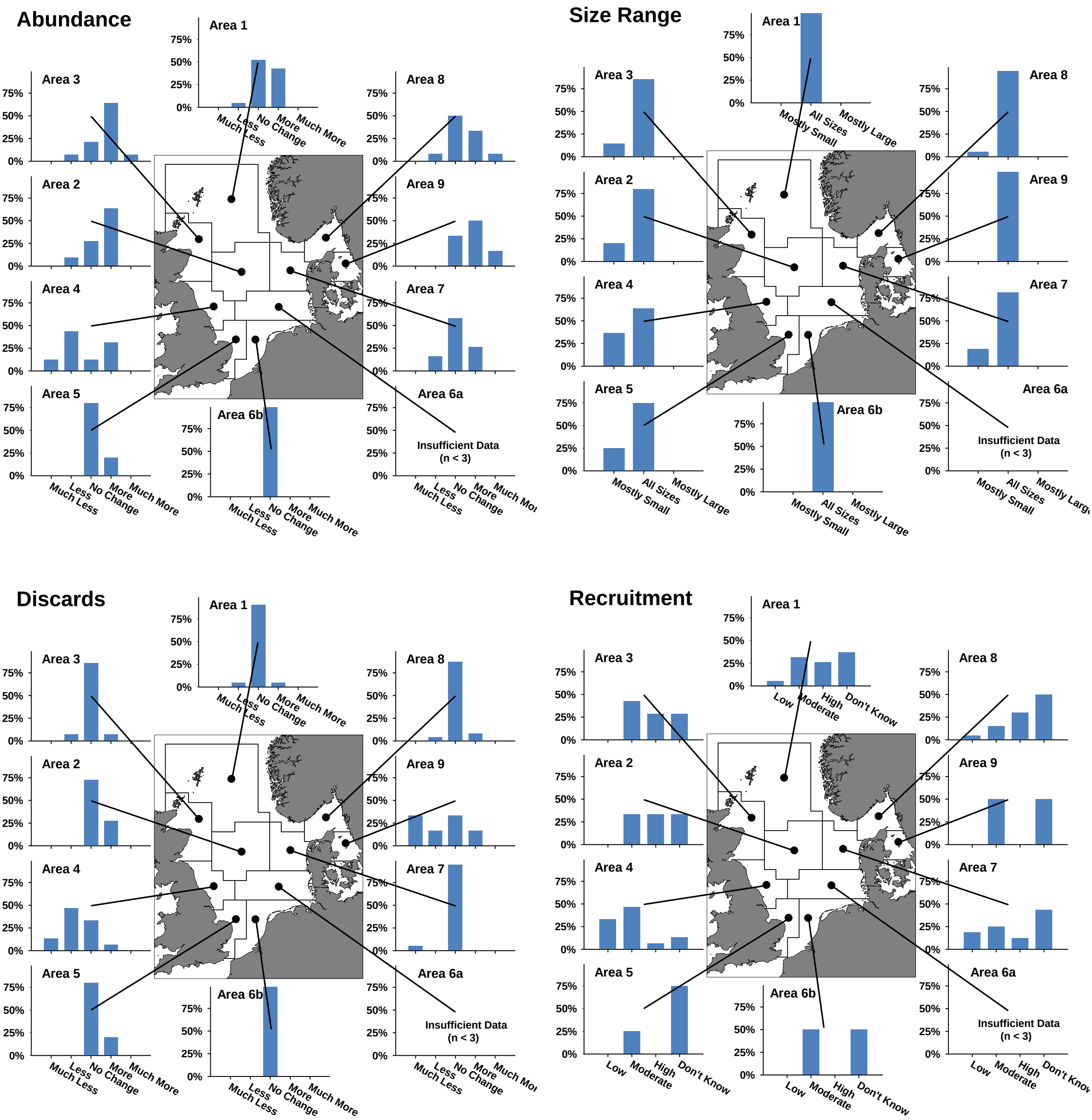

Figure 22 Perceptions of the abundance and size range of haddock, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category. No results are shown for Area 6a due to the small number of responses from that area (see Table 11, p. 28).

Abundance Index

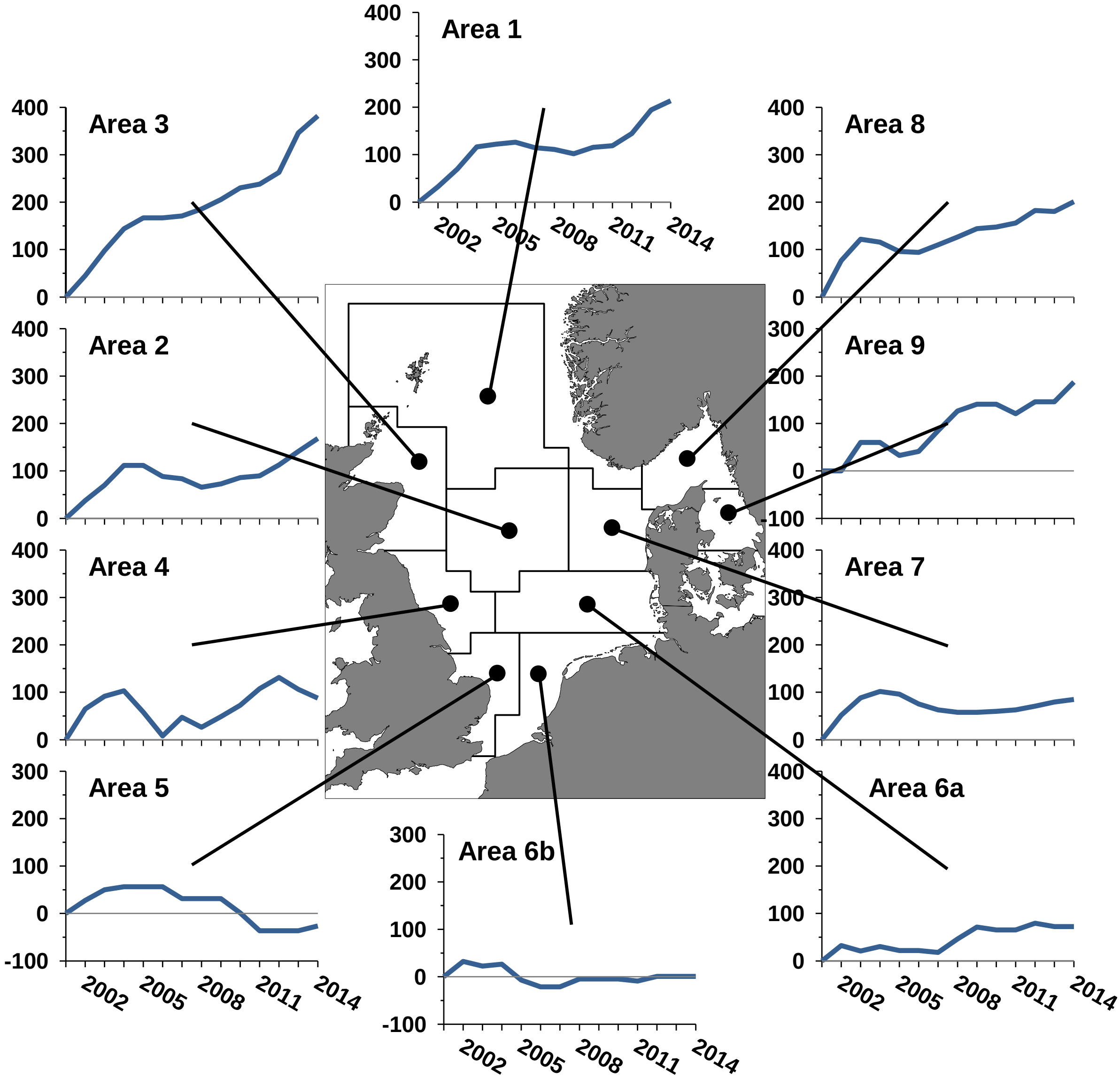

Figure 23 Cumulative time series of index of perceptions of abundance of haddock, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

Table 17 Numbers of responses by area and category for perceptions of the abundance, size, level of discarding and level of recruitment of haddock.

	Area									
	1	**2**	**3**	**4**	**5**	**6a**	**6b**	**7**	**8**	**9**
Number	23	11	15	16	5	2	3	19	24	6
Abundance										
Much Less	0	0	0	2	0	0	0	0	0	0
Less	1	1	1	7	0	0	0	3	2	0
No Change	11	3	3	2	4	2	3	11	12	2
More	9	7	9	5	1	0	0	5	8	3
Much More	0	0	1	0	0	0	0	0	2	1
No Answer	2	0	1	0	0	0	0	0	0	0
Size										
Mostly Small	0	2	2	4	1	0	0	3	1	0
All Sizes	17	8	12	7	3	1	2	13	18	5
Mostly Large	0	0	0	0	0	0	0	0	0	0
No Answer	6	1	1	5	1	1	1	3	5	1
Discards										
Much Less	0	0	0	2	0	0	0	1	0	2
Less	1	0	1	7	0	0	0	0	1	1
No Change	19	8	12	5	4	2	3	18	21	2
More	1	3	1	1	1	0	0	0	2	1
Much More	0	0	0	0	0	0	0	0	0	0
No Answer	2	0	1	1	0	0	0	0	0	0
Recruitment										
Low	1	0	0	5	0	0	0	3	1	0
Moderate	6	3	6	7	1	0	1	4	3	3
High	5	3	4	1	0	0	0	2	6	0
Don't Know	7	3	4	2	3	1	1	7	10	3
No Answer	4	2	1	1	1	1	1	3	4	0

Whiting

Of the 177 valid questionnaires received, 104 (59%) provided information on whiting. The proportion of responses providing information on whiting was lowest in central and eastern areas (areas 2, 7, 8 & 9), and highest in the north and west (areas 1, 3, 4 & 5) (Figure 24).

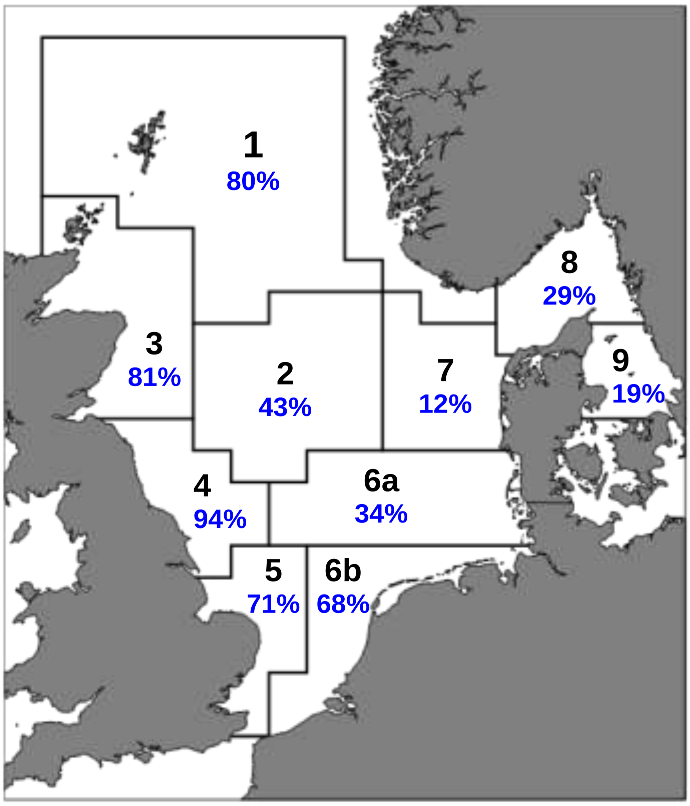

Figure 24 The proportions of responses from each area that provided information on whiting.

Table 18 shows the responses broken down by fishing gear and vessel size class. Equal proportions of responses were received from medium-sized (15-24m) and larger (>24m) vessels, with the smallest proportion from small (<15m) vessels. Of the fishing gears, otter trawls accounted for the largest proportions of responses, followed by *Nephrops* trawls and beam trawls.

Figure 25 and Figure 26 provide a more detailed breakdown of the responses for whiting by vessel size and fishing gear.

Table 18 Numbers of responses for whiting by fishing gear type and vessel size class. Percentages show % of vessels in each size class using each gear type (at right), and % of vessels using each gear type in each size class (at bottom). (Excludes vessels that did not provide information on fishing gear and/or vessel size class.)

FISHING GEAR		VESSEL SIZE CLASS: Numbers <15m	15-24m	>24m	ALL	% by Gear Type <15m	15-24m	>24m	ALL
Numbers	Otter Trawl	6	16	13	**35**	29%	39%	32%	34%
	***Nephrops* Trawl**	5	15	1	**21**	24%	37%	2%	20%
	Beam Trawl	0	5	12	**17**	0%	12%	29%	17%
	Pulse Trawl	0	1	12	**13**	0%	2%	29%	13%
	Gill Net	10	1	0	**11**	48%	2%	0%	11%
	Seine Net	0	3	3	**6**	0%	7%	7%	6%
	ALL	**21**	**41**	**41**	**103**	100%	100%	100%	100%
% by Size	**Otter Trawl**	17%	46%	37%	100%				
	***Nephrops* Trawl**	24%	71%	5%	100%				
	Beam Trawl	0%	29%	71%	100%				
	Pulse Trawl	0%	8%	92%	100%				
	Gill Net	91%	9%	0%	100%				
	Seine Net	0%	50%	50%	100%				
	ALL	20%	40%	40%	100%				

Table 19 Summary of perceptions of the abundance, size, level of discarding and level of recruitment of whiting this year and last year. Proportion of responses in each category this year and last year for all areas combined, and change in proportions (+/-).

Abundance	**2013**	**2014**	**+/-**	**Fish Size**	**2013**	**2014**	**+/-**
'Less' [1]	13%	21%	+8%	**Mostly Small**	13%	21%	+8%
No Change	55%	57%	+2%	**All Sizes**	88%	78%	-9%
'More' [2]	31%	22%	-9%	**Mostly Large**	0%	1%	+1%
Discards	**2013**	**2014**	**+/-**	**Recruitment**	**2013**	**2014**	**+/-**
'Less' [1]	16%	19%	+3%	**Low**	26%	19%	-7%
No Change	64%	66%	+1%	**Moderate**	42%	56%	+14%
'More' [2]	20%	16%	-4%	**High**	32%	24%	-8%

[1] 'Less' = sum of 'Less' and 'Much Less' responses.
[2] 'More' = sum of 'More' and 'Much More' responses.

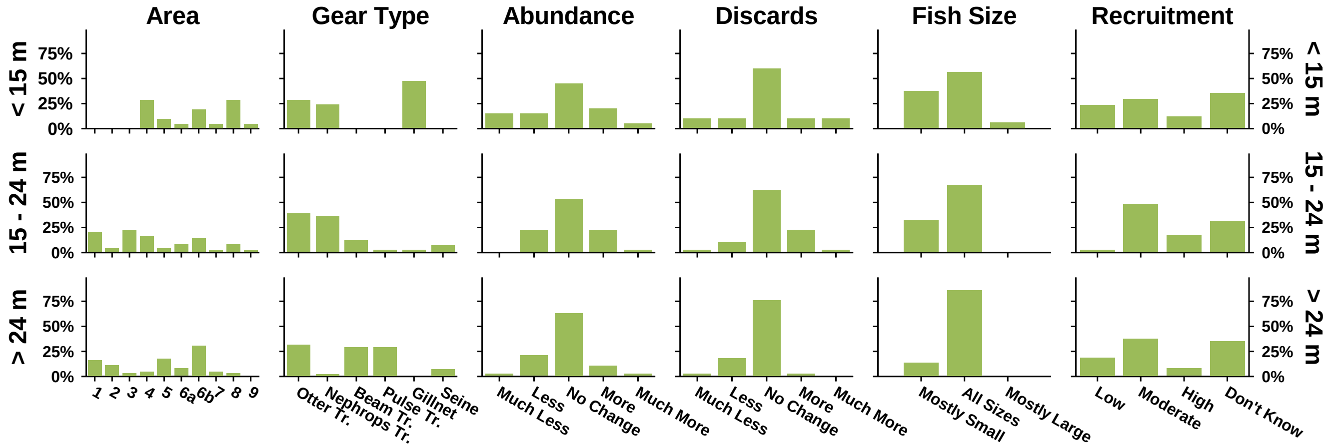

Figure 25 Breakdown of responses for whiting by fishing vessel size class. Percentage of responses for each size class in each category.

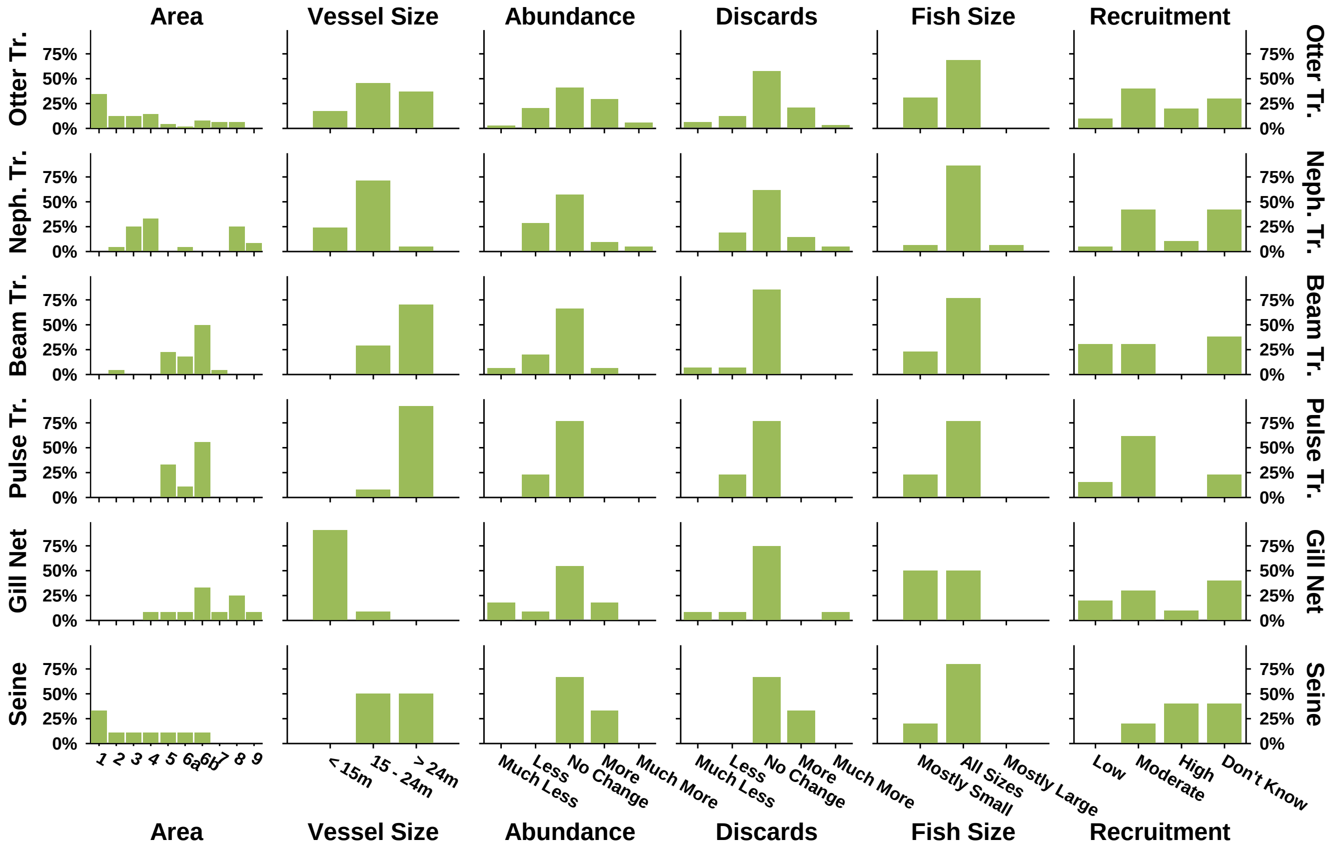

Figure 26 Breakdown of responses for whiting by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

Abundance

More than half of responses (57%) reported no change in the abundance of whiting in 2014, slightly more than in 2013 (Table 19). The remaining responses were roughly equally split between reporting increased and decreased abundances. There was a fall in the proportion reporting a higher abundance of whiting in 2014, matched by a similar increase in the proportion reporting a lower abundance.

Across individual areas the majority of responses reported no change in the abundance of whiting in all areas (Figure 28). The proportions reporting higher abundances of whiting tended to be highest in the north and west (areas 1, 2 & 3) while the proportions reporting lower abundances tended to be higher in the south and east (areas 4, 5, 6a, 6b & 9).

The cumulative index of perceptions of the abundance of whiting (Figure 29) increased in about half of the areas, mainly in the north and west (areas 1, 2 & 3) and east (areas 7 & 8), albeit mostly by relatively small amounts.

Size Range

More than three-quarters of responses reported all sizes of whiting in 2014 (Table 19), although this was less than in 2013. Almost all the remaining responses reported mostly small whiting, with an increase from 2013, while only a very small proportion reported mostly large whiting in 2014.

Across individual areas, reports of mostly small whiting tended to be more common in the south and east (areas 4, 5, 6b & 7) while reports of mostly large whiting were confined to the Kattegat (area 9) (Figure 29).

Discards

Two-thirds of responses reported no change in the level of whiting discards in 2014, almost unchanged from 2013 (Table 19). The remaining responses were roughly evenly split between reporting lower and higher levels of discards, with a small increase in the former and a similar decrease in the latter.

No change in whiting discards was the most frequent response across all individual areas (Figure 29), but no clear pattern was apparent in the distribution of responses reporting lower or higher levels of whiting discard.

Recruitment

More than half of responses reported a moderate level of recruitment in 2014 (Table 19), markedly more than in 2013. Almost one-quarter reported high levels of recruitment, with a small decrease from 2013 and a similar decrease in the proportion reporting mostly small whiting.

No clear pattern in responses on recruitment of whiting were apparent across individual areas (Figure 29).

Comparison with ICES Stock Assessment

There was some agreement between the abundance index derived from the Fishers' North Sea Stock Survey and the ICES estimates of the North Sea whiting spawning stock biomass (Figure 27), although the relationship was statistically weak.

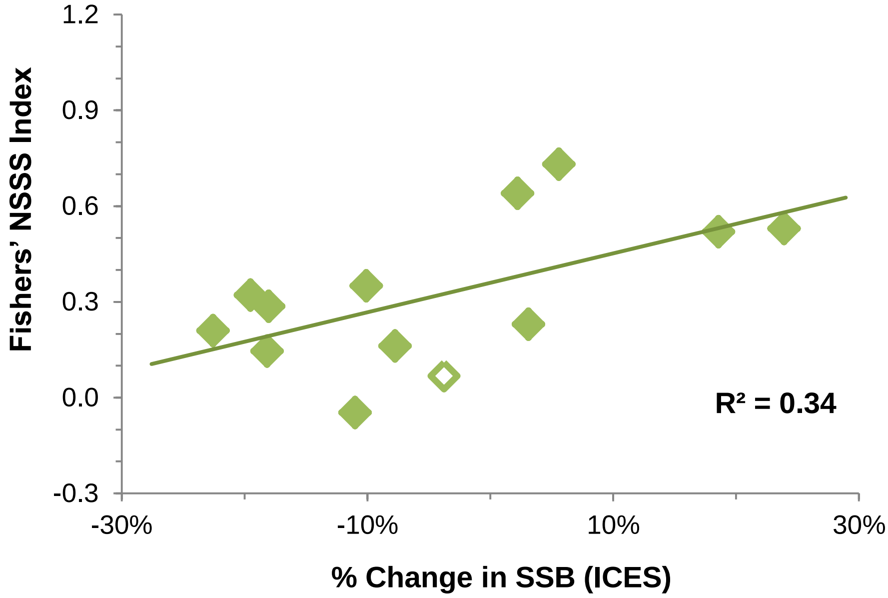

Figure 27 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea whiting spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination (R^2 values closer to 1 indicate a better agreement). The unshaded point is based on the predicted SSB for 2015.

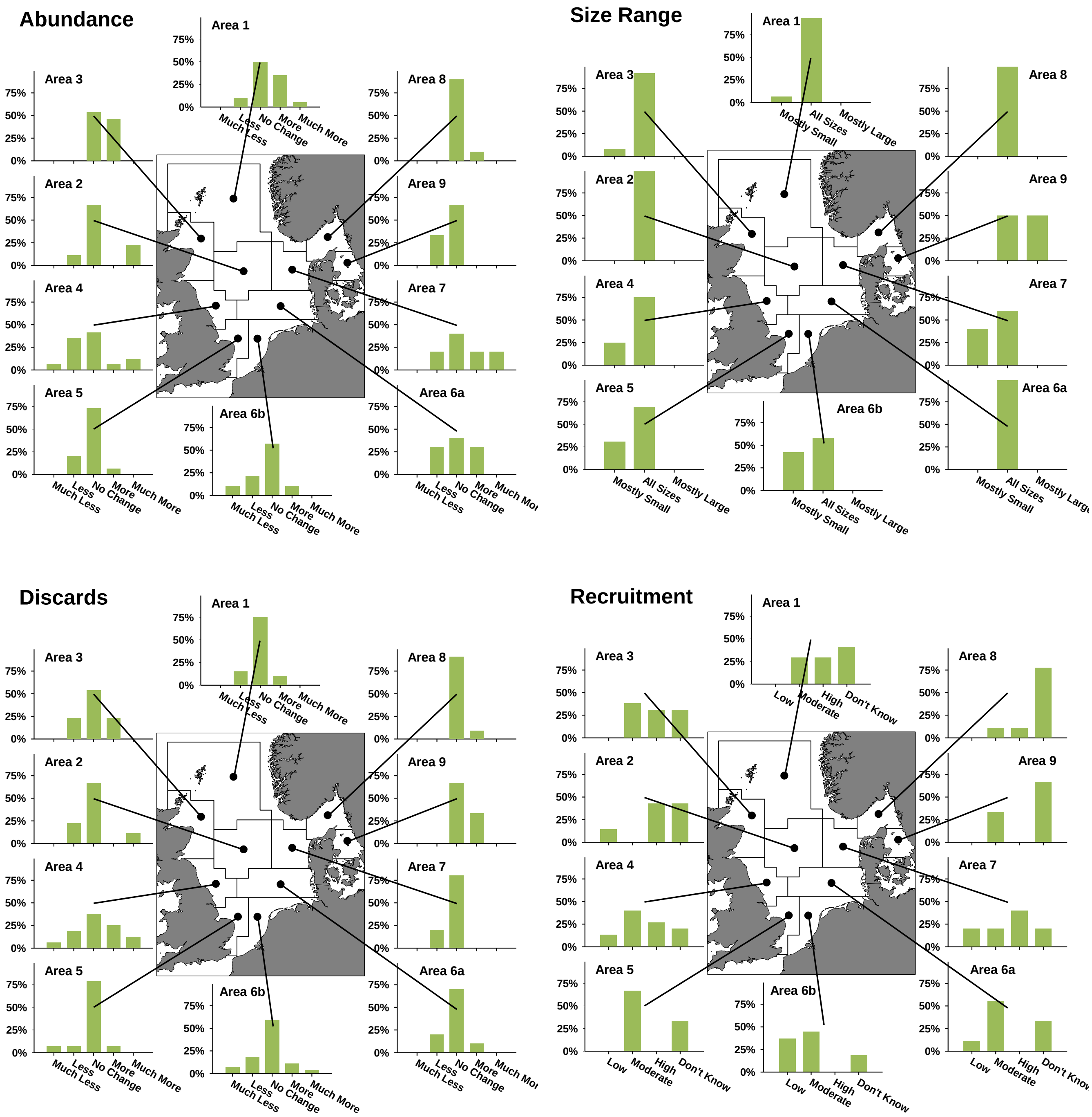

Figure 28 Perceptions of the abundance and size range of whiting, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category.

Abundance Index

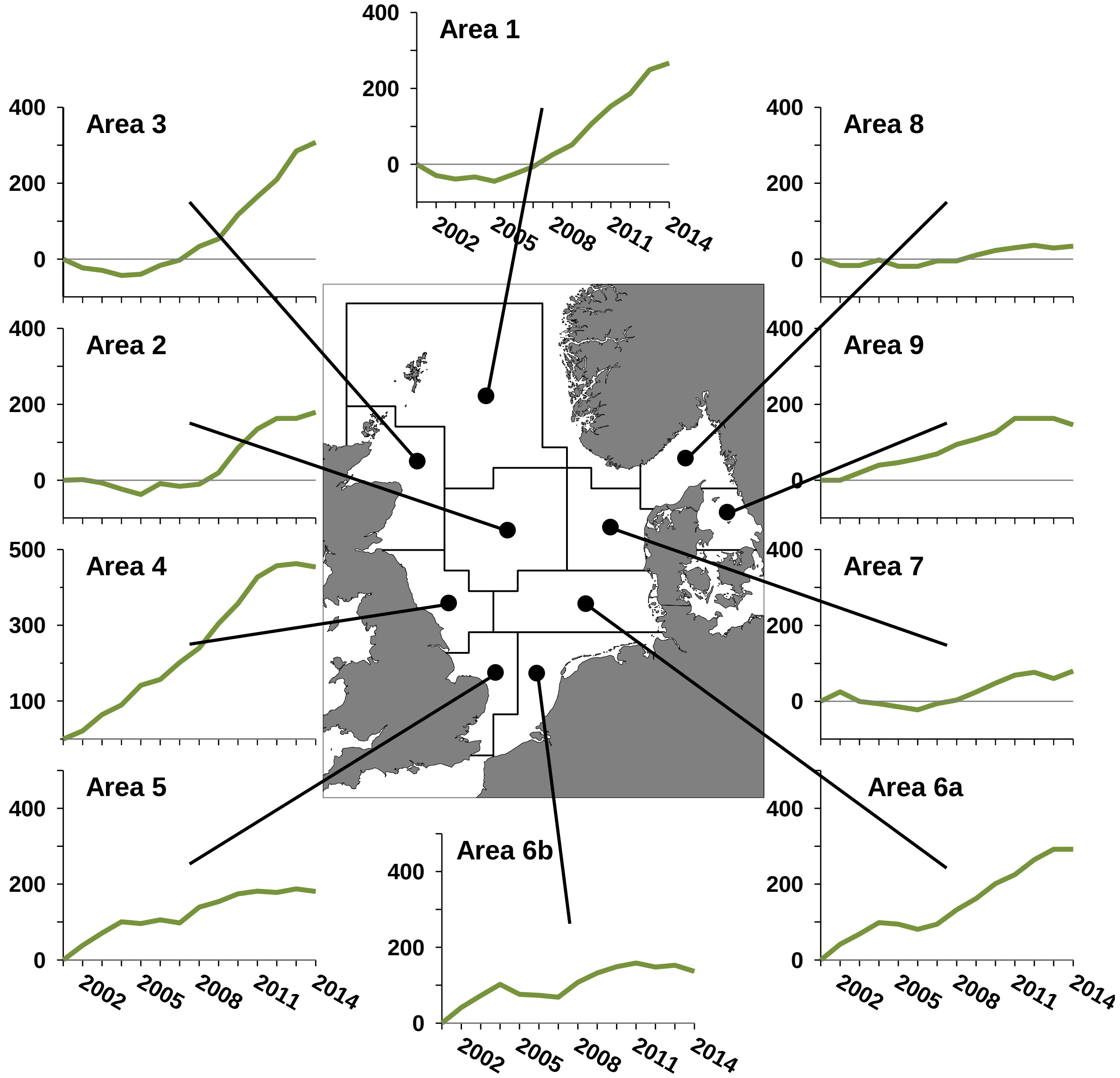

Figure 29 Cumulative time series of index of perceptions of abundance of whiting, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

Table 20 Numbers of responses by area and category for perceptions of the abundance, size, level of discarding and level of recruitment of whiting.

	Area									
	1	**2**	**3**	**4**	**5**	**6a**	**6b**	**7**	**8**	**9**
Number	20	9	13	17	15	10	30	5	12	3
Abundance										
Much Less	0	0	0	1	0	0	3	0	0	0
Less	2	1	0	6	3	3	6	1	0	1
No Change	10	6	7	7	11	4	16	2	9	2
More	7	0	6	1	1	3	3	1	1	0
Much More	1	2	0	2	0	0	0	1	0	0
No Answer	0	0	0	0	0	0	2	0	2	0
Size										
Mostly Small	1	0	1	4	4	0	11	2	0	0
All Sizes	14	7	11	12	9	8	15	3	6	1
Mostly Large	0	0	0	0	0	0	0	0	0	1
No Answer	5	2	1	1	2	2	4	0	6	1
Discards										
Much Less	0	0	0	1	1	0	2	0	0	0
Less	3	2	3	3	1	2	5	1	0	0
No Change	15	6	7	6	11	7	16	4	10	2
More	2	0	3	4	1	1	3	0	1	1
Much More	0	1	0	2	0	0	1	0	0	0
No Answer	0	0	0	1	1	0	3	0	1	0
Recruitment										
Low	0	1	0	2	0	1	10	1	0	0
Moderate	5	0	5	6	8	5	12	1	1	1
High	5	3	4	4	0	0	0	2	1	0
Don't Know	7	3	4	3	4	3	5	1	7	2
No Answer	3	2	0	2	3	1	3	0	3	0

Saithe

Of the 177 valid responses received, 79 (45%) provided information on saithe. The proportion of responses providing information on saithe was highest in the northern North Sea (area 1), and lowest in the south (areas 5, 6a & 6b) (Figure 30).

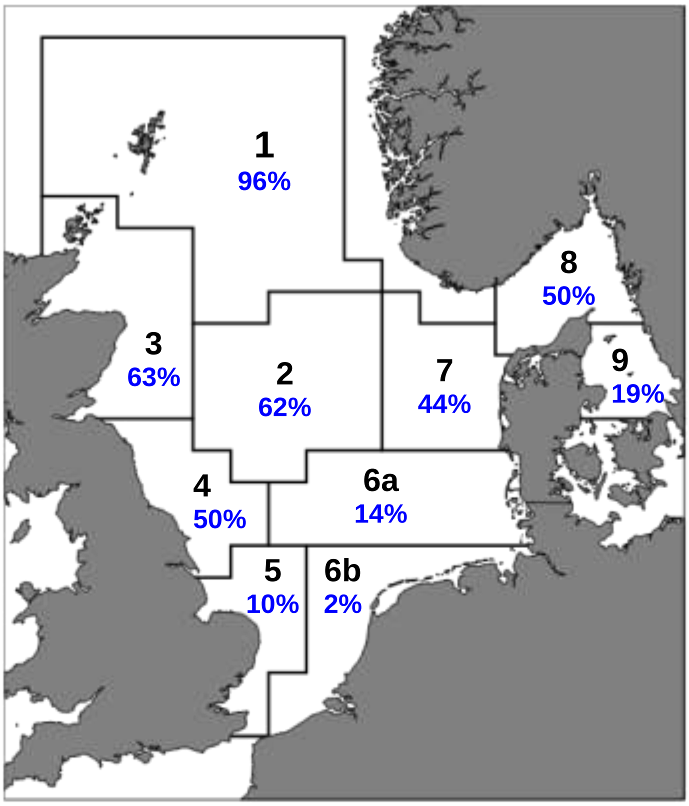

Figure 30 The proportions of responses from each area that provided information on saithe.

Table 21 shows the responses broken down by fishing gear and vessel size class. Almost half of responses were from medium-sized (15-24m) vessels, with the remainder roughly equally split between small (<15m) and large (>24m) vessels. By fishing gear, the biggest proportions of responses were from otter trawls and *Nephrops* trawls.

Figure 31 and Figure 32 provide a more detailed breakdown of the responses for saithe by vessel size and fishing gear.

Table 21 Numbers of responses for saithe by fishing gear type and vessel size class. Percentages show % of vessels in each size class using each gear type (at right), and % of vessels using each gear type in each size class (at bottom). (Excludes vessels that did not provide information on fishing gear and/or vessel size class.)

FISHING GEAR		VESSEL SIZE CLASS: Numbers <15m	15-24m	>24m	ALL	% by Gear Type <15m	15-24m	>24m	ALL
Numbers	Otter Trawl	2	15	13	**30**	11%	39%	59%	38%
	Nephrops Trawl	7	15	0	**22**	39%	39%	0%	28%
	Beam Trawl	0	1	2	**3**	0%	3%	9%	4%
	Pulse Trawl	0	0	2	**2**	0%	0%	9%	3%
	Gill Net	9	3	0	**12**	50%	8%	0%	15%
	Seine Net	0	4	5	**9**	0%	11%	23%	12%
	ALL	**18**	**38**	**22**	**78**	100%	100%	100%	100%
% by Size	Otter Trawl	7%	50%	43%	100%				
	Nephrops Trawl	32%	68%	0%	100%				
	Beam Trawl	0%	33%	67%	100%				
	Pulse Trawl	0%	0%	100%	100%				
	Gill Net	75%	25%	0%	100%				
	Seine Net	0%	44%	56%	100%				
	ALL	23%	49%	28%	100%				

Table 22 Summary of perceptions of the abundance, size, level of discarding and level of recruitment of saithe this year and last year. Proportion of responses in each category for all areas combined this year and last year, and change in proportions (+/-).

Abundance	2013	2014	+/-	Fish Size	2013	2014	+/-
'Less' [1]	27%	12%	-15%	Mostly Small	33%	21%	-12%
No Change	35%	52%	+17%	All Sizes	64%	71%	+7%
'More' [2]	39%	37%	-2%	Mostly Large	3%	7%	+5%
Discards	**2013**	**2014**	**+/-**	**Recruitment**	**2013**	**2014**	**+/-**
'Less' [1]	13%	10%	-3%	Low	16%	5%	-10%
No Change	60%	67%	+8%	Moderate	50%	47%	-3%
'More' [2]	28%	23%	-5%	High	34%	47%	+13%

[1] 'Less' = sum of 'Less' and 'Much Less' responses.

[2] 'More' = sum of 'More' and 'Much More' responses.

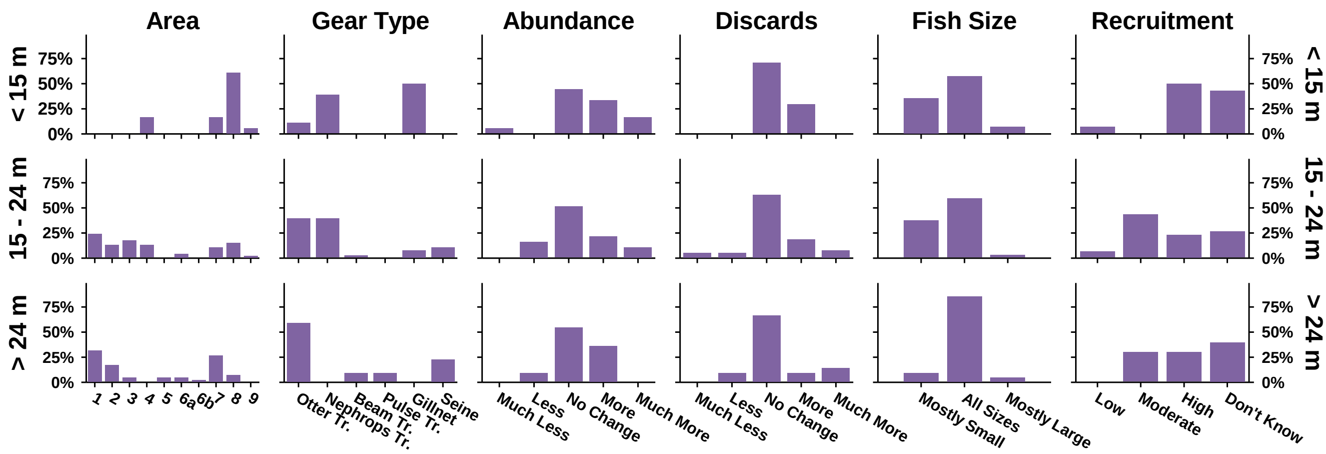

Figure 31 Breakdown of responses for saithe by fishing vessel size class. Percentage of responses for each size class in each category.

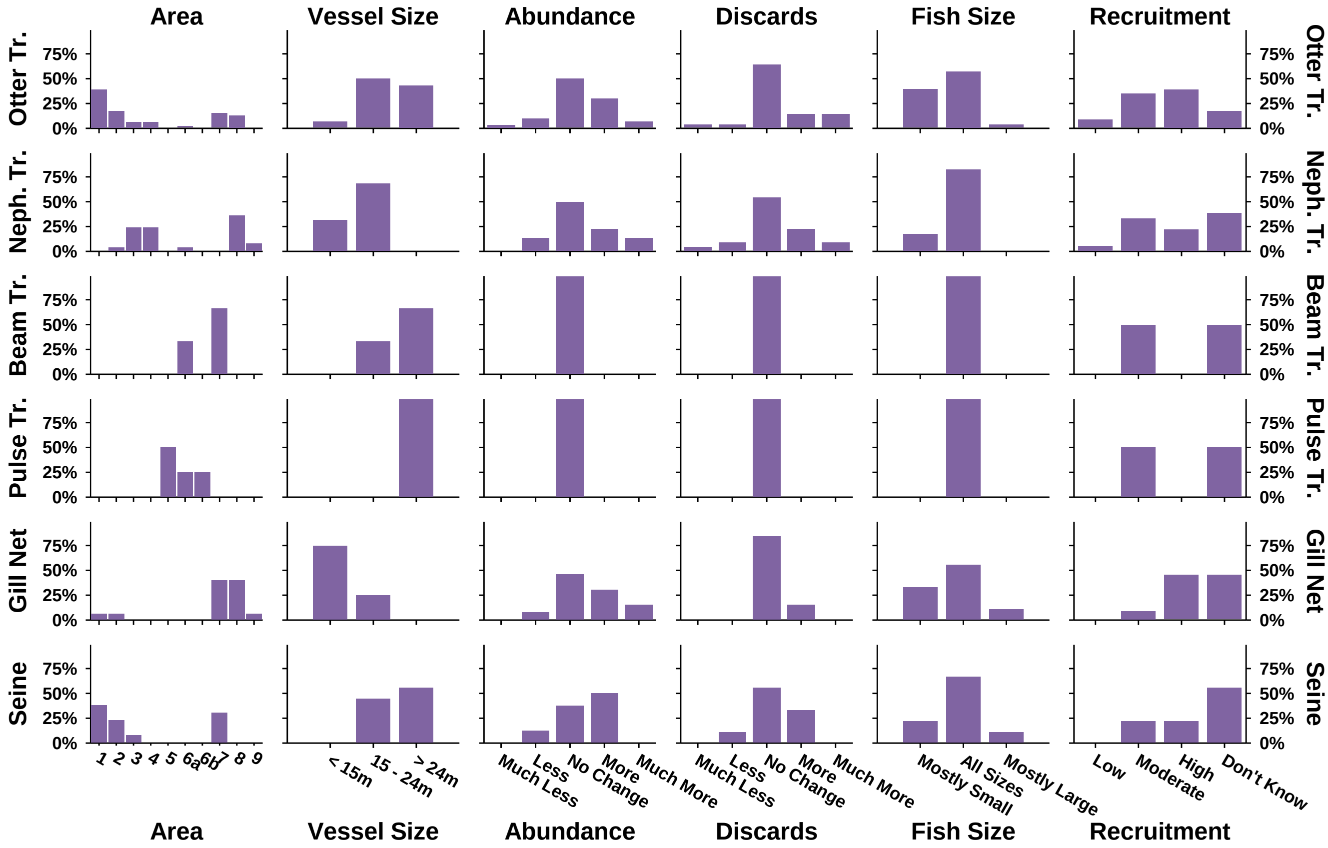

Figure 32 Breakdown of responses for saithe by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

Abundance

Just over half of responses reported no change in the abundance of saithe in 2014, substantially more than in 2013 (Table 22). One-third of responses reported an increase in abundance, almost unchanged from 2013, while there was a marked fall in the proportion reporting a lower abundance of saithe in 2014.

Across individual areas the proportions reporting higher abundances of saithe in 2014 tended to be greater in more northern areas (areas 1, 2, 3 & 8), while the proportins reporting lower abundances tended to be higher in more southerly areas (areas 4, 6a & 7) (Figure 34).

The cumulative index of perceptions of the abundance of saithe (Figure 35) increased in just over half the areas, with the biggest increases in the north and west (areas 1, 2, 3 & 8).

Size Range

Almost three-quarters of responses reported catching all sizes of saithe in 2014 (Table 22), with a small increase from 2013. Most of the remaining responses reported catching mostly small saithe, markedly less than in 2013, while there was a small increase in the (small) proportion reporting mostly large saithe in 2014.

Across most individual areas the majority of responses reported all sizes of saithe in 2014 (Figure 34). The proportions reporting mostly small saithe were higher in central, norther and western areas (area 1, 2 & 4).

Discards

Two-thirds of responses reported no change in the level of discarding of saithe in 2014 (Table 22), somewhat more than in 2013. About one-quarter of responses reported higher levels of discarding, slightly less than in 2013, while the proportion reporting lower levels of discards fell slightly.

The majority of responses in all individual areas reported no change in the level of saithe discards in 2014 (Figure 34), but no clear pattern was apparent in the remaining responses.

Recruitment

Almost all responses reported moderate or high levels of recruitment of saithe in 2014 (Table 22), with the same proportion of responses in each category. There was a marked increase in the proportion reoprting high levels of recruitment in 2014, and a small decrease in the proportion reporting moderate levels. There was also a marked decrease in the proportion of responses reporting low levels of recruitment of saithe in 2014.

No clear pattern was apparent across individual areas in the breakdown of responses on levels of recruitment (Figure 34).

Comparison with ICES Stock Assessment

ICES assesses the abundance of a single saithe stock covering both the North Sea and West of Scotland (subarea VI) areas. There was little evidence of any relationship between these data and the saithe abundance index derived from the Fishers' North Sea Stock Survey (Figure 33).

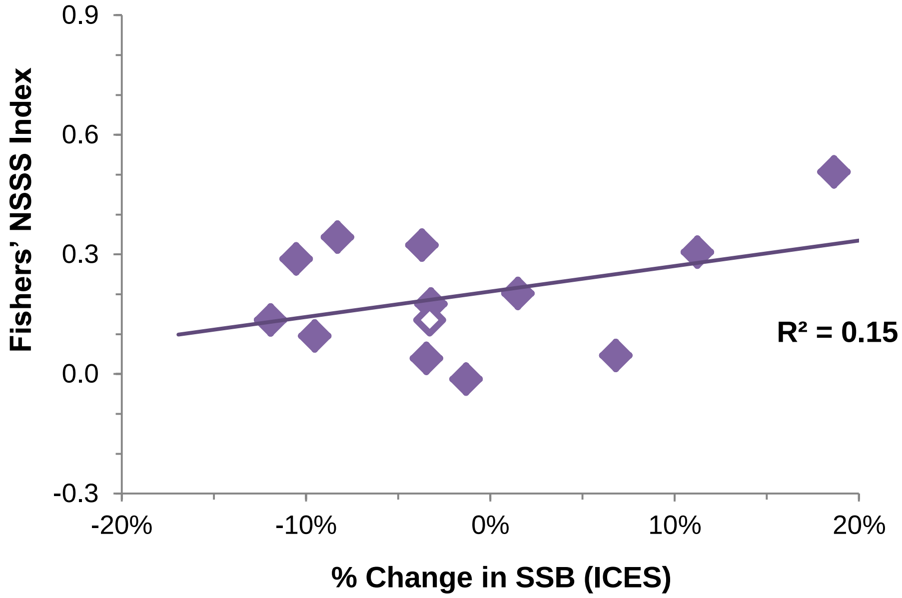

Figure 33 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea and West of Scotland saithe spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination (R^2; values closer to 1 indicate a better agreement). The unshaded point is based on the predicted SSB for 2015.

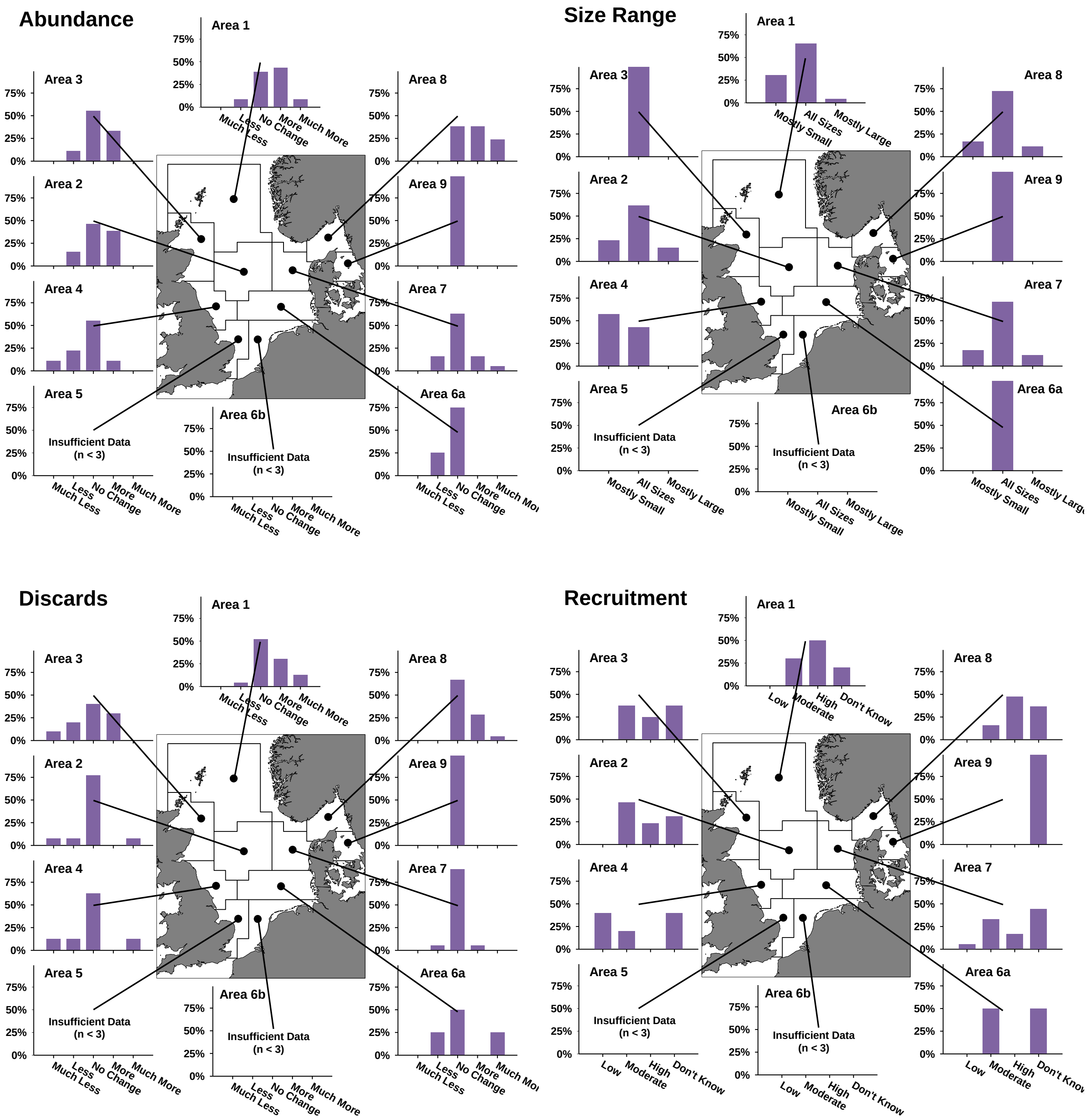

Figure 34 Perceptions of the abundance and size range of saithe, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category. No results are shown for Areas 5 and 6b due to the small number of responses from those areas (see Table 11, p. 28).

Abundance Index

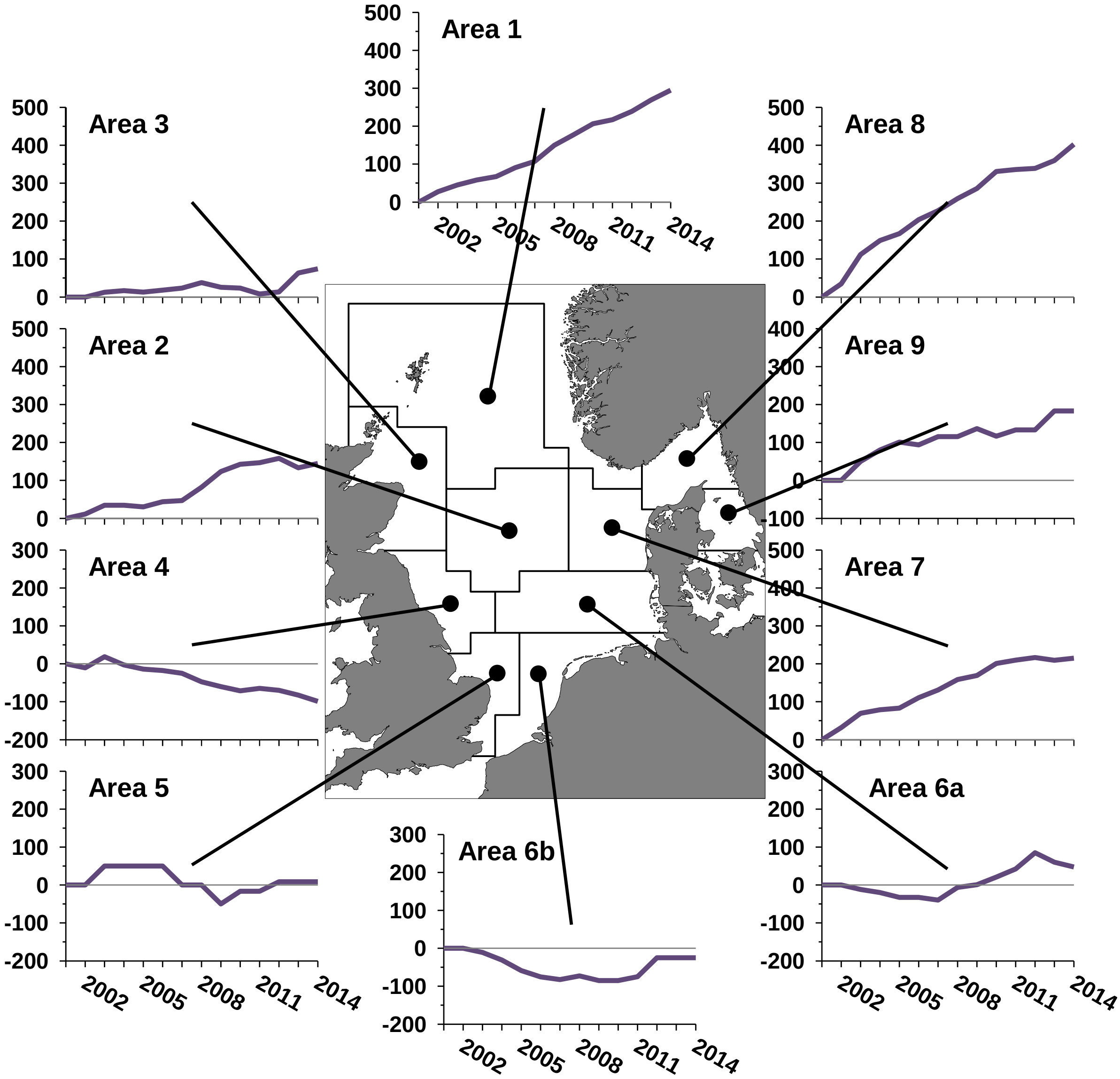

Figure 35 Cumulative time series of index of perceptions of abundance of saithe, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

Table 23 Numbers of responses by area and category for perceptions of the abundance, size, level of discarding and level of recruitment of saithe.

	Area									
	1	2	3	4	5	6a	6b	7	8	9
Number	24	13	10	9	2	4	1	19	21	3
Abundance										
Much Less	0	0	0	1	0	0	0	0	0	0
Less	2	2	1	2	0	1	0	3	0	0
No Change	9	6	5	5	2	3	1	12	8	3
More	10	5	3	1	0	0	0	3	8	0
Much More	2	0	0	0	0	0	0	1	5	0
No Answer	1	0	1	0	0	0	0	0	0	0
Size										
Mostly Small	7	3	0	4	0	0	0	3	3	0
All Sizes	15	8	9	3	2	2	1	12	13	2
Mostly Large	1	2	0	0	0	0	0	2	2	0
No Answer	1	0	1	2	0	2	0	2	3	1
Discards										
Much Less	0	1	1	1	0	0	0	0	0	0
Less	1	1	2	1	0	1	0	1	0	0
No Change	12	10	4	5	2	2	1	17	14	3
More	7	0	3	0	0	0	0	1	6	0
Much More	3	1	0	1	0	1	0	0	1	0
No Answer	1	0	0	1	0	0	0	0	0	0
Recruitment										
Low	0	0	0	2	0	0	0	1	0	0
Moderate	6	6	3	1	1	1	0	6	3	0
High	10	3	2	0	0	0	0	3	9	0
Don't Know	4	4	3	2	1	1	1	8	7	3
No Answer	4	0	2	4	0	2	0	1	2	0

Monkfish

Of the 177 valid questionnaires received, 89 (50%) provided information on monkfish. The proportion of responses providing information on monkfish was lowest in the southern North Sea (area 6b) and Kattegat (area 9), and highest in the north (area 1) (Figure 36).

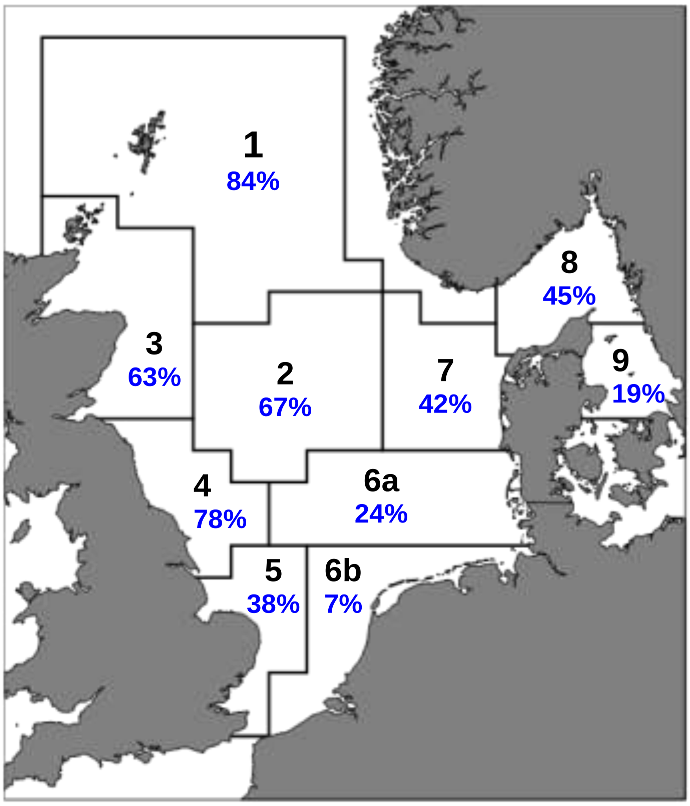

Figure 36 The proportions of responses from each area that provided information on monkfish.

Table 24 shows the responses broken down by fishing gear and vessel size class. By vessel size, most responses were received from medium sized vessels (15-24m), followed by large vessels (>24m) and small vessels (<15m). Of the fishing gears, otter trawls accounted for the largest number of responses, followed by *Nephrops* trawls.

Figure 37 and Figure 38 provide a more detailed breakdown of the responses for monkfish by vessel size and fishing gear.

Table 24 Numbers of responses for monkfish by fishing gear type and vessel size class. Percentages show % of vessels in each size class using each gear type (at right), and % of vessels using each gear type in each size class (at bottom). (Excludes vessels that did not provide information on fishing gear and/or vessel size class.)

FISHING GEAR		VESSEL SIZE CLASS – Numbers <15m	15-24m	>24m	ALL	% by Gear Type <15m	15-24m	>24m	ALL
Numbers	Otter Trawl	6	15	14	**35**	27%	39%	50%	40%
	Nephrops Trawl	8	15	1	**24**	36%	39%	4%	27%
	Beam Trawl	0	2	6	**8**	0%	5%	21%	9%
	Pulse Trawl	0	0	5	**5**	0%	0%	18%	6%
	Gill Net	8	2	0	**10**	36%	5%	0%	11%
	Seine Net	0	4	2	**6**	0%	11%	7%	7%
	ALL	**22**	**38**	**28**	**88**	100%	100%	100%	100%
% by Size	Otter Trawl	17%	43%	40%	100%				
	Nephrops Trawl	33%	63%	4%	100%				
	Beam Trawl	0%	25%	75%	100%				
	Pulse Trawl	0%	0%	100%	100%				
	Gill Net	80%	20%	0%	100%				
	Seine Net	0%	67%	33%	100%				
	ALL	25%	43%	32%	100%				

Table 25 Summary of perceptions of the abundance, size, level of discarding and level of recruitment of monkfish this year and last year. Proportion of responses in each category for all areas combined this year and last year, and change in proportions (+/-).

Abundance	2013	2014	+/-	Fish Size	2013	2014	+/-
'Less' [1]	31%	9%	-22%	Mostly Small	14%	16%	+2%
No Change	46%	54%	+7%	All Sizes	86%	79%	-7%
'More' [2]	23%	38%	+15%	Mostly Large	0%	5%	+5%
Discards	**2013**	**2014**	**+/-**	**Recruitment**	**2013**	**2014**	**+/-**
'Less' [1]	13%	11%	-2%	Low	32%	12%	-20%
No Change	84%	83%	-2%	Moderate	53%	55%	+2%
'More' [2]	3%	6%	+4%	High	15%	33%	+18%

[1] 'Less' = sum of 'Less' and 'Much Less' responses.

[2] 'More' = sum of 'More' and 'Much More' responses.

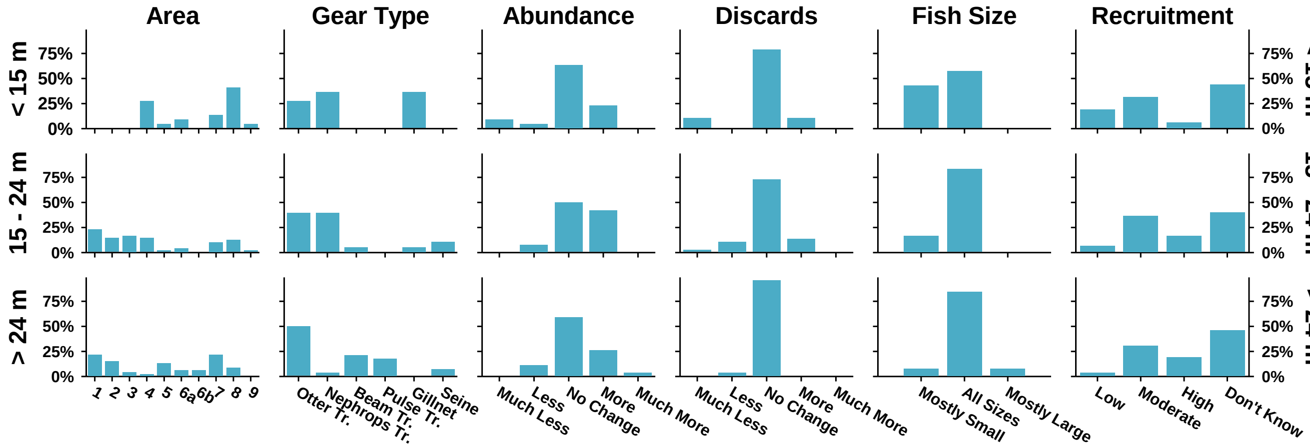

Figure 37 Breakdown of responses for monkfish by fishing vessel size class. Percentage of responses for each size class in each category.

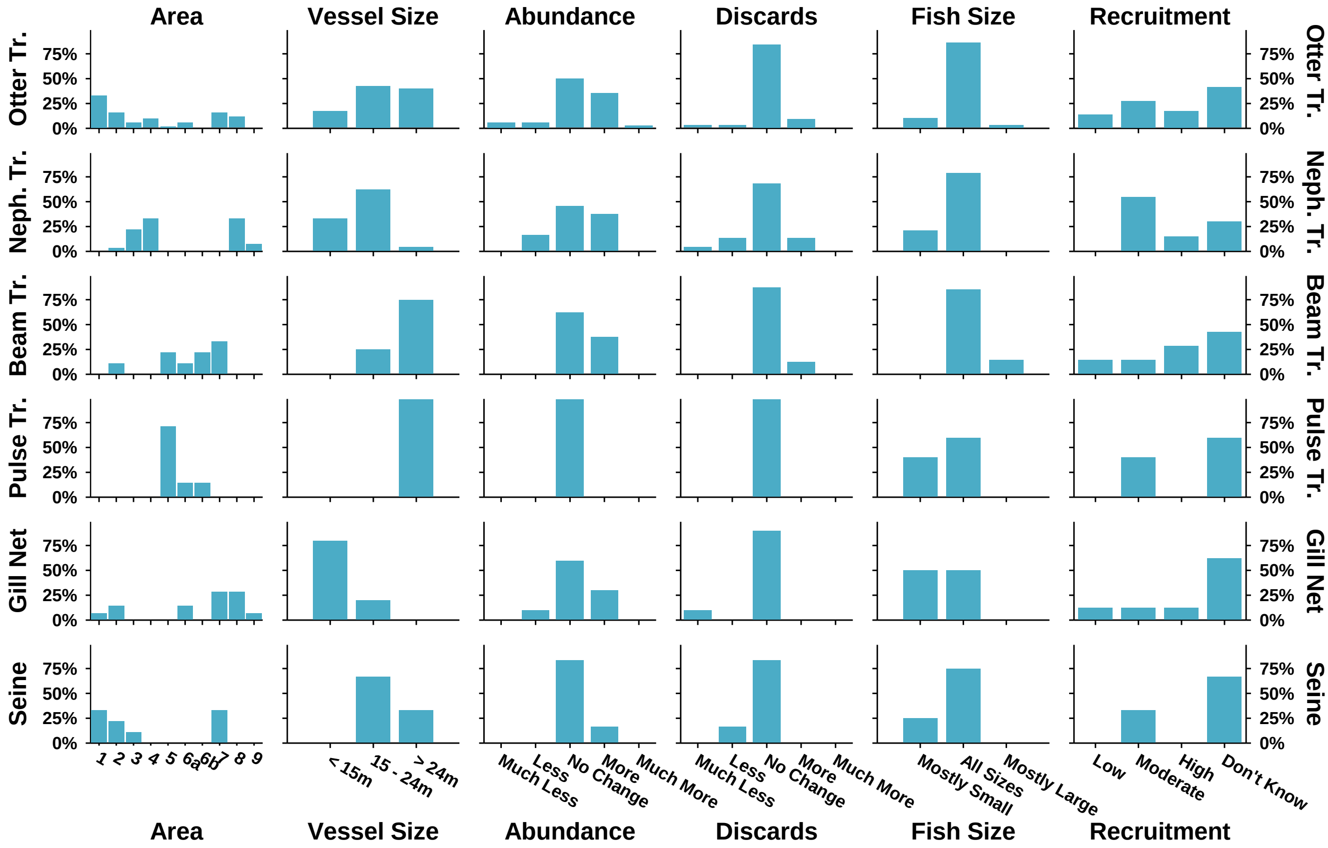

Figure 38 Breakdown of responses for monkfish by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

Abundance

Just over half of responses reported no change in the abundance of monkfish in 2014, slightly more than in 2013 (Table 25). Of the balance, most responses – more than one-third overall – reported a higher abundance in 2014, markedly more than in 2013. There was a large fall in the proportion reporting a lower abundance of monkfish in 2014.

The majority of responses reported no change in the abundance of monkfish across most individual areas (Figure 40). Reports of higher abundances tended to be highest in central and northern areas (areas 1, 2, 3 & 7).

The cumulative index of perceptions of the abundance of monkfish increased in most areas (Figure 41), especially in the north and west (areas 1, 2 & 3).

Size Range

More than three-quarters of responses reported catching all sizes of monkfish in 2014, slightly less than in 2013 (Table 25). Of the remainder, most reported catching mostly small monkfish, slightly more than in 2013, while there was also a small increase in the proportion reporting mostly large monkfish.

Across most individual areas the majority of responses reported all sizes of monkfish (Figure 40). The proportions reporting mostly small monkfish were highest in the south-west (areas 4 & 5), and also in the Kattegat (area 9).

Discards

The majority of responses (83%) reported no change in the level of discards of monkfish in 2014 (Table 25), slightly less than in 2013. There was also a slight fall in the proportion reporting lower levels of monkfish discards in 2014 and a small increase in the (small) proportion reporting higher levels of discards.

Across most individual areas most, if not all, responses reported no change in the levels of monkfish discards (Figure 40). The exceptions tended to be in the central and western North Sea (areas 2, 3 & 4), although there responses tended to be split between reporting lower and higher levels of discards.

Recruitment

More than half of responses reported a moderate level of monkfish recruitment in 2014 (Table 25), slightly more than in 2013, while a further third reported a high level of recruitment, markedly more than in 2013. There was a fairly large fall in the proportion reporting low levels of monkfish recruitment in 2014.

The picture was broadly similar across most individual areas (Figure 40). The proportions reporting low levels of monkfish recruitment were highest in the south (areas 5 & 6b).

Comparison with ICES Stock Assessment

Estimates of the biomass of North Sea monkfish were published by ICES for the period from 2005 to 2012. There was no evidence of a relationship between these estimates and the NSSS index (Figure 33).

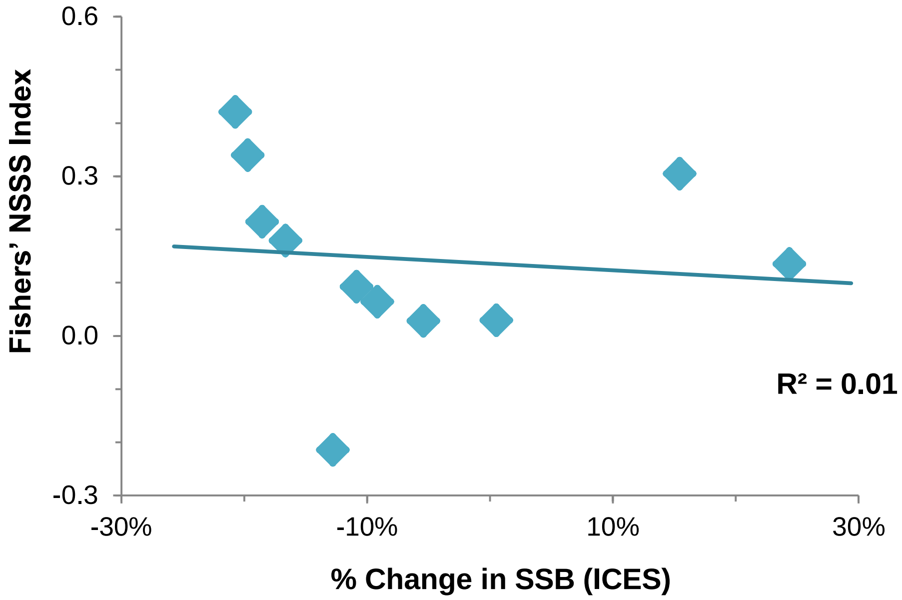

Figure 39 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea monkfish biomass (B), with fitted linear trend line and coefficient of determination. (R^2; values closer to 1 indicate a better agreement.)

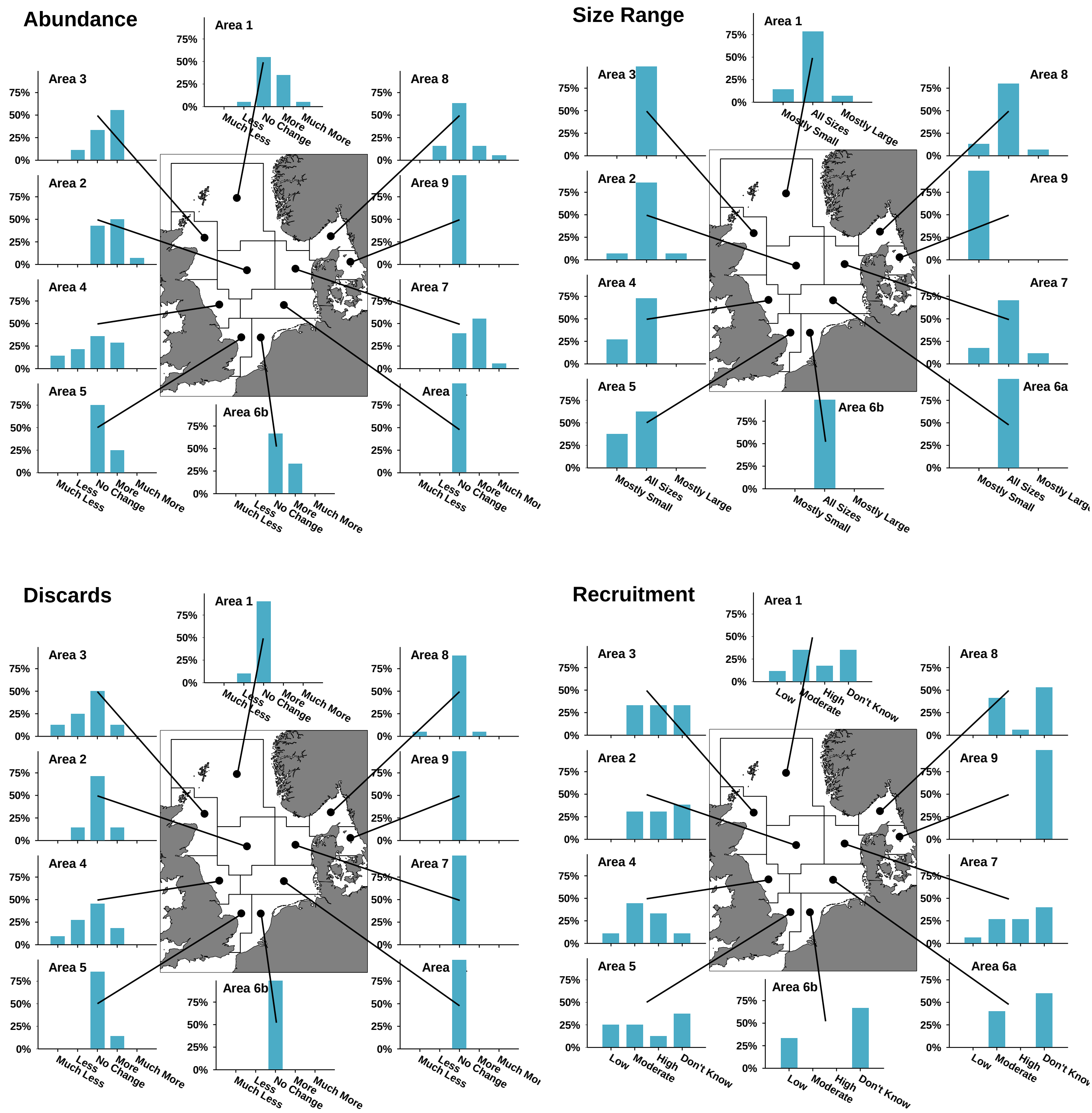

Figure 40 Perceptions of the abundance and size range of monkfish, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category.

Abundance Index

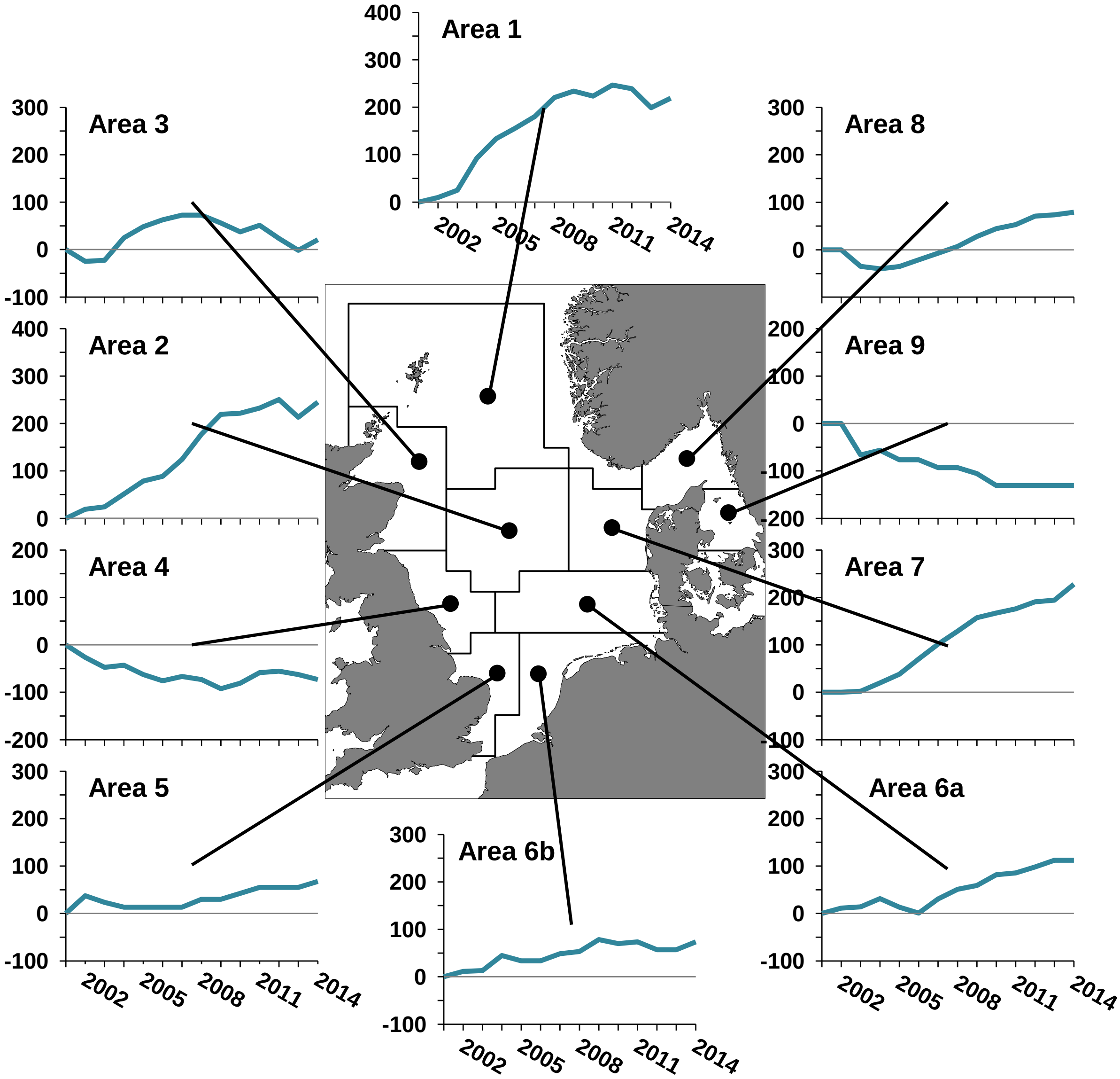

Figure 41 Cumulative time series of index of perceptions of abundance of monkfish, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

Table 26 Numbers of responses by area and category for perceptions of the abundance, size, level of discarding and level of recruitment of monkfish.

	Area									
	1	2	3	4	5	6a	6b	7	8	9
Number	21	14	10	14	8	7	3	18	19	3
Abundance										
Much Less	0	0	0	2	0	0	0	0	0	0
Less	1	0	1	3	0	0	0	0	3	0
No Change	11	6	3	5	6	7	2	7	12	2
More	7	7	5	4	2	0	1	10	3	0
Much More	1	1	0	0	0	0	0	1	1	0
No Answer	1	0	1	0	0	0	0	0	0	1
Size										
Mostly Small	2	1	0	3	3	0	0	3	2	1
All Sizes	11	12	8	8	5	5	3	12	12	0
Mostly Large	1	1	0	0	0	0	0	2	1	0
No Answer	7	0	2	3	0	2	0	1	4	2
Discards										
Much Less	0	0	1	1	0	0	0	0	1	0
Less	2	2	2	3	0	0	0	0	0	0
No Change	18	10	4	5	6	7	3	18	17	2
More	0	2	1	2	1	0	0	0	1	0
Much More	0	0	0	0	0	0	0	0	0	0
No Answer	1	0	2	3	1	0	0	0	0	1
Recruitment										
Low	2	0	0	1	2	0	1	1	0	0
Moderate	6	4	3	4	2	2	0	4	7	0
High	3	4	3	3	1	0	0	4	1	0
Don't Know	6	5	3	1	3	3	2	6	9	1
No Answer	4	1	1	5	0	2	0	3	2	2

Nephrops

Of the 177 valid questionnaires received, 54 (31%) provided information on *Nephrops*. The proportion of responses providing information on *Nephrops* was highest in the west (areas 3 & 4) (Figure 42).

No responses were received in 2014 to the supplementary question based on the functional units (FUs) used by ICES in their assessment of the North Sea Nephrops stock (see page 12).

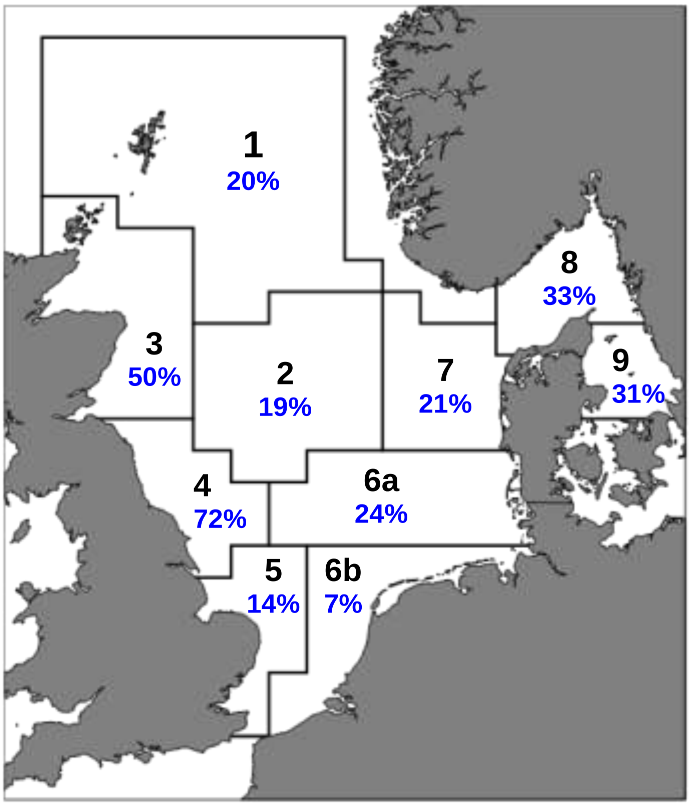

Figure 42 The proportions of responses from each area that provided information on *Nephrops*.

Table 27 shows the responses broken down by fishing gear and vessel size class. Almost half the responses were from medium-sized (15-24m) and one-third from small (<15m) vessels. The majority of responses were from *Nephrops* trawls or otter trawls.

Figure 43 and Figure 44 provide a more detailed breakdown of the responses for *Nephrops* by vessel size and fishing gear.

Table 27 Numbers of responses for *Nephrops* by fishing gear type and vessel size class. Percentages show % of vessels in each size class using each gear type (at right), and % of vessels using each gear type in each size class (at bottom). (Excludes vessels that did not provide information on fishing gear and/or vessel size class.)

FISHING GEAR		VESSEL SIZE CLASS: Numbers <15m	15-24m	>24m	ALL	% by Gear Type <15m	15-24m	>24m	ALL
Numbers	Otter Trawl	5	8	6	**19**	29%	32%	50%	35%
	***Nephrops* Trawl**	8	15	1	**24**	47%	60%	8%	44%
	Beam Trawl	0	1	3	**4**	0%	4%	25%	7%
	Pulse Trawl	0	0	2	**2**	0%	0%	17%	4%
	Gill Net	4	0	0	**4**	24%	0%	0%	7%
	Seine Net	0	1	0	**1**	0%	4%	0%	2%
	ALL	**17**	**25**	**12**	**54**	100%	100%	100%	100%
% by Size	Otter Trawl	26%	42%	32%	100%				
	***Nephrops* Trawl**	33%	63%	4%	100%				
	Beam Trawl	0%	25%	75%	100%				
	Pulse Trawl	0%	0%	100%	100%				
	Gill Net	100%	0%	0%	100%				
	Seine Net	0%	100%	0%	100%				
	ALL	31%	46%	22%	100%				

Table 28 Summary of perceptions of the abundance, size, level of discarding and level of recruitment of *Nephrops* this year and last year. Proportion of responses in each category for all areas combined this year and last year, and change in proportions (+/-).

Abundance	2013	2014	+/-	Fish Size	2013	2014	+/-
'Less' [1]	65%	13%	-52%	Mostly Small	17%	16%	-1%
No Change	23%	17%	-6%	All Sizes	80%	69%	-11%
'More' [2]	13%	70%	+58%	Mostly Large	3%	15%	+12%
Discards	**2013**	**2014**	**+/-**	**Recruitment**	**2013**	**2014**	**+/-**
'Less' [1]	43%	20%	-23%	Low	16%	2%	-14%
No Change	58%	62%	+4%	Moderate	80%	80%	+0%
'More' [2]	0%	18%	+18%	High	4%	17%	+13%

[1] 'Less' = sum of 'Less' and 'Much Less' responses.
[2] 'More' = sum of 'More' and 'Much More' responses.

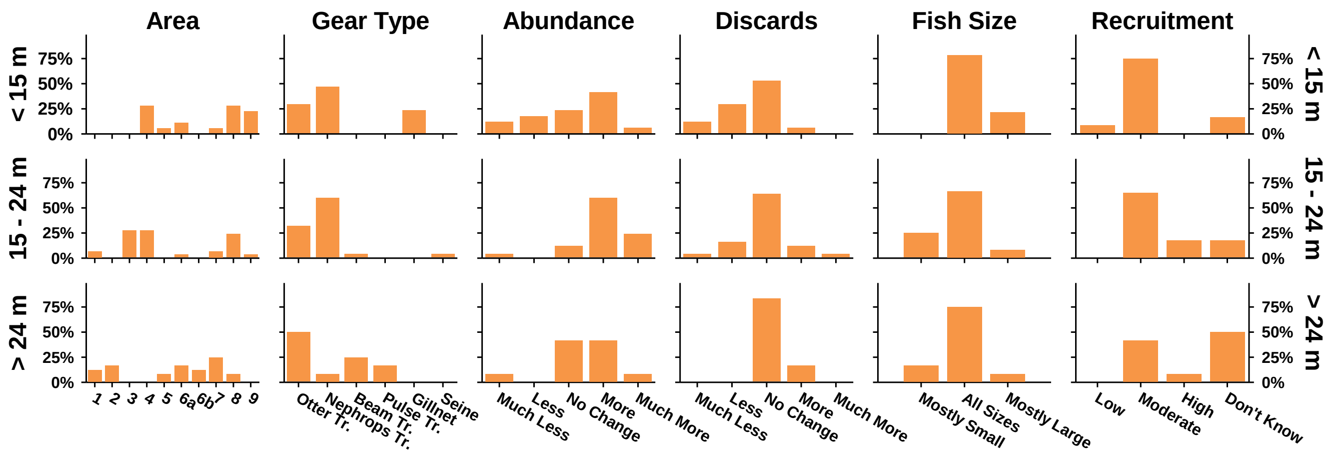

Figure 43 Breakdown of responses for *Nephrops* by fishing vessel size class. Percentage of responses for each size class in each category.

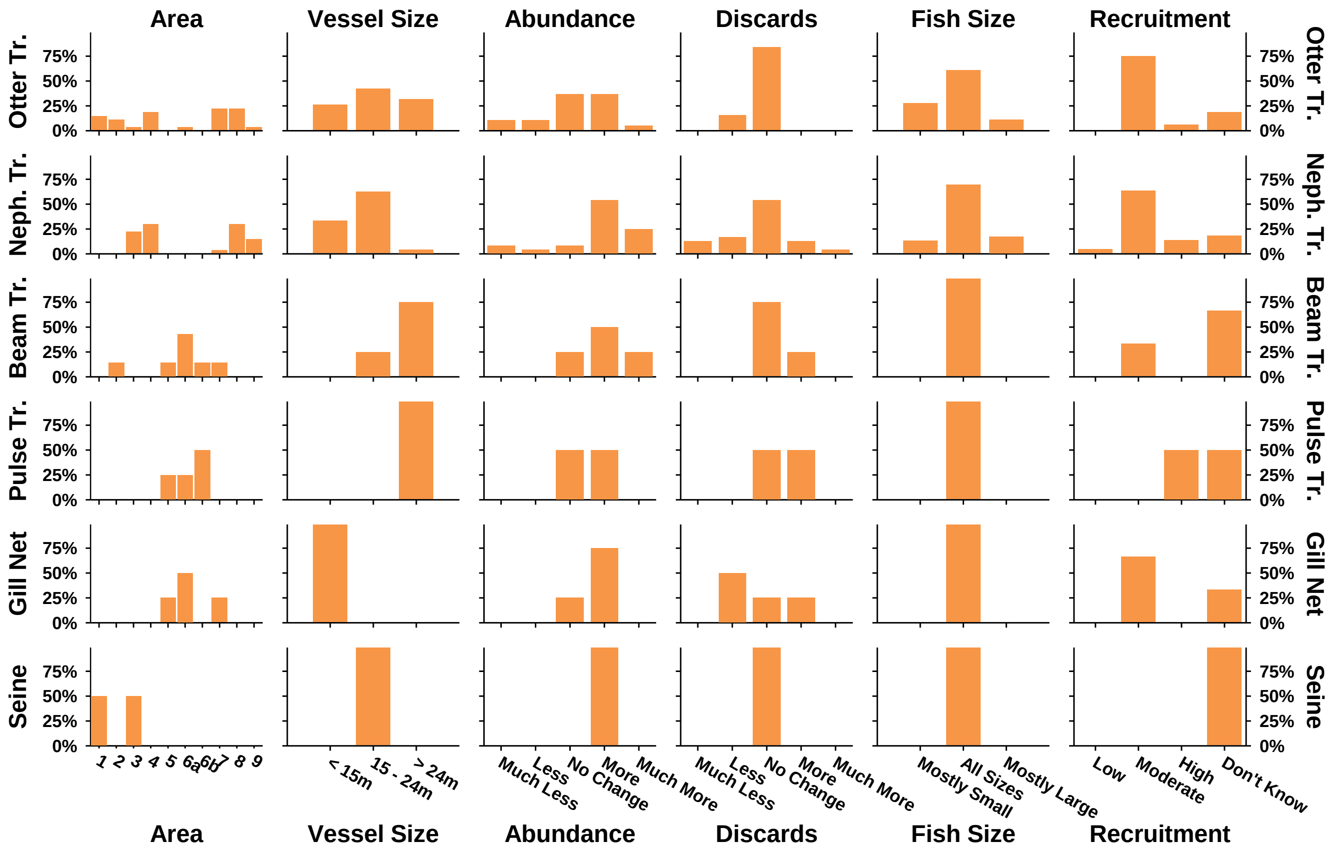

Figure 44 Breakdown of responses for *Nephrops* by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

Abundance

Almost three-quarters of responses reported a higher abundance of *Nephrops* in 2014 (Table 28), substantially more than in 2013. There was also a substantial fall in the proportion of responses reporting a lower abundance of *Nephrops* in 2014.

The majority of responses reported higher abundances of *Nephrops* in all individual areas (Figure 46). Reports of no change in abundance tended to be most common in the south and east, while reports of lower abundances were more common in the central, northern and western North Sea.

The cumulative index of perceptions of the abundance of *Nephrops* (Figure 47) increased in all areas except the most northern (area 1).

Size Range

More than two-thirds of responses reported catching all sizes of *Nephrops* in 2014 (Table 28), a decrease from 2013. The remaining responses were fairly evenly split between mostly small and mostly large *Nephrops*. The former was almost unchanged from 2013, while the latter had increased.

The majority of responses from all individual areas reported all sizes of *Nephrops* (Figure 46), but no clear pattern was apparent in the remaining responses.

Discards

Almost two-thirds of responses reported no change in the level of discards of *Nephrops* in 2014 (Table 28), slightly more than in 2013. The remaining responses were roughly equally split between reporting lower and higher levels of discards. A fairly large increase in the proportion reporting higher levels of discards in 2014 was matched by a similar fall in the proportion reporting lower levels.

The majority of responses from all individual areas reported no change in levels of discards of *Nephrops* (Figure 46), but no clear pattern was apparent in the remaining responses.

Recruitment

More than three-quarters of responses reported moderate levels of *Nephrops* recruitment in 2014 (Table 28), unchanged from 2013. Most of the remaining responses reported high levels of recruitment, with a fairly large increase from 2013 matched by a fall in the proportion reporting low levels of recruitment.

Across most individual areas the majority of responses reported moderate levels of *Nephrops* recruitment (Figure 46). Reports of high levels of recruitment tended to be most common in the south (areas 5 & 6b).

Comparison with ICES Stock Assessment

ICES provides advice for nine separate *Nephrops* 'functional units' (sub-stocks) within the North Sea (**Error! Reference source not found.**)[1], although abundance estimates are only available for four of these: FU6 (Farn Deeps), FU7 (Fladen Ground), FU8 (Firth of Forth), and FU9 (Moray Firth). These four units accounted for more than three-quarters (78%) of all the *Nephrops* landings from the North Sea in 2013.

For the purposes of this comparison, the sum of the estimated abundances of *Nephrops* in these four functional units was used.

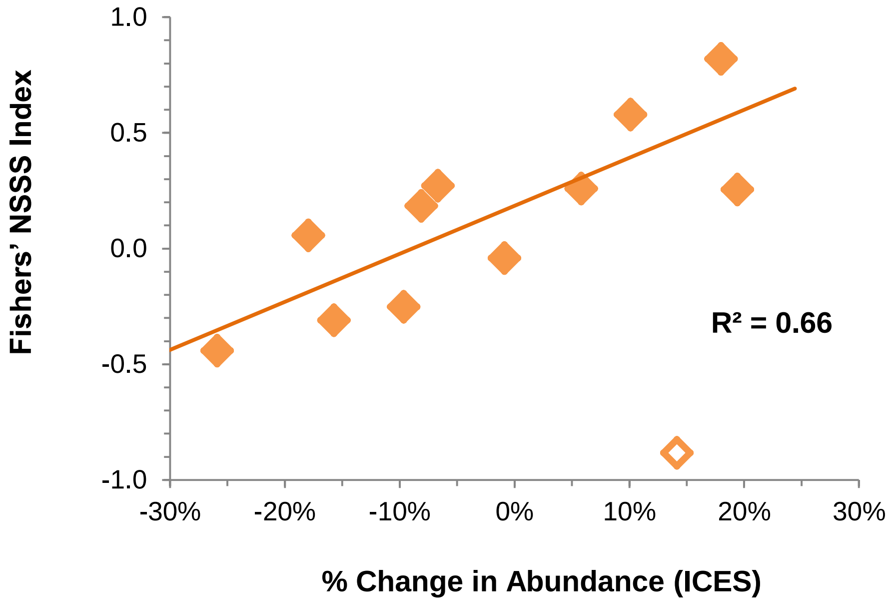

Figure 45 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the total estimated mid-year *Nephrops* abundance for the Farn Deeps (Functional Unit 6), Fladen Ground (FU 7), Firth of Forth (FU8) and Moray Firth (FU9) with fitted linear trend line and coefficient of determination <u>for the years to 2012</u> (R^2; values closer to 1 indicate a better agreement.) The unshaded point is for 2013.

A fairly good relationship was apparent between the estimated abundance of *Nephrops* in these four functional units and the Fishers' North Sea Stock Survey index for the whole North Sea (Figure 45) for the years up to 2012. Although the relationship was not particularly strong statistically, it was stronger than those for most other species in this survey. The data point or 2013 clearly did not fit this

[1] For further information see the ICES advice for Nephrops in Subarea IV (North Sea), available online at: www.ices.dk/sites/pub/Publication%20Reports/Advice/2014/2014/Neph-IV.pdf .

relationship, possibly because of the very small number of responses for *Nephrops* received from the Fishers’ North Sea Stock Survey in 2013.

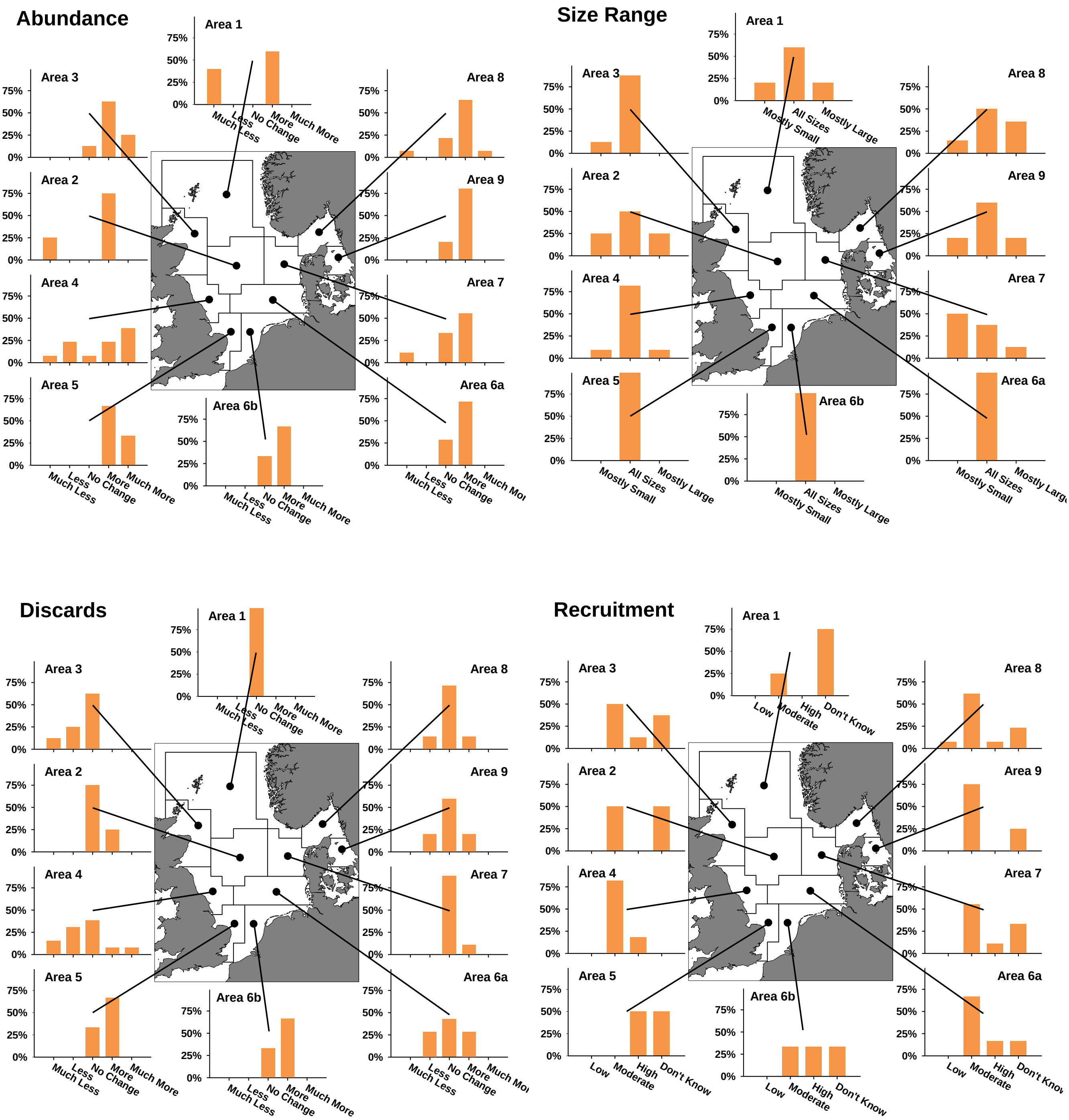

Figure 46 Perceptions of the abundance and size range of *Nephrops*, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category.

Abundance Index

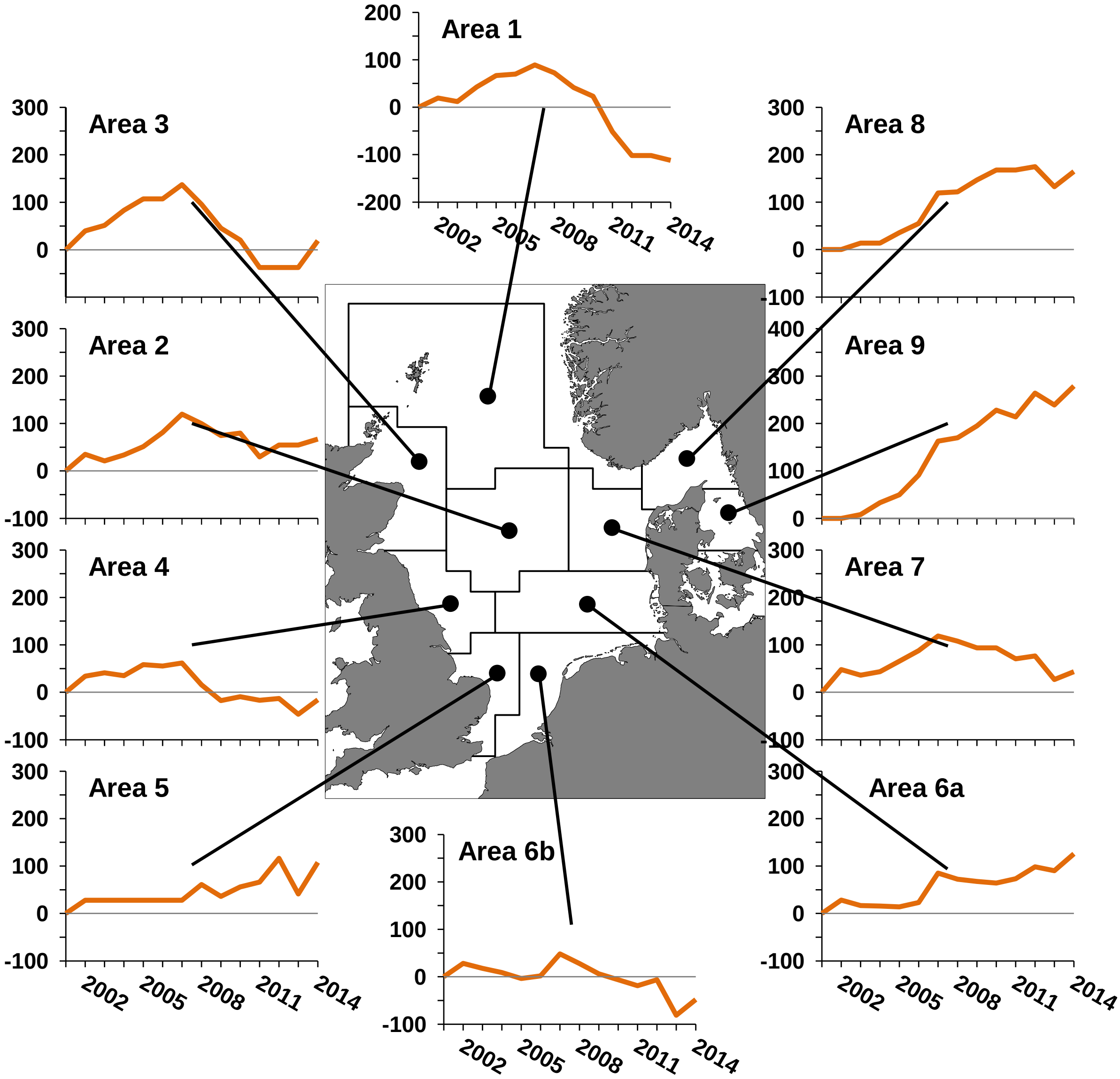

Figure 47 Cumulative time series of index of perceptions of abundance of *Nephrops*, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

Table 29 Numbers of responses by area and category for perceptions of the abundance, size, level of discarding and level of recruitment of *Nephrops*.

	Area									
	1	**2**	**3**	**4**	**5**	**6a**	**6b**	**7**	**8**	**9**
Number	5	4	8	13	3	7	3	9	14	5
Abundance										
Much Less	2	1	0	1	0	0	0	1	1	0
Less	0	0	0	3	0	0	0	0	0	0
No Change	0	0	1	1	0	2	1	3	3	1
More	3	3	5	3	2	5	2	5	9	4
Much More	0	0	2	5	1	0	0	0	1	0
No Answer	0	0	0	0	0	0	0	0	0	0
Size										
Mostly Small	1	1	1	1	0	0	0	4	2	1
All Sizes	3	2	7	9	3	6	3	3	7	3
Mostly Large	1	1	0	1	0	0	0	1	5	1
No Answer	0	0	0	2	0	1	0	1	0	0
Discards										
Much Less	0	0	1	2	0	0	0	0	0	0
Less	0	0	2	4	0	2	0	0	2	1
No Change	5	3	5	5	1	3	1	8	10	3
More	0	1	0	1	2	2	2	1	2	1
Much More	0	0	0	1	0	0	0	0	0	0
No Answer	0	0	0	0	0	0	0	0	0	0
Recruitment										
Low	0	0	0	0	0	0	0	0	1	0
Moderate	1	2	4	9	0	4	1	5	8	3
High	0	0	1	2	1	1	1	1	1	0
Don't Know	3	2	3	0	1	1	1	3	3	1
No Answer	1	0	0	2	1	1	0	0	1	1

Common Sole

Of the 177 valid responses received, 118 (67%) provided information on common (Dover) sole. The proportion of responses providing information on sole was greatest in the southern North Sea (areas 5 & 6b) and the Kattegat (area 9) and lowest in the central and northern North Sea (areas 1 & 2).

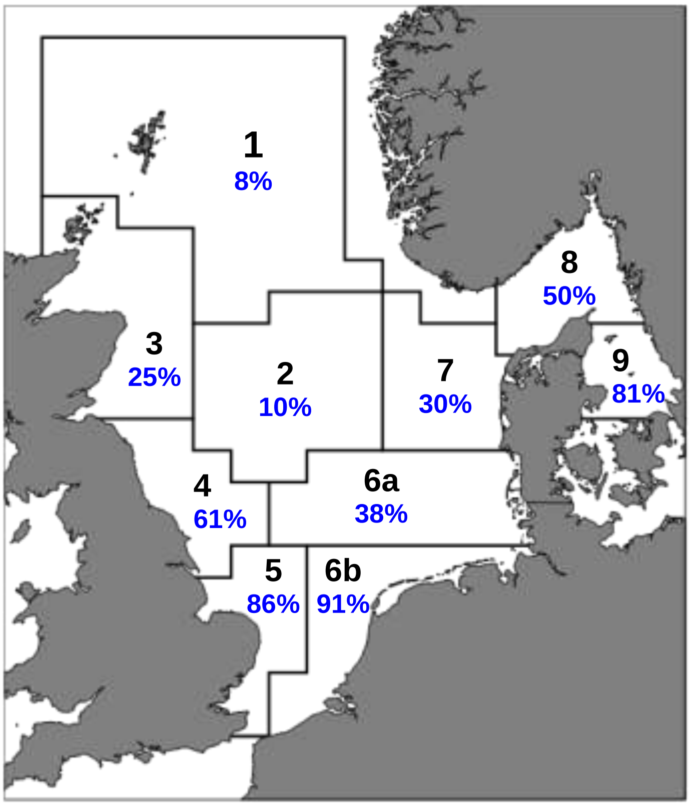

Figure 48 Proportion of responses from each area that provided information on common (Dover) sole.

Table 30 shows the responses broken down by fishing gear and vessel size class. By vessel size, somewhat more responses were received from small (<15 m) vessels, with the remainder equally split between medium-sized (15-24 m) and large (>24 m) vessels. Of the fishing gears, gill nets accounted for the largest proportion of responses, with the remainder roughly equally divided between the other fishing gear types except the seine net.

Figure 49 and Figure 50 provide a more detailed breakdown of the responses for common sole by vessel size and fishing gear.

Table 30 Numbers of responses for common sole by fishing gear type and vessel size class. Percentages show % of vessels in each size class using each gear type (at right), and % of vessels using each gear type in each size class (at bottom). (Excludes vessels that did not provide information on fishing gear and/or vessel size class.)

FISHING GEAR		VESSEL SIZE CLASS: Numbers <15m	15-24m	>24m	ALL	% by Gear Type <15m	15-24m	>24m	ALL
Numbers	Otter Trawl	8	7	3	**18**	17%	21%	9%	15%
	Nephrops Trawl	8	13	0	**21**	17%	38%	0%	18%
	Beam Trawl	0	6	14	**20**	0%	18%	40%	17%
	Pulse Trawl	0	1	18	**19**	0%	3%	51%	16%
	Gill Net	32	6	0	**38**	67%	18%	0%	32%
	Seine Net	0	1	0	**1**	0%	3%	0%	1%
	ALL	**48**	**34**	**35**	**117**	100%	100%	100%	100%
% by Size	Otter Trawl	44%	39%	17%	100%				
	Nephrops Trawl	38%	62%	0%	100%				
	Beam Trawl	0%	30%	70%	100%				
	Pulse Trawl	0%	5%	95%	100%				
	Gill Net	84%	16%	0%	100%				
	Seine Net	0%	100%	0%	100%				
	ALL	41%	29%	30%	100%				

Table 31 Summary of perceptions of the abundance, size, level of discarding and level of recruitment of common sole this year and last year. Proportion of responses in each category for all areas combined this year and last year, and change in proportions (+/-).

Abundance	2013	2014	+/-	Fish Size	2013	2014	+/-
'Less' [1]	27%	24%	-3%	Mostly Small	28%	31%	+3%
No Change	34%	29%	-5%	All Sizes	67%	65%	-1%
'More' [2]	39%	47%	+8%	Mostly Large	5%	3%	-2%
Discards	**2013**	**2014**	**+/-**	**Recruitment**	**2013**	**2014**	**+/-**
'Less' [1]	20%	20%	+1%	Low	16%	13%	-3%
No Change	52%	58%	+6%	Moderate	44%	42%	-2%
'More' [2]	28%	21%	-7%	High	40%	45%	+5%

[1] 'Less' = sum of 'Less' and 'Much Less' responses.
[2] 'More' = sum of 'More' and 'Much More' responses.

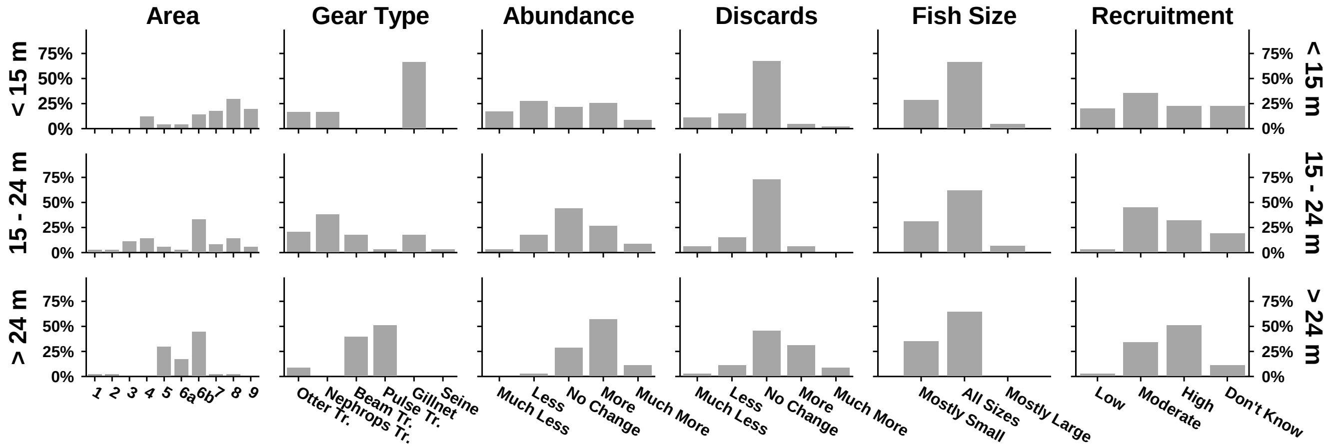

Figure 49 Breakdown of responses for common sole by fishing vessel size class. Percentage of responses for each size class in each category.

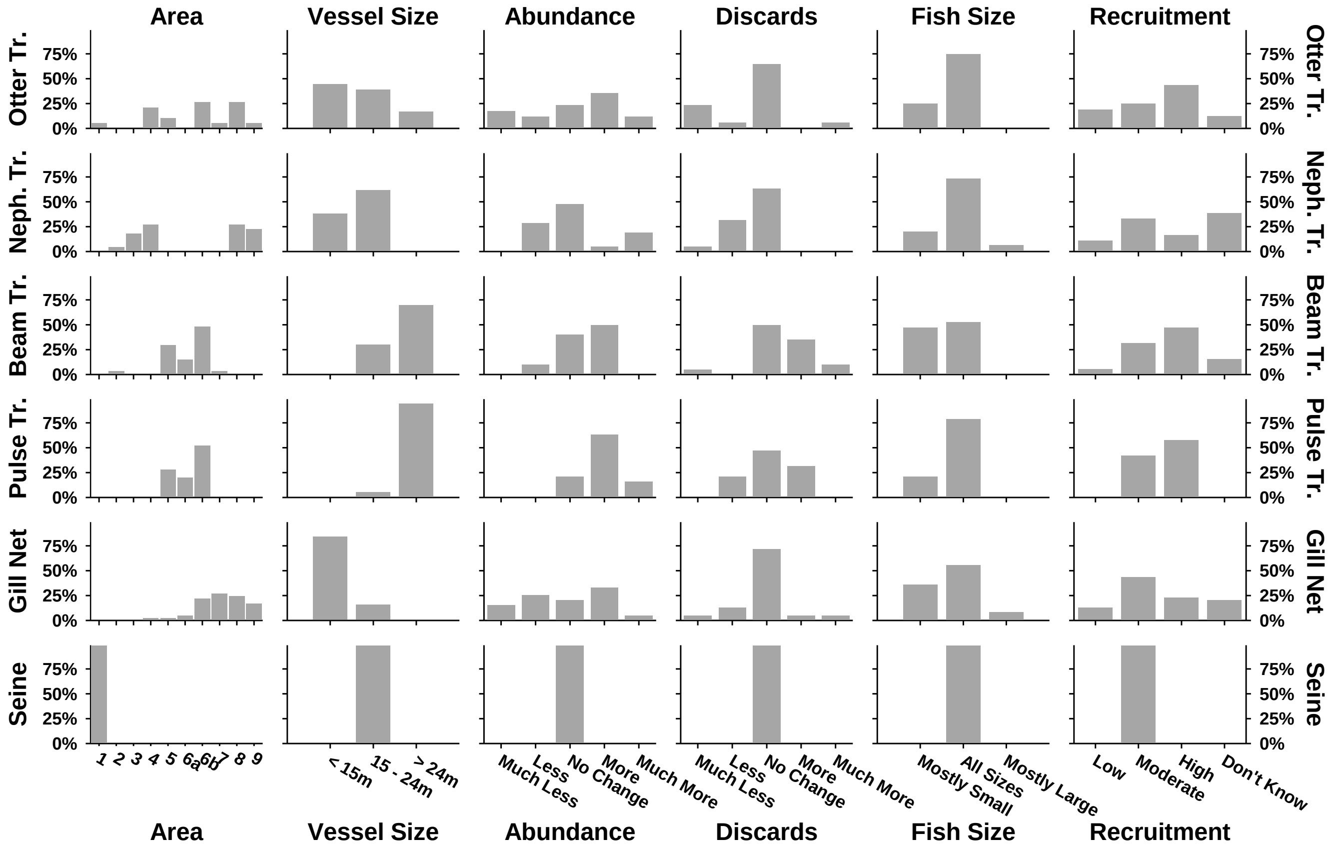

Figure 50 Breakdown of responses for common sole by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

Abundance

Almost half of responses reported a greater abundance of sole in 2014 (Table 31), an increase on 2013. Of the remaining responses, slightly more reported no change in the abundance of sole in 2014, than a lower abundance, with small declines in both.

No clear pattern was apparent in responses across individual areas (Figure 52).

The cumulative index of perceptions of the abundance of common sole (Figure 53) increased in about half of the areas (mainly in the south and east), but declined or remained the same in the others.

Size Range

Two-thirds of responses reported catching all sizes of sole in 2014 (Table 31), almost unchanged from 2013. Most of the remaining responses reported mostly small sole in 2014, slightly more than in 2013.

Across individual areas (Figure 52), all sizes of sole were most commonly reported across most areas. Mostly small sole tended to be most commonly reported in southern and eastern areas.

Discards

More than half of responses reported no change in the level of discards of sole in 2014 (Table 31), somewhat more than in 2013. The remaining responses were equally split between reporting lower and higher levels of discards, with a small fall in the latter.

Across individual areas most responses reported no change in the level of discards (Figure 52). Higher levels of discarding tended to be most commonly reported in the south and east and lower levels in the west.

Recruitment

The majority of responses reported moderate or high levels of recruitment of sole in 2014 (Table 31), with similar proportions of responses in each category. The proportion reporting high levels of recruitment was slightly greater than in 2013, while there were small falls in the other categories.

No clear pattern was apparent in responses across individual areas (Figure 52).

Comparison with ICES Stock Assessment

There was no evidence of a relationship between the sole abundance index derived from the Fishers' North Sea Stock Survey index and the ICES estimates of the sole spawning stock biomass (Figure 51).

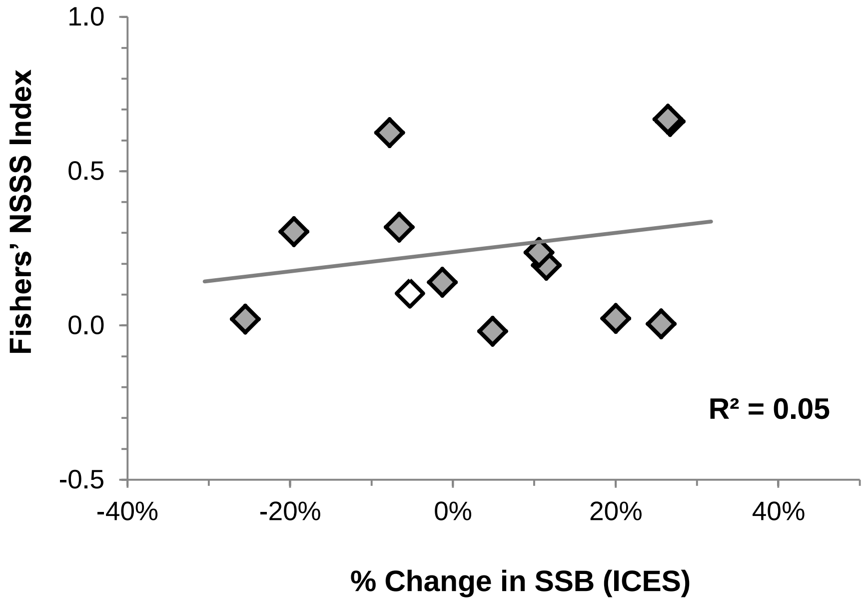

Figure 51 Plots of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea common sole spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination. Unshaded points are based on the predicted SSB for 2015. (R^2; values closer to 1 indicate a better agreement.)

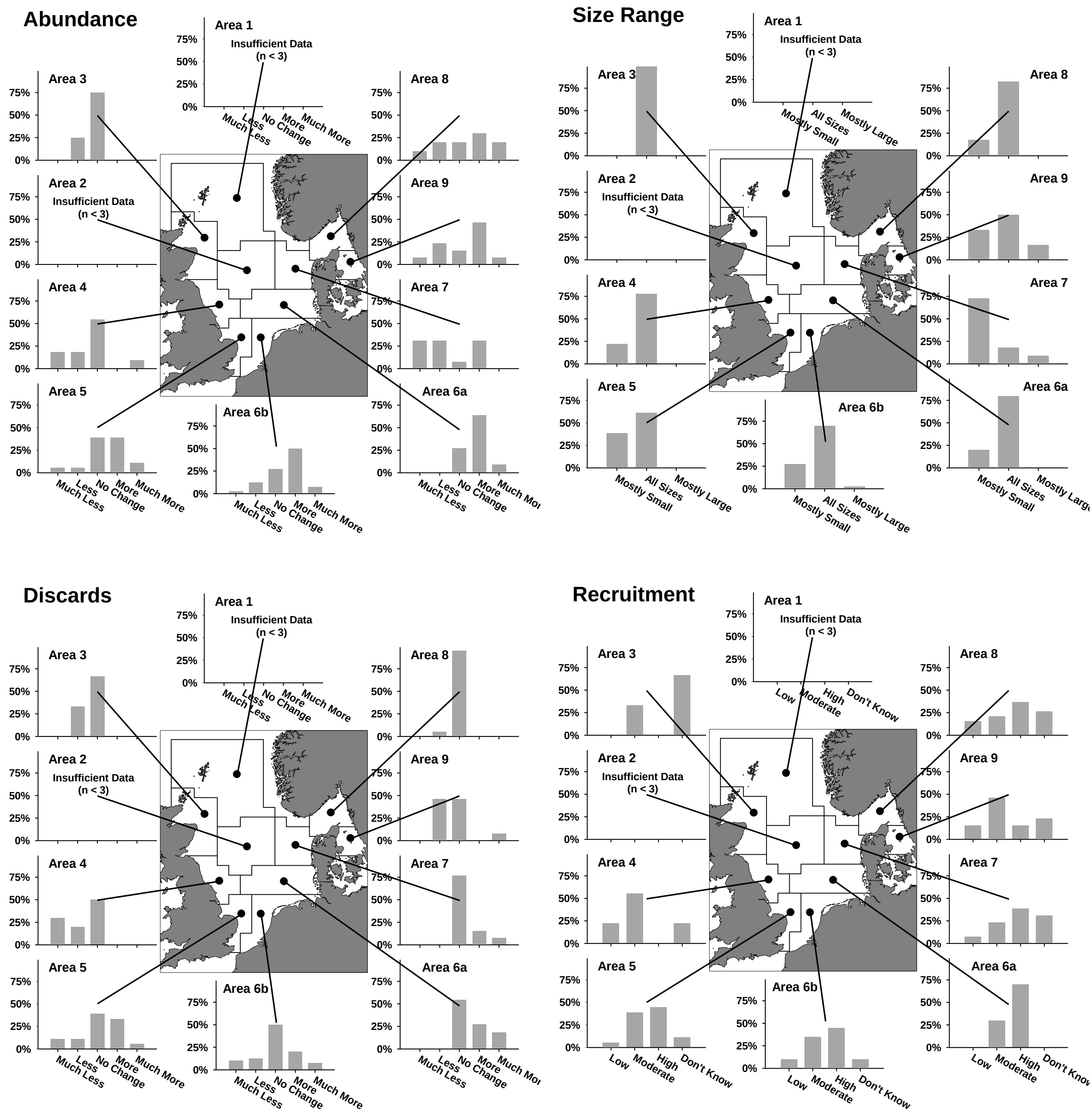

Figure 52 Perceptions of the abundance and size range of common sole, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category. No results are shown for Areas 1 and 2 due to the small number of responses from those areas (see Table 11, p. 28).

Abundance Index

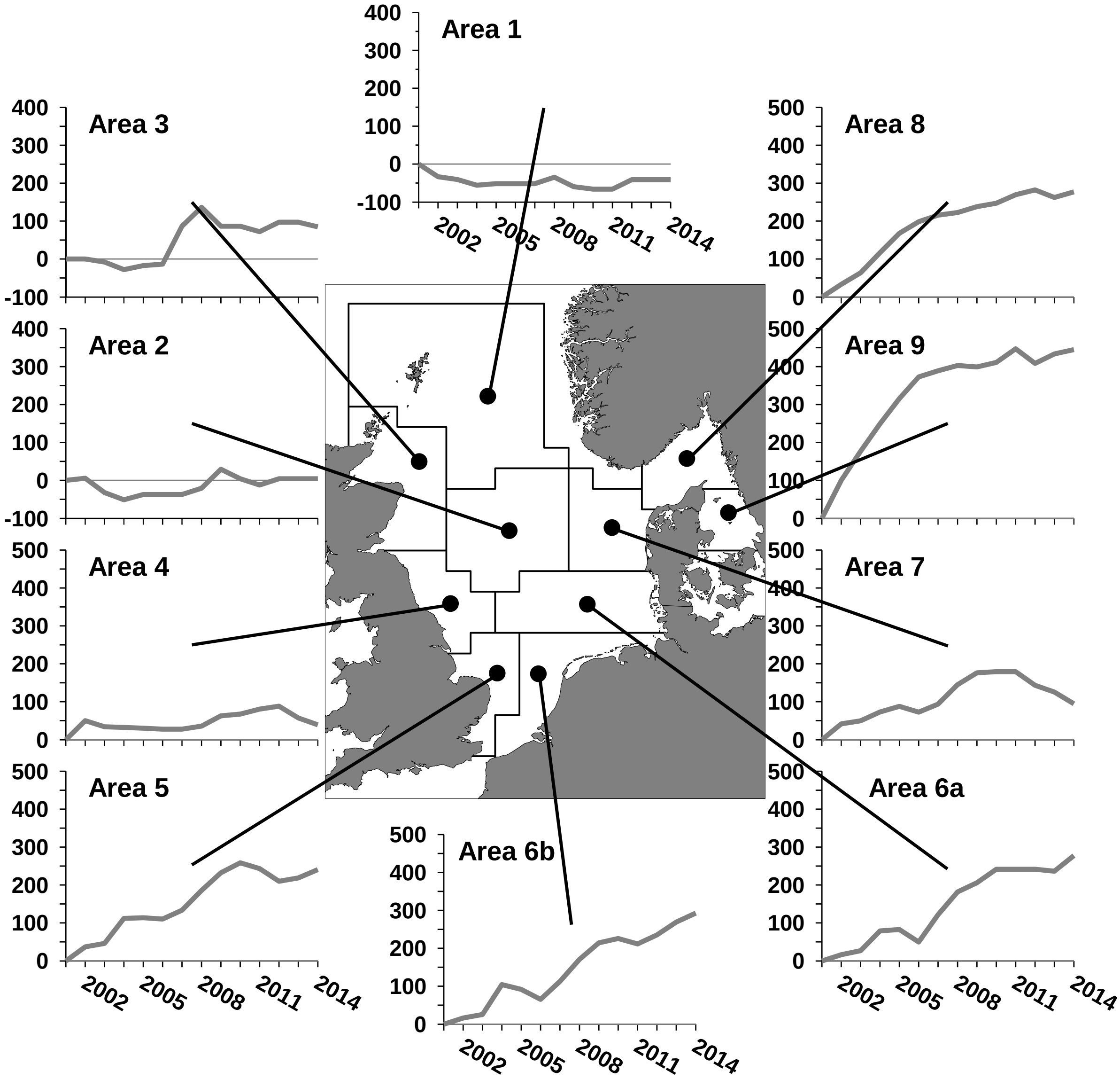

Figure 53 Cumulative time series of index of perceptions of abundance of common sole, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

Table 32 Numbers of responses by area and category for perceptions of the abundance, size, level of discarding and level of recruitment of common sole in 2011.

	Area									
	1	**2**	**3**	**4**	**5**	**6a**	**6b**	**7**	**8**	**9**
Number	2	2	4	11	18	11	40	13	21	13
Abundance										
Much Less	0	0	0	2	1	0	1	4	2	1
Less	0	1	1	2	1	0	5	4	4	3
No Change	2	0	3	6	7	3	11	1	4	2
More	0	1	0	0	7	7	20	4	6	6
Much More	0	0	0	1	2	1	3	0	4	1
No Answer	0	0	0	0	0	0	0	0	1	0
Size										
Mostly Small	0	1	0	2	7	2	11	8	3	4
All Sizes	1	1	1	7	11	8	28	2	14	6
Mostly Large	0	0	0	0	0	0	1	1	0	2
No Answer	1	0	3	2	0	1	0	2	4	1
Discards										
Much Less	0	0	0	3	2	0	4	0	0	0
Less	0	1	1	2	2	0	5	0	1	6
No Change	2	0	2	5	7	6	20	10	19	6
More	0	0	0	0	6	3	8	2	0	0
Much More	0	1	0	0	1	2	3	1	0	1
No Answer	0	0	1	1	0	0	0	0	1	0
Recruitment										
Low	0	1	0	2	1	0	4	1	3	2
Moderate	1	0	1	5	7	3	14	3	4	6
High	0	1	0	0	8	7	18	5	7	2
Don't Know	1	0	2	2	2	0	4	4	5	3
No Answer	0	0	1	2	0	1	0	0	2	0

Plaice

Of the 177 valid questionnaires received, 157 (89%) provided information on plaice. The proportions of responses providing information on plaice was fairly high in most areas (Figure 54), except area 3.

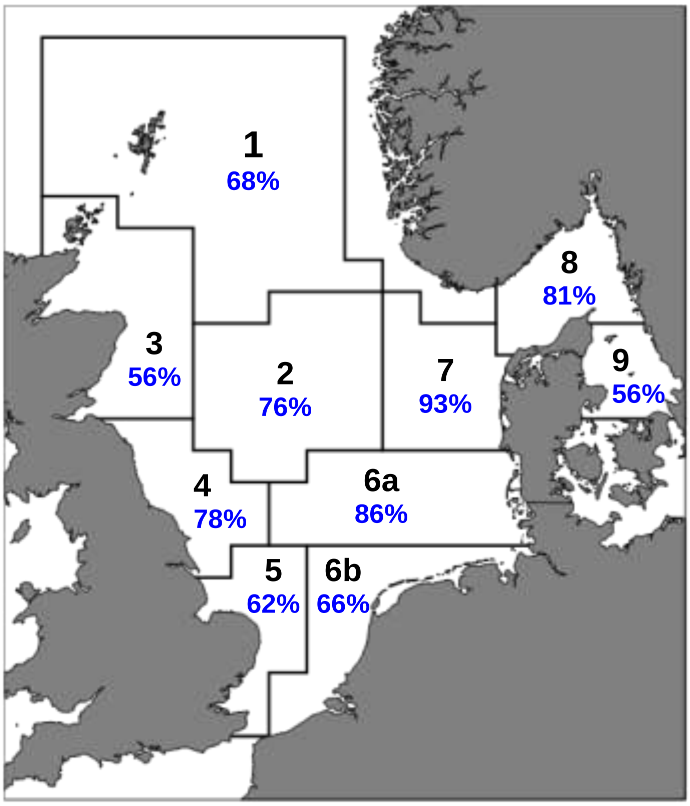

Figure 54 Proportion of responses from each area that provided information on plaice.

Table 33 shows the responses broken down by fishing gear and vessel size class. Responses were fairly evenly divided between the three vessel size classes. Otter trawls accounted for the largest proportion of responses by fishing gear type, followed by gill nets, with most of the remaining responses roughly equally split between the other gear types (except seine nets).

Figure 55 and Figure 56 provide a more detailed breakdown of the responses for plaice by vessel size and fishing gear.

Table 33 Numbers of responses for plaice by fishing gear type and vessel size class. Percentages show % of vessels in each size class using each gear type (at right), and % of vessels using each gear type in each size class (at bottom). (Excludes vessels that did not provide information on fishing gear and/or vessel size class.)

		VESSEL SIZE CLASS							
		Numbers				% by Gear Type			
FISHING GEAR		<15m	15-24m	>24m	ALL	<15m	15-24m	>24m	ALL
Numbers	Otter Trawl	11	21	15	**47**	22%	39%	29%	30%
	Nephrops Trawl	8	16	1	**25**	16%	30%	2%	16%
	Beam Trawl	0	6	14	**20**	0%	11%	27%	13%
	Pulse Trawl	0	1	17	**18**	0%	2%	33%	12%
	Gill Net	31	5	0	**36**	62%	9%	0%	23%
	Seine Net	0	5	5	**10**	0%	9%	10%	6%
	ALL	**50**	**54**	**52**	**156**	100%	100%	100%	100%
% by Size	Otter Trawl	23%	45%	32%	100%				
	Nephrops Trawl	32%	64%	4%	100%				
	Beam Trawl	0%	30%	70%	100%				
	Pulse Trawl	0%	6%	94%	100%				
	Gill Net	86%	14%	0%	100%				
	Seine Net	0%	50%	50%	100%				
	ALL	32%	35%	33%	100%				

Table 34 Summary of perceptions of the abundance, size, level of discarding and level of recruitment of plaice this year and last year. Proportion of responses in each category for all areas combined this year and last year, and change in proportions (+/-).

Abundance	2013	2014	+/-	Fish Size	2013	2014	+/-
'Less' [1]	15%	14%	-1%	Mostly Small	24%	27%	+3%
No Change	21%	27%	+6%	All Sizes	70%	65%	-4%
'More' [2]	64%	59%	-5%	Mostly Large	6%	7%	+1%
Discards	**2013**	**2014**	**+/-**	**Recruitment**	**2013**	**2014**	**+/-**
'Less' [1]	14%	12%	-2%	Low	5%	3%	-2%
No Change	61%	62%	+1%	Moderate	43%	42%	-1%
'More' [2]	24%	26%	+2%	High	52%	55%	+3%

[1] 'Less' = sum of 'Less' and 'Much Less' responses.
[2] 'More' = sum of 'More' and 'Much More' responses.

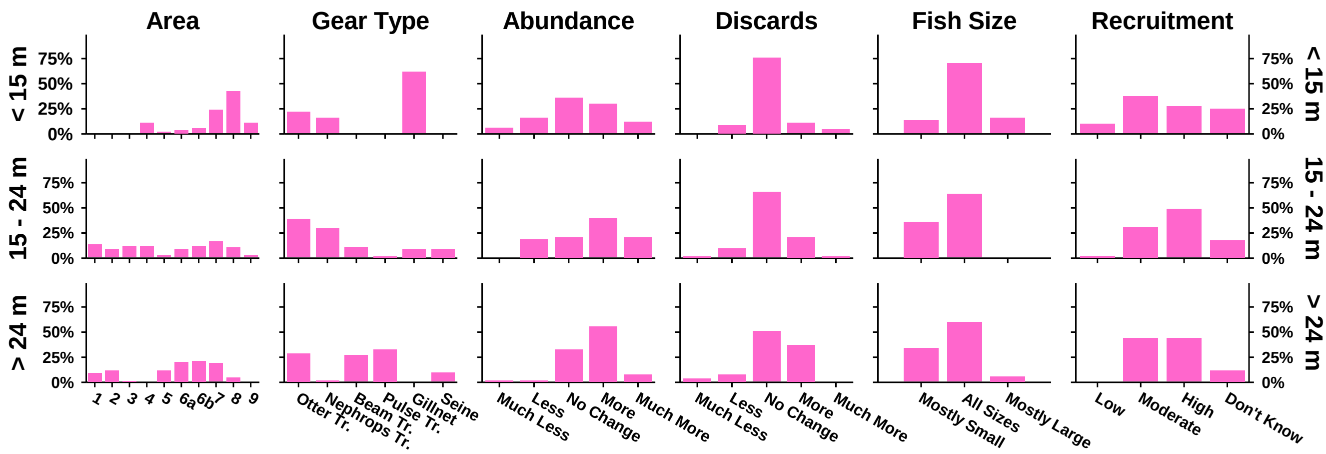

Figure 55 Breakdown of responses for plaice by fishing vessel size class. Percentage of responses for each size class in each category.

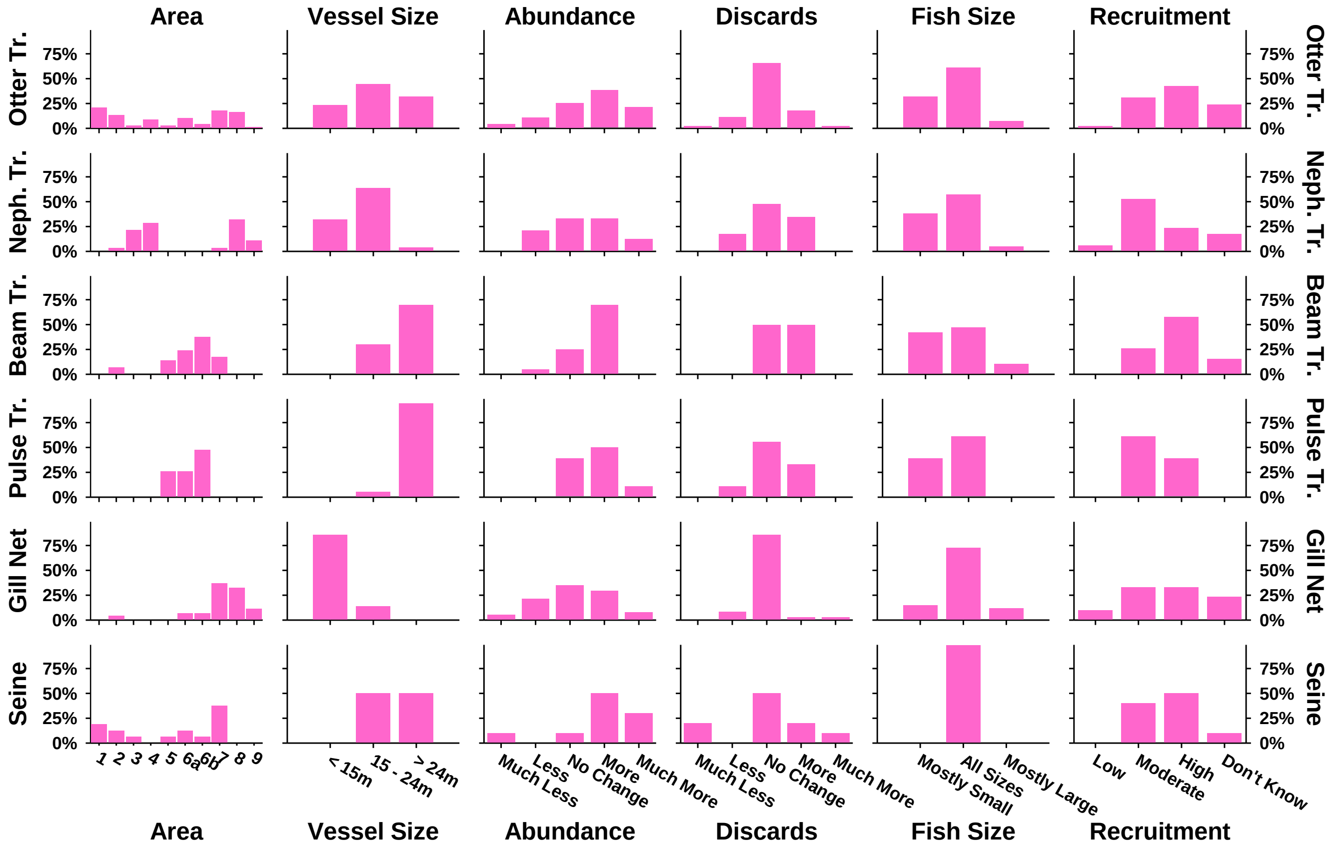

Figure 56 Breakdown of responses for plaice by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

Abundance

More than half of responses reported a higher abundance of plaice in 2014 (Table 34), slightly less than in 2013. There was a similar increase, to about one quarter, in the proportion reporting no change in abundance in 2014, while the proportion reporting fewer plaice was almost unchanged from 2013.

No clear pattern was apparent in the responses across individual areas (Figure 58).

The cumulative index of perceptions of the abundance of plaice (Figure 59) increased in all but one area (area 4).

Size Range

Two-thirds of responses reported catching all sizes of plaice in 2014 (Table 34), slightly less than in 2013. One-quarter of responses reported mostly small plaice in 2013, slightly more than in 2014, while the (small) proportion reporting mostly small plaice was almost unchanged.

The pattern of responses was broadly similar across all individual areas (Figure 58), with no clear spatial patterns apparent.

Discards

Almost two-thirds of responses reported no change in the level of discarding of plaice in 2014 (Table 34), almost unchanged from 2013. About one-quarter of responses reported higher levels of plaice discarding in 2014, again almost unchanged from 2013, as was the proportion reporting lower levels of discards.

Most responses in most individual areas reported no change in the level of plaice discarding (Figure 58), but no clear pattern was apparent in the other responses.

Recruitment

More than half of responses reported high levels of recruitment of plaice in 2014 (Table 34), slightly more than in 2013, with most of the remainder reporting moderate levels.

The picture was mixed across individual areas (Figure 58), with no clear pattern apparent.

Comparison with ICES Stock Assessment

No real relationship was apparent between the plaice abundance index derived from the Fishers' North Sea Stock Survey and the ICES estimates of the North Sea plaice spawning stock biomass (Figure 57).

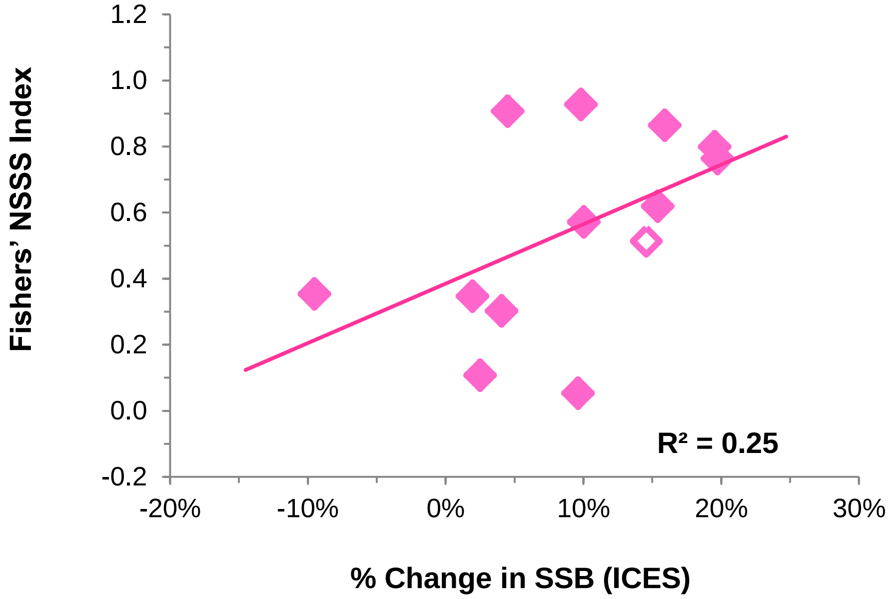

Figure 57 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea plaice spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination (R^2; values closer to 1 indicate a better agreement). The unshaded point is based on the predicted SSB for 2015.

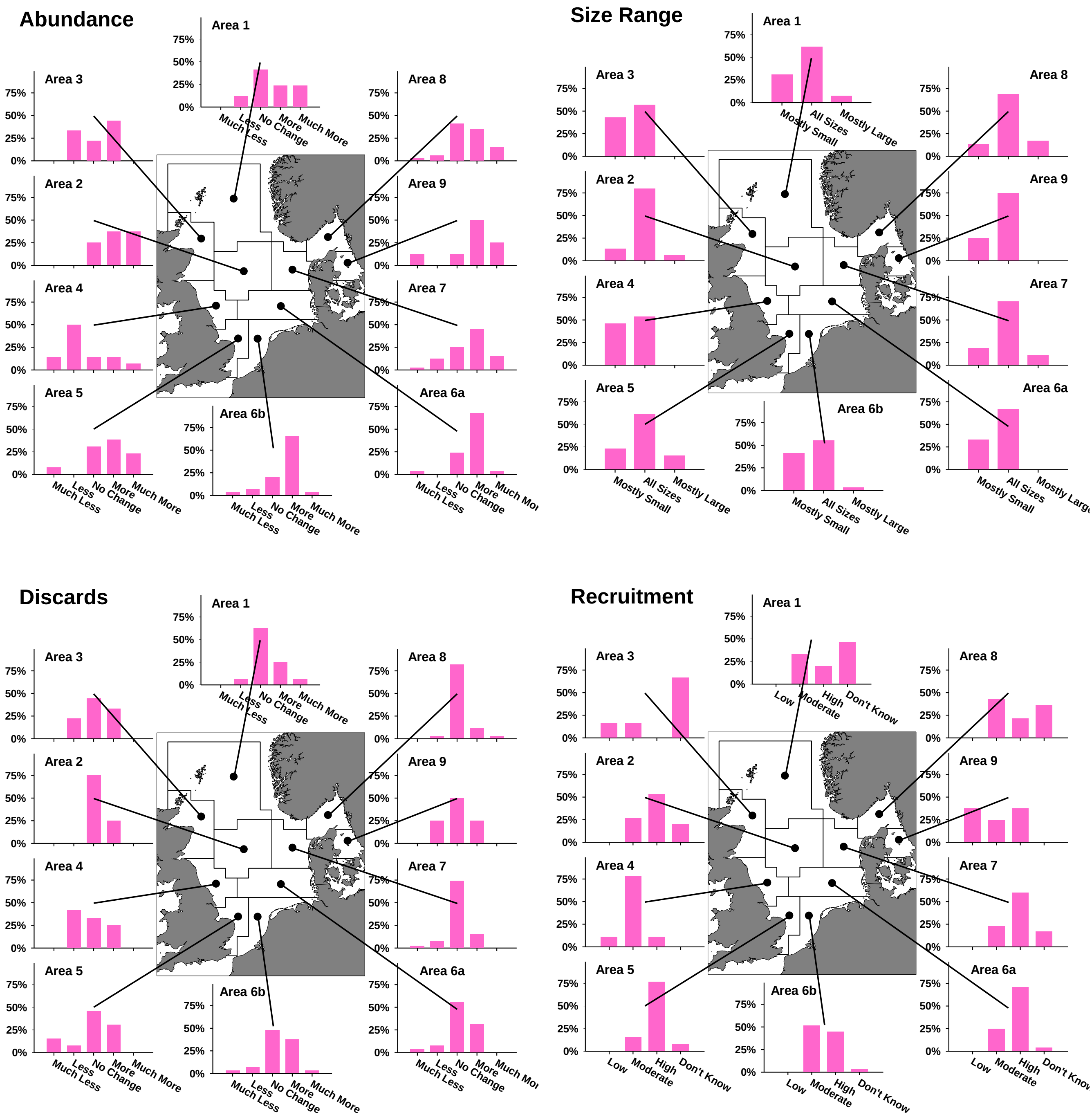

Figure 58 Perceptions of the abundance and size range of plaice, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category.

Abundance Index

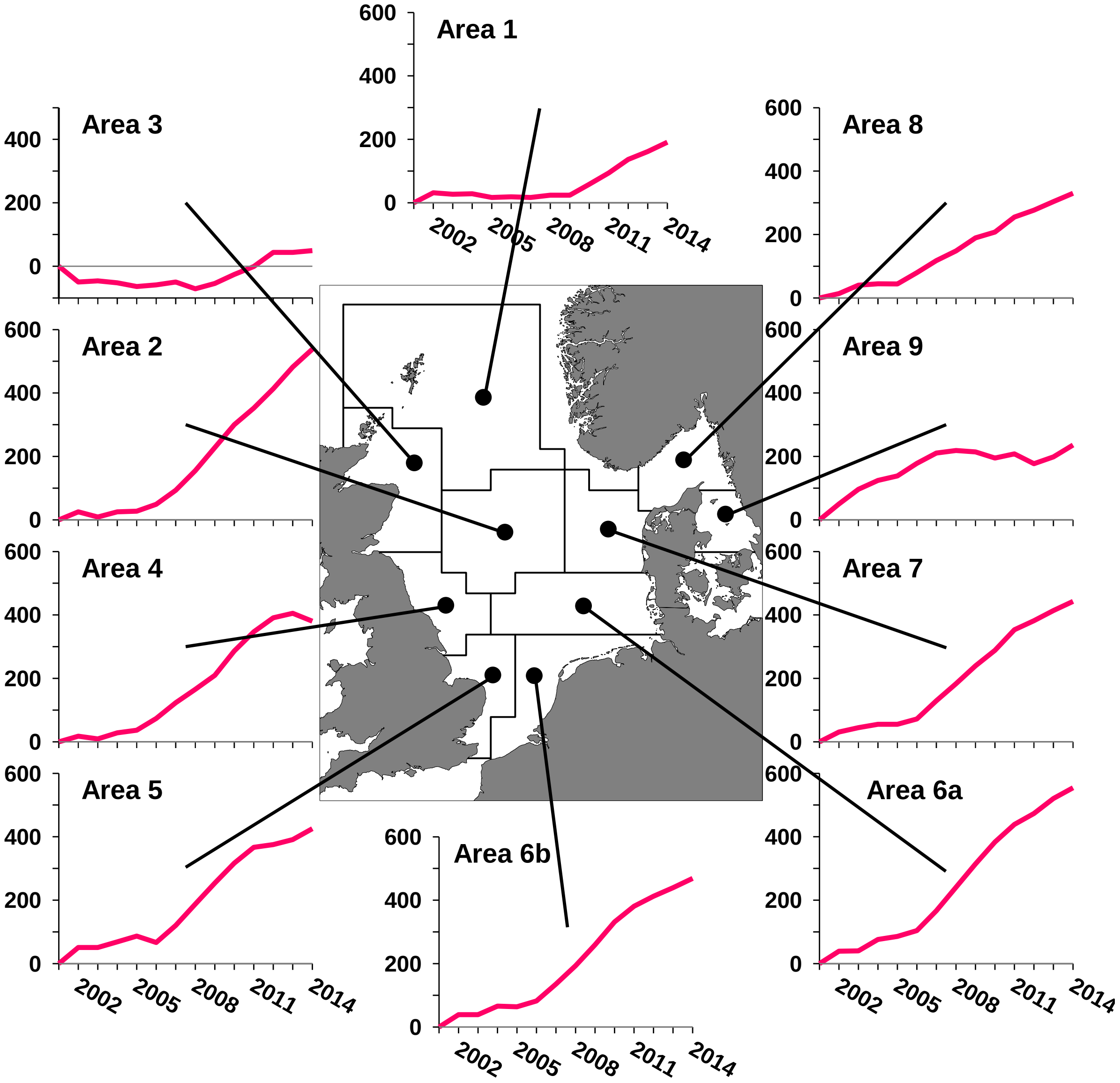

Figure 59 Cumulative time series of index of perceptions of abundance of plaice, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

Table 35 Numbers of responses by area and category for perceptions of the abundance, size, level of discarding and level of recruitment of plaice.

	Area									
	1	**2**	**3**	**4**	**5**	**6a**	**6b**	**7**	**8**	**9**
Number	17	16	9	14	13	25	29	40	34	9
Abundance										
Much Less	0	0	0	2	1	1	1	1	1	1
Less	2	0	3	7	0	0	2	5	2	0
No Change	7	4	2	2	4	6	6	10	14	1
More	4	6	4	2	5	17	19	18	12	4
Much More	4	6	0	1	3	1	1	6	5	2
No Answer	0	0	0	0	0	0	0	0	0	1
Size										
Mostly Small	4	2	3	6	3	8	12	7	4	2
All Sizes	8	12	4	7	8	16	16	26	20	6
Mostly Large	1	1	0	0	2	0	1	4	5	0
No Answer	4	1	2	1	0	1	0	3	5	1
Discards										
Much Less	0	0	0	0	2	1	1	1	0	0
Less	1	0	2	5	1	2	2	3	1	2
No Change	10	12	4	4	6	14	14	29	27	4
More	4	4	3	3	4	8	11	6	4	2
Much More	1	0	0	0	0	0	1	0	1	0
No Answer	1	0	0	2	0	0	0	1	1	1
Recruitment										
Low	0	0	1	1	0	0	0	0	0	3
Moderate	5	4	1	7	2	6	15	8	12	2
High	3	8	0	1	10	17	13	21	6	3
Don't Know	7	3	4	0	1	1	1	6	10	0
No Answer	2	1	3	5	0	1	0	5	6	1

Comparison of Areas

Economic Parameters

The economic parameter index values (Figure 60) were - with the exception of changes in getting or retaining crew - universally negative across all areas. The index values suggest that in general perceptions of economic parameters tended to be most negative in the east (areas 7, 8 & 9) and north west (areas 1 & 3) and least negative in the south (areas 5, 6a & 6b).

Species Parameters

The species-based parameter indices (Figure 61) were more variable between areas, with less evidence of clear spatial patterns. The abundance and recruitment indices tended to be broadly similar across all areas, but the size range and discards indices were more variable.

The overall species parameter index was also broadly similar across all areas.

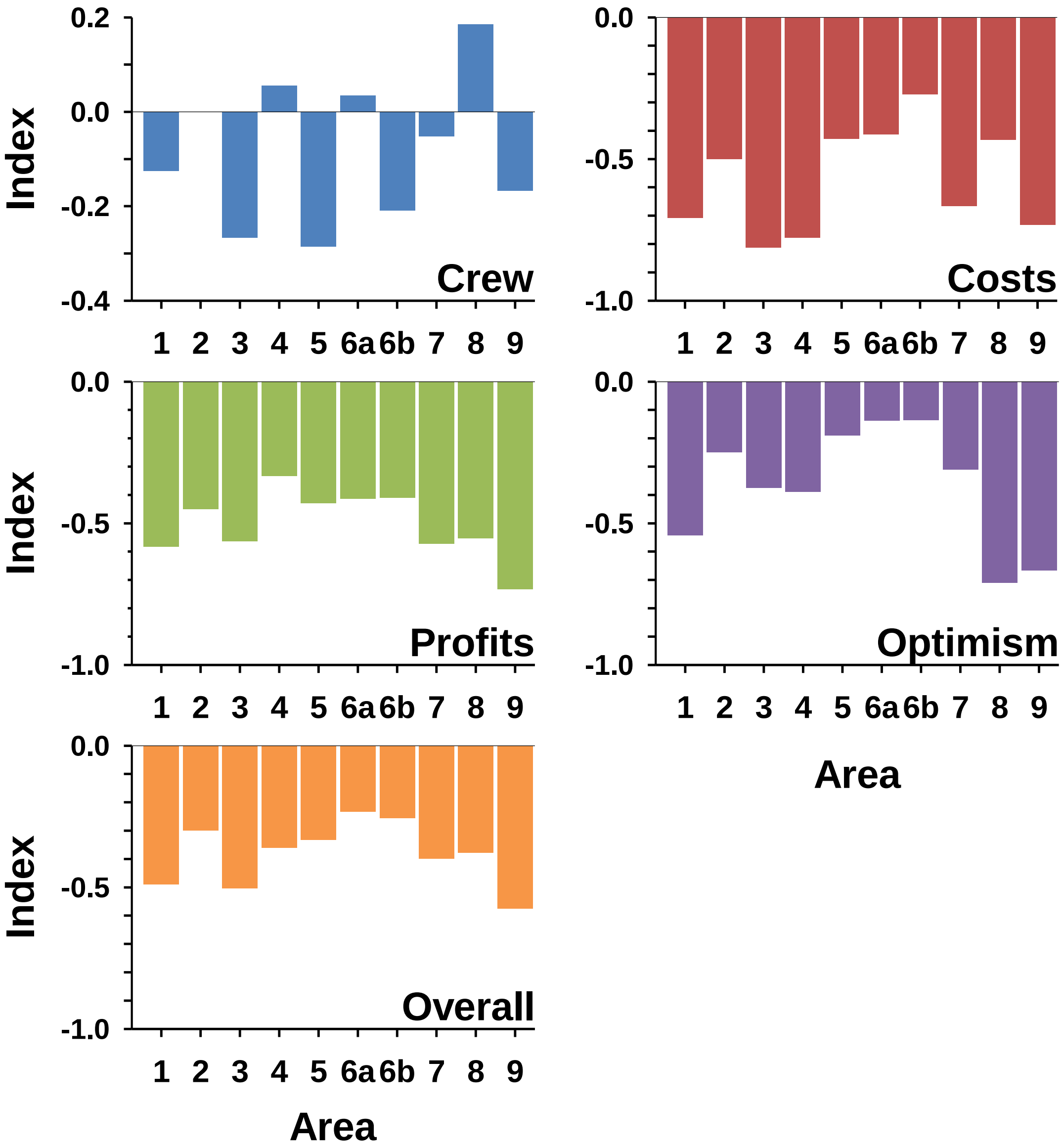

Figure 60 The indices of economic parameters for each area: perceptions of changes in difficulty of getting / retaining crew; costs, profits, optimism, and overall average economic parameter index. Negative index values indicate a more negative perception (e.g. higher costs, lower profits, etc.). See p. 15 for explanation of the indices.

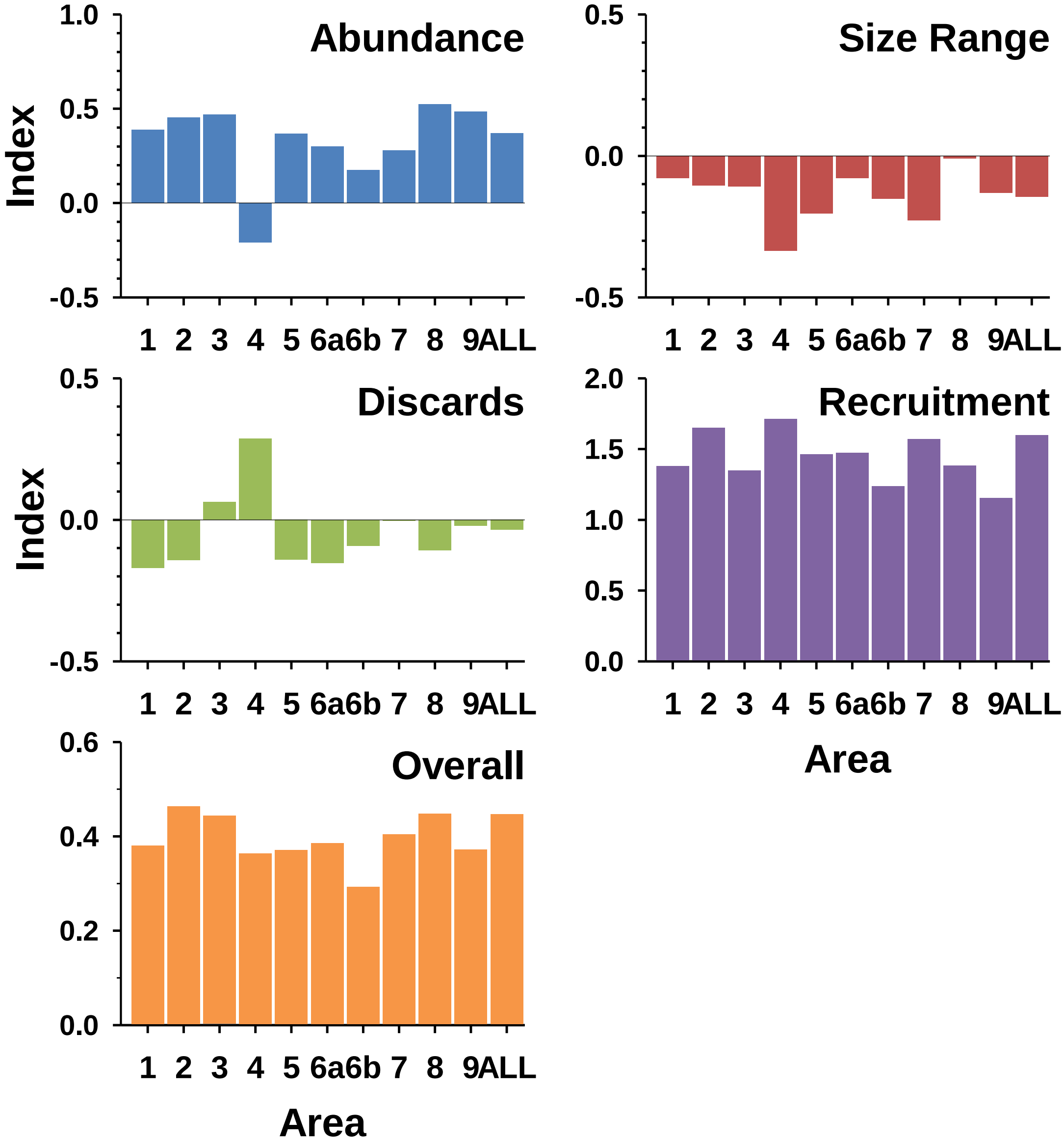

Figure 61 The indices for each area of perceptions of changes in the abundance of fish, the size range of fish caught, the levels of discards and the levels of recruitment. Negative index values indicate a more negative perception (e.g. lower abundance, higher discards, etc.). See p. 15 for explanation of the indices.

General Remarks

This report presents the results of an analysis of the data collected through the Fishers' North Sea Stock Survey in 2014. Given the non-quantitative and subjective nature of this survey these results need to be interpreted and used with caution. Given the constraints of time and resources it has not been possible to fully analyse or explore all of the possible permutations of fish species, areas, fishing gear, vessel sizes and nationalities.

One disadvantage of this form of survey is that it only provides information on perceived changes; it does not tell us anything about absolute levels. For example, it can tell us whether fishermen think their costs this year were higher or lower than last year, but not how high those costs actually are. For this reason, further caution is necessary in interpreting the results; a decline in the proportion of fishermen reporting high costs might look like a positive result, but if their costs remain very high those fishermen may still face economic difficulties.

Overall, the number of (valid) questionnaires returned increased in 2014, almost (but not entirely) reversing the fall seen in 2013. Despite this increase the number of responses received remained the second lowest since the survey was started and remains relatively small in relation to the number of active fishermen in the areas covered by the survey.

Anecdotal evidence in previous years suggests that a factor behind the decline in the number of responses over recent years may be that fishers do not perceive that the results of the survey have any influence on assessments of fish stocks or on management decisions, and thus are losing faith in the value of the survey.

Overall, the results of the 2014 survey appear to be fairly positive in terms of the state of fish stocks. For four of the eight stocks covered by the survey most responses reported higher abundances in 2014 than in 2013, while for the other four most responses reported no change in abundance.

For all species the majority of responses reported catching all sizes of fish, no change in the level of discards and moderate or high levels of recruitment.

Fishermen's perceptions of economic circumstances in 2014 were fairly negative (as is usual), with most responses reporting higher costs, lower profits, less optimism and more difficulty in getting or retaining crew.

The comparison of fishermen's perceptions of changes in the abundance of fish and the scientific assessments of their abundance showed at least some level of agreement in some cases, although the relationship was often weak in statistical terms. The difficulty of interpreting theses comparisons remains, especially when the two do not agree (which raises the question of which is ‘right’).

NEFMC SSC Panel Peer Review of the Fishery Data for Stock Assessment Working Group Report

Patrick J. Sullivan (Chair), Hirotsugu Uchida, John Wiedenmann

November 30, 2018

Hotel Providence, Providence, RI

Introduction

A panel of three representatives (Sullivan, Uchida, and Wiedenmann) from the Scientific and Statistical Committee of the New England Fisheries Management Council were asked to provide a peer review of the *Fishery Data for Stock Assessment Working Group Report* coauthored by Cadrin (Chair), Frede, Keiley, Linton, Maguire, Rago, Bell, Giacalone, Demarest, Brown and Gibson with contributions by O'Keefe, DeCelles, Wright, Hansell, McGuire and Hennen.

The panel found the Working Group Report to be clear and thorough in its coverage of the strengths and weaknesses of information collected from fishery dependent sources such as might be derived from commercial and recreational landing statistics, logbooks, vessel trip reports, onshore monitoring and observer programs. Particular attention was given to the usefulness and biases associated with Catch Per Unit Effort (CPUE) and Landings Per Unit Effort (LPUE) data as might be employed to assess relative changes in stock abundance to supplement federal or state survey CPUE indices. The quality and usefulness of discard data collected from the fishery, although an important category of fishery dependent data, are not addressed in this review, as these data sources were not included for consideration in the Terms of Reference for the Working Group Report and will be considered elsewhere[1].

The Working Group Report, through its executive summary, the main body of the report, and adjoining appendices, provides a clear and concise summary of the complex topic of how fishery data is gathered and utilized for the purposes of informing science and management actions. In contrast, federal and state scientific surveys collect information through a proscribed unbiased statistical design to obtain relative abundance indices (e.g. survey CPUE) that are intended to be representative of the population over its entire domain, while gathering other pertinent biological information in an unbiased manner such as age, size and sex composition, growth, maturity and fecundity. Data gathered from fishery dependent sources, while abundant and rich in information, may not be, more specifically, globally representative of the total stock dynamics because of economic incentives for fishermen to maximize harvest and consequently be more likely to "sample" areas that are higher in abundance. Nevertheless, fishery dependent data is

[1] The Peer Review acknowledges the Council is considering potential improvements to monitoring and collection of discard data in the development of Amendment 23.

an abundant, rich and often underutilized source of information worth careful examination.

Responses to the Terms of Reference

This peer review report will step through each Term of Reference and comment on the completeness of the report and how well it addresses the strengths and weakness of the fishery dependent data.

TOR1: *Explain how fishery dependent and fishery independent data are used in stock assessments, including how different data elements are used and interact in an age-based analytic assessment.*

The report clearly explains how fishery dependent and fishery independent data are used in fishery stock assessments. Both data sources are used in a variety of ways including the estimation of population relative abundance indices that are used to characterize trends in age-based and other analytic assessment methods. In New England, stock assessments often rely on standardized statistically designed surveys using abundant survey information. Other regions, that do not have regular standardized surveys often rely solely on fishery dependent data sources, while still other regions, such as in the North Pacific, often incorporate both. The reasons for this are partly historical, partly philosophical and partly practical. However, the advances now being made in how data are collected and analyzed suggests that further consideration be given to using fishery dependent data not only to supplement existing survey-based relative abundance indices, but also to provide more localized abundance data to inform spatial management, for example, and to usefully characterize how the fleet sees changes in population abundance relative to survey estimates.

A classic example of how fishery dependent data can be susceptible to bias associated with targeting behavior is the CPUE used for assessment that came from the herring purse seine fishery in the North Atlantic. Here, because the fish school, the perceived CPUE did not change as the stock decreased, because the fleet continued to be able to find schools to set on until no more schools were left. The abundances within a school remained the same while the number of schools decreased. Managers were unintentionally misled about stock status and the stock collapsed. This example is not uncommon in occurrence and is often used to justify scientific survey sampling as the gold standard. However, fishery dependent data serves to inform as well.

While fishery dependent data, such as CPUE, can, under the right circumstances, be folded into the more comprehensive designed scientific surveys, as discussed in more detail later, it is useful to consider other information that may come from fishery dependent data sources. For example, greater focus is being given to understanding the social and economic consequences of risk and decision making relative to fishing behavior and responses to management actions. This is because fishermen are guided by economic incentives. For commercial fisheries this would be primarily the (expected) profit; for recreational fisheries this would be more vaguely captured as “utility” – number of fish kept or caught (kept + release), spending time on water, hanging out with friends, etc. Understanding these incentives and developing the behavioral models could reduce the biases of fishery dependent data and hence enhance the usefulness of CPUE data. However, this requires the collection of socioeconomic information on fisheries, which is typically available through fishery dependent data sources. Note that this type of information not only can be used to help correct for targeting biases, but can be used directly to reduce risk to the fishery and optimize management actions.

Should fishery dependent data be considered for expanded use in New England, data handling and quality assurance procedures already in use in areas outside the northeast might be considered (e.g. SEDAR, STAR) as was noted in the Working Group Report.

Again, to echo observations made in the Working Group Report, technological advances in terms of computational and data gathering hardware and software can greatly improve the acquisition and use of fishery dependent data.

TOR 2: *Summarize the theoretical utility and limitations of using catch per unit effort (CPUE) and landings per unit effort (LPUE) as indexes of abundance for Northeast multispecies (groundfish) stocks, including recent efforts to create a CPUE for any of these stocks and the results of those efforts.*

The Working Group Report provides a thorough consideration of the pros and cons of using fishery independent and fishery dependent catch rates. The summaries provided of examples of where and when CPUE from both sources was used was seen to be valuable.

Consideration of the use of CPUE from any source requires recognition of the potential utility of CPUE and fishery and survey data more generally beyond its specific use as a relative abundance index for tuning assessment models. For example, it is important to recognize that catch by itself is necessary and effort by itself is informative relative to spatial and temporal fishing pressure, and that CPUE can be used to examine local catch rates and reasons why fishers make the choices they make. Furthermore, the quality of information that comes out of CPUE measurements from fishery dependent data includes providing information that can be shared with the assessment community about what the fishermen are seeing in their landings relative to what the scientists might see from their data sources.

In any quest for new or additional information some effort should be spent on examining the costs relative to the benefits of collecting that information. Special attention should be given to examining elements of the fishery that may act as a greater source of information, for example, sub-fleets representing fishing vessels and captains that have been consistently operating over time.

In thinking beyond relative abundance indices, consideration should be given to whether fishery dependent CPUE might be used to better assess discard species, for example in the groundfish fishery, the non-target bycatches of windowpane flounder and ocean pout, or constraining stocks such as Georges Bank yellowtail flounder.

Fishery dependent CPUE can be used in some instances when fishery independent data is not available, such as for assessing inshore measures of relative abundance. Cooperative surveys are also helpful in this regard.

Model-based statistical estimation methods (e.g. GLM, GLMM, GAM, GAMM) have advanced greatly in recent years and can be used to augment and even merge fishery dependent data with fishery independent data.

TOR 3: *Identify the fishery factors and fishery dependent data needed to create a CPUE that would be a reliable index of abundance for Northeast multispecies stocks – without regard to existing fishing practices, regulations, or monitoring systems.*

As mentioned in the report, ideally one would like to have the fleet be homogenous (uniform) in fishing power, gear used, timing, and location. In many cases, not all of these criteria can be met or even standardized for all fisheries, but in some cases they can.

There is an expected change in efficiency with catch shares that could be taken advantage of, but may also add an extra level of complexity; for example, what impact do catch-share programs and other incentives have on the technical efficiency of the fleet (e.g. sharing captains, or reduced number of vessels fishing)?

While it may be impossible to manage the fleet in such a way as to make it fully homogenous in behavior, other approaches to this problem exist to standardize these indices, including modern methods for statistical modeling, incentives for reporting, and the use of study fleet, for example.

The usefulness of conducting cost/benefit analyses, as mentioned under TOR 1, is applicable here as well. For example, conducting a standardization using GLMM might take time away from conducting an assessment or managing a database, but then again it might be worth it!

Directed research on factors influencing CPUE for both fishery dependent and fishery independent CPUE measures is needed and should be prioritized.

Fine scale spatial and temporal resolution of catch, effort, and behavior information can now be gathered and interwoven with other biophysical phenomena through, remote sensing and oceanographic modeling, for example. This should be done for data from both fishery independent as well as fishery dependent sources. Often, a greater quantity of data is available from the fishery dependent sources, albeit targeted data, than can be collected from (expensive) surveys. Just this order of magnitude difference in quantity makes considering the utility of using such data sources worthwhile to consider.

We fully endorse the use of action plans as outlined and exemplified in the Working Group Report in the recommendations section to implement efficient mechanisms for gathering data from all sources.

TOR 4: *Compare the desired factors identified with existing conditions and data for the fishery through a gap analysis of factors and data needed, as well as the analytical approaches necessary, to create a CPUE that would be a reliable index of abundance for Northeast multispecies stocks.*

One should recognize that differences in implementation of these recommendations exist when applying these methods to data gathered from the commercial fleet when compared to that available from the recreational fleet, and even within sub components of these fleets there are differences in reporting. Some balance is needed in the quantity and quality of information gathered, especially for those stocks that have significant landings by both fleets (in other words, not to put all your eggs/otoliths/tows in one basket). Other potential sources of uncertainty outside the scope of this review still need to be considered, including monitoring of landings, discards, compliance, enforcement, and environmental conditions.

If monitoring is to be considered for gathering any additional information, percent coverage of the fleet is an important consideration. In the North Pacific, debates continue to exist on whether partial coverage is adequate for observer programs.

We strongly concur with the Working Group Report that gap analysis should be used to identify factors and data needed, including mechanisms for *a priori* identification of targeted fishing, clear effort metrics, use of advanced technologies for monitoring, and finer time and spatial scale standardization. In addition, we might add greater coverage of social and economic indicators. One example of this would be the quantity and quality of the dealer report data.

We note that fishery dependent CPUE data was thoroughly examined several years ago and deemed of limited usefulness, but improvements in technology, statistical methods, and increasing need by management suggests that this analysis should be revisited.

Should fishery dependent CPUE metrics be developed, thought would need to be given to its relationship to other metrics such as those from the survey, as well as other indicators from the past. Any new data set generated should have some comparability to the past, so that, ideally, a single CPUE index could be generated combining historical data and new information collected.

Conclusion

The Working Group Report provides a clear, thorough and comprehensive analysis of how fishery dependent data can be used, the strengths and weaknesses of such data and how they compare in their characterization of the fishery relative to data gathered from fishery independent sources.

In this report, we expand slightly on the type of information that might be gathered from fishery dependent sources and why reconsideration of these data as input into stock assessment and management should be made.

Amendment 23

To the

Northeast Multispecies Fishery Management Plan

Appendix II

Groundfish Plan Development Team Dockside Monitoring Discussion Paper

Dockside Monitoring Discussion Paper

Groundfish Plan Development Team

Version 2
December 20, 2018

New England Fishery Management Council

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Overview

On April 7, 2016, the Groundfish Committee unanimously passed the following motion:

> *Move that the Committee task staff and/or PDT, as appropriate, to develop a draft white paper and report to the Council at the June meeting on monitoring strategies (ASM, shoreside, electronic, etc.) that would primarily contribute to accuracy and secondarily precision of groundfish catch reporting.*
>
> *The white paper should include a review of existing shoreside monitoring programs as well as past Council decisions on dockside monitoring with respect to achieving accuracy and precision in reporting of groundfish bycatch and landings as well as funding sources for the programs.*

This discussion document responds to the second component to the motion by considering dockside monitoring and management goals for monitoring in Amendment 16 to the Northeast Multispecies Fishery Management Plan (FMP) as modified by subsequent actions. Amendment 16 implemented at-sea monitoring (ASM) and dockside monitoring (DSM), to "assure that sector ACEs are not exceeded..."[1] The at-sea monitoring program remains in place today, but the groundfish dockside monitoring program has been discontinued through Framework 48. This document provides background information to summarize the development and implementation of the Groundfish Dockside Monitoring Program, including the refinements (Framework 45) and termination of the program (Framework 48). This document also reviews existing shoreside monitoring programs as case studies.

Outline

1. Development of Amendment 16 and the Groundfish Dockside Monitoring Program
2. Overview of Amendment 16's Proposed Monitoring Measures
3. Amendment 16 and public comments (summary)
4. Overview of Implementation of Amendment 16's Measures
5. Summary of Modifications to the Groundfish Dockside Monitoring Program (2010-2011)
    - 5.1. Framework 45 and public comments (summary)
    - 5.2. Framework 48 and public comments (summary)
6. Case Studies
    - 6.1 Case Study #1: Groundfish Dockside Monitoring Program (2010-2011)
    - 6.2 Case Study #2: Fisheries and Oceans Canada - Pacific Region Groundfish Dockside Monitoring Program

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[1] New England Fishery Management Council. Oct. 16, 2009. *Amendment 16 to the Northeast Multispecies FMP*. http://s3.amazonaws.com/nefmc.org/091016_Final_Amendment_16.pdf

1. Development of Amendment 16 and the Groundfish Dockside Monitoring Program

During the development of Amendment 16, the Gulf of Maine Research Institute (GMRI) provided research support to inform sector management and policies. In 2008, GMRI hired Archipelago Marine Research, the largest observer service provider for Western Canada, and Pacific Fisheries Management Incorporated to provide feedback on reporting and monitoring needs for the groundfish sector program. Archipelago Marine Research and Pacific Fisheries Management Inc., developed a report for GMRI that suggested several monitoring options for management consideration (McElderry et al., May 2008).[2]

The McElderry et al., (2008) report suggested that if dockside monitoring is used for groundfish monitoring, that these reports should be used to calculate landings, and dealer reports should be used to calculate landings on trips without dockside monitoring coverage. However, the group also point out that: "the proposed system overlaps with monitoring systems that the National Marine Fisheries Service (NMFS) currently runs and, if implemented, …would create redundancy, as NMFS would need to continue to maintain monitoring systems in a variety of other fisheries."[3] The McElderry et al., (2008) report did not provide a recommendation to resolve this redundancy.

Archipelago Marine Research and Pacific Fisheries Management Inc. recommended that, for roving monitors, monitoring every offload may not be necessary (e.g., monitoring offloads to trucks then to dealers for same trip is duplicative). Instead, the idea would be to keep the probability of monitoring these offloads sufficiently high to facilitate compliance with regulations.

Archipelago Marine Research and Pacific Fisheries Management Inc. recommended a centralized data management system for consistency in data collection methods for all sectors, particularly when multiple service providers are used. The group also recommended that the

[2] McElderry, Howard and Turris, Bruce. May 2008. *Evaluation of Monitoring and Reporting Needs for Groundfish Sectors in New England Phase II Report*. Archipelago Marine Research Ltd. and Pacific Fisheries Management Incorporated, http://walker-foundation.org/Files/walker/2009/GroundfishMonitoringNeedsFinalReportAug1208.pdf.
[3] Ibid.

centralized data system hold all reporting information from multiple sources (i.e., dockside data, dealer data, Vessel Trip Report (VTR) data).

GMRI held a group meeting on July 2, 2008 to discuss groundfish monitoring and reporting, with sector managers, environmental groups, New England Fishery Management Council (NEFMC) staff and members, NMFS staff, and Northeast Fisheries Science Center staff. Based on the meeting outcome report regarding dockside monitoring, the group of attendees concluded that a monitoring and reporting program should be efficient and transparent and build upon existing monitoring programs administered by NMFS (i.e., avoid redundant monitoring/data collection). In addition, data should be available real-time, and address accountability. The meeting report also concluded that dockside monitoring at 100 percent coverage is necessary for enforcement and stock assessments, with adjustment in coverage levels for less active ports.[4]

Based on the outcome of the meeting, the following issues remained unresolved[5]:

1. *The details of how to do dockside monitoring in smaller, less-used ports.*
2. *Who should do dockside monitoring?*
    a. *Single contractor for the whole northeast?*
    b. *Government establishes standards and then sectors select contractors from an approved list?*
    c. *Local law enforcement officials involved?*
        i. *Local people certified to do monitoring on behalf of the contractor*
        ii. *NMFS staff were concerned about legal issues associated with using local law enforcement officials as dockside monitors, including conflicts associated with the potential for industry funding of local, state, or federal enforcement agents*
3. *How to pay for dockside monitoring.*
4. *How monitoring and reporting will mesh with existing efforts.*

2. Overview of Amendment 16's Proposed Monitoring Measures

The current program for monitoring in the groundfish fleet was adopted in Amendment 16, and further modified by Framework 45, Framework 48, and Framework 55 to the Northeast Multispecies Fishery Management Plan (FMP). Amendment 16 required sector operation plans to include detailed strategies for monitoring, reporting, and enforcing catch and landings for all members within the sector. These detailed plans would ensure that sector members:

1. Land all legal-sized fish under FMP management; and
2. Do not exceed the ACE allocations by developing and implementing a dockside monitoring program, used in conjunction with an observer program, to report

[4] Good Group Decisions. July 2, 2008. *Monitoring and Reporting Discussion: Meeting Report*.
[5] Ibid.

catch information:

- Landings by species, reported by stock, statistical area, and gear type
- Discard estimates applied to landing events by gear type

An observer program would be used in conjunction with a dockside monitoring program to achieve monitoring goals for the sector system. Amendment 16 defines an observer as:

> "any person required or authorized to be carried on a vessel for conservation and management purposes by regulations or permits under this Act."[6]

Amendment 16 stated that: "[t]he primary goal of observers or at-sea monitors for sector monitoring is to verify area fished, catch, and discards by species, by gear type. This data will be reported to the sector managers and to the NMFS. Electronic monitoring may be used in place of actual observers or at-sea monitors if the technology is deemed sufficient for a specific trip based on gear type and area fished. Less than 100% electronic monitoring and at-sea observation will be required."[7] For trips without an observer onboard, an assumed sector-specific discard rate would apply, unless another monitoring program (deemed adequate by NMFS) is used to accurately report discard rates. An assumed sector-specific discard rate is based on the discard estimates derived from at-sea samplers.

Dockside monitors would certify dealer-reported landings by verifying accuracy of dealer-reported weights by observing offload activity. In 2010, dockside monitoring would cover 50 percent of trips for each sector, and for 20 percent of trips for each sector in subsequent years. Amendment 16 states that sectors should be able to demonstrate to NMFS that an adequate industry-funded monitoring system is in place to monitor a sector's Annual Catch Entitlement (ACE) by 2012 fishing year.

Amendment 16 stated that the following elements should exist for the sector dockside monitoring program: (1) List of ports that vessels within the sector plan to land fish; and (2) Pre-sail and pre-land hails to inform portside sampler deployment.

3. <u>Summary of Public Comments on Amendment 16</u>

A summary of comments related to Amendment 16 are addressed in this section, including the comments related to the proposed rule. The comments related to the proposed rule are also summarized in the Federal Register notice for the final rule (Refer to Appendix 2). A public hearing document and a Draft Amendment 16 with Draft Environmental Impact Statement was made available to the public. Comments received during the public hearings and

[6] New England Fishery Management Council. Oct. 16, 2009. Amendment 16 to the Northeast Multispecies FMP. http://s3.amazonaws.com/nefmc.org/091016_Final_Amendment_16.pdf
[7] Ibid.

submitted written comments are also summarized in this section.

Eleven individual commenters, five Congressional representatives (Delahunt, Hodes, and McGovern, Pingree, Michaud), one form letter with over 500 signatures (Jessica Lane et. al), and one form letter with over 8,800 signatures (Diane Luera et. al) supported the establishment of a comprehensive monitoring system. Many commenters, including Congressmen Delahunt, Hodes, and McGovern, the Cape Cod Commercial Hook Fishermen's Association, the Port Clyde Sector, the Island Institute, PEW, and one individual, supported a monitoring program for the sectors and common pool vessels. These commenters noted concerns regarding equity among the groundfish vessels, and the need to account for catch by both sector and common pool vessels.

For dockside monitoring coverage levels, two options were available for public comment, one option for 100 percent DSM coverage, and another option for less than 100 percent DSM coverage. Environmental Defense Fund (EDF), PEW, Conservation Law Foundation (CLF), MA DMF, one form letter with 174 signatures (David Butman et. al.), one individual, Island Institute, Ocean Conservancy, Port Clyde Sector, and Cape Cod Commercial Hook Fishermen's Association and one of its affiliates supported 100 percent dockside monitoring and 100 percent at-sea monitoring of the fishery. The Hook Gear Sector and the Georges Bank Fixed Gear Sector supported relatively high levels of DSM coverage.

The Associated Fisheries of Maine supported less than 100 percent DSM coverage, and suggested that the DSM requirement be waived if the SBRM coverage was able to achieve the Coefficient of Variation (CV) standard. Several commenters opposed the 100 percent DSM coverage, including two individual commenters representing the groundfish fishery. Several commenters expressed concern regarding the high monitoring costs, including thirteen individuals and the Penobscot East Resource Center. The Northeast Coastal Communities Sector supported a threshold for dockside monitoring coverage in ports with relatively low groundfish landings, to reduce dockside monitoring costs. Three commercial fishermen, the Associated Fisheries of Maine, and the Sustainable Harvest Sector proposed a removal of dockside monitoring requirements for trips monitored at sea.

Three commenters supported daily reporting requirements, including one state agency (MA DMF) and two fishing industry groups (Lunds Fisheries and Garden State Seafood Association). Garden State Seafood Association, Penobscot East Resource Center, Hook Gear Sector, Georges Bank Fixed Gear Sector, Cape Cod Commercial Hook Fishermen's Association, Associated Fisheries of Maine, Lunds Fisheries, Ocean Conservancy, CLF, EDF, and MA DMF supported Option 2, area-specific reporting requirements, in which catch data is attributed to the stock area.[8] This option would improve the accuracy of location information

[8] New England Fishery Management Council. April 15, 2009. Draft Amendment 16 to the Northeast Multispecies FMP.

used to attribute landings by area. The monitoring and reporting system uses location of catch from vessel-trip reports.

During the development of Amendment 16, timely monitoring of the catch by location was difficult because vessel operators were required to submit their reports up to fourteen days following the end of each month. Vessel trip reporting instructions were modified on December 5, 2014, and northeast multispecies permit holders are now required to submit their reports weekly, on the Tuesday following the previous fishing week.[9]

The proposed measures also stated that an assumed discard rate would apply for sectors, unless a sector's operations plan describe how discards would be monitored, reported, and enforced. Options for calculating assumed discard rate includes Option 1, which calculates an assumed discard rate based on the most recent stock assessment to calculate gear-specific discard rates (if available); and Option 2, which calculates an assumed discard rate using observer data from the previous year to calculate gear-specific discard rates. The Cape Cod Commercial Hook Fishermen's Association and the Associated Fisheries of Maine supported Option 2, Area-specific reporting requirements for calculating sectors and common pool assumed discard rates. Several group commenters (EDF and PEW) support Option 1. The Cape Cod Commercial Hook Fishermen's Association supported timely monitoring of discards. The Ocean Conservancy and CLF supported Option 3, which accounts for discards by non-sector vessels.

MA DMF expressed concerns regarding the enforcement of catch limits under the sector system with insufficient incentives for compliance with minimized state and Federal law enforcement. EDF also supported clear enforcement provisions. One groundfish fisherman raised concerns regarding the need to wait for a dockside monitor prior to catch offloading and suggested a six-hour hail is sufficient notice.

4. Overview of Implementation of Amendment 16's Measures

Amendment 16's final rule revised the dealer reporting and record keeping requirements, to "require dealers to provide a copy of any dealer weigh-out documents or dealer receipts for a particular offloading event to dockside/roving monitors, allow the dockside/roving monitor to sign a copy of the official weigh-out document or dealer receipt retained by the dealer, or sign a dockside monitoring report provided by a dockside/roving monitor."[10]

Accurate catch monitoring is important for fishery managers, and ensures all sectors are held to the same standards regarding catch accounting. Amendment 16's final rule "requires sectors

[9] National Marine Fisheries Service. December 5, 2014. Fishing Vessel Trip Report (VTR) Reporting Instructions. http://www.greateratlantic.fisheries.noaa.gov/aps/evtr/vtr_inst.pdf

[10] "Magnuson-Stevens Fishery Conservation and Management Act Provisions; Fisheries of the Northeastern United States; Northeast (NE) Multispecies Fishery; Amendment 16; Final Rule," 68 Federal Register 75 (9 April 2010), pp. 18262-18353. http://s3.amazonaws.com/nefmc.org/fA16inal_rule.pdf

to develop mechanisms to adequately monitor catch and discards by participating vessels. One of these mechanisms is an independent third-party dockside/roving monitoring program that observes offloads by sector vessels to ensure that landings are accurately reported. This dockside/ roving monitoring program is required starting in FY 2010, and will be funded by sectors, unless otherwise specified by NMFS. Dockside monitors observe offloadings directly to a dealer, while roving monitors are used to monitor offloads to a truck for later delivery to a dealer."[11]

At-sea monitoring and/or electronic monitoring would be used "to verify area fished and catch (landings and discards), by species and gear type, for the purposes of monitoring sector ACE utilization."[12] The manner in which discard estimates are derived may differ annually, and is based on the availability of data to determine a discard rate by fish stock and gear type. The level of coverage necessary would meet the CV standard established under the SBRM. At the time of implementation of Amendment 16, electronic monitoring was not yet approved for use in monitoring catch

The final rule specified the types of monitoring programs that would be used to monitor catch by sectors. There is general consistency between the proposed measures in Amendment 16 and the final rule. However, the language in the final rule is more prescriptive regarding the utility of the dockside monitoring program, compared to the language in the Amendment/Environmental Impact Statement (EIS). Amendment 16 and EIS for the action states that: "[s]ector operations plans will specify how a sector will monitor its catch to assure that sector catch does not exceed the sector allocation. At the end of the fishing year, NMFS will evaluate catch using IVR, VMS, and any other available information to determine whether a sector has exceeded any of its allocations based on the list of participating vessels submitted in the operations plan."[13]

5. Summary of Modifications to the Groundfish Dockside Monitoring Program (2010-2011)

5.1 Framework 45 – Changes to the Sector Dockside Monitoring Program

Framework 45 removed the requirement for the industry to fund the sector dockside monitoring program for the 2011 and 2012 fishing years. Instead, NMFS would fund the program for up to 100 percent of sector trips, subject to availability of funds. The rationale for removal of the

[11] "Magnuson-Stevens Fishery Conservation and Management Act Provisions; Fisheries of the Northeastern United States; Northeast (NE) Multispecies Fishery; Amendment 16; Final Rule," 68 Federal Register 75 (9 April 2010), pp. 18262-18353. http://s3.amazonaws.com/nefmc.org/fA16inal_rule.pdf
[12] Ibid.
[13] New England Fishery Management Council. Oct. 16, 2009. Amendment 16 to the Northeast Multispecies FMP. http://s3.amazonaws.com/nefmc.org/091016_Final_Amendment_16.pdf

requirement for industry to fund DSM is based on the utility of the data, which is minimal when considering other data sources collecting similar information, including vessel trip reports and dealer reports. However, the industry saw benefit in continuing the program with agency support to cover the dockside monitoring program costs.

> "Dockside monitoring was adopted by Amendment 16 to verify the accuracy of landings by commercial fishing vessels. The requirement was imposed immediately for vessels fishing in sectors and in FY 2012 for common pool vessels. Because this measure did not replace dealer reporting or VTRs, it did not produce a new data stream that assists the assessment and management of the fishery. Eliminating the requirement will reduce monitoring costs to industry, avoid duplication of effort, and will not reduce the availability of landings information. If the cost is to be covered by NMFS, the industry sees some benefit in continuation of the program."[14]

The final rule for Framework 45 stated that: "For FY 2011, NMFS estimates that it has sufficient funding to cover approximately 100 percent of sector trips that are not assigned an observer or at-sea monitor. NMFS will specify coverage levels for FY 2012 based upon available NMFS funding."[15]

Sector vessels were required to submit a trip-end hail that included the following information: "Vessel permit number; vessel trip report serial number, or other applicable trip ID specified by NMFS; landing state; landing port city; dealer name/offload location; estimated arrival date and time; estimated offload date and time; second offload port city and state (if applicable); and total amount of groundfish and non-groundfish species kept."[16] This end hail reporting requirement was intended to allow enforcement to efficiently ensure compliance with regulations, but was not used by dockside monitors.

Framework 45 altered the 2010 Dockside Monitoring Program by requiring monitors to inspect fish holds: "based on further evaluation of the performance of the dockside monitoring program and consideration of concerns expressed by enforcement personnel, this action now requires that dockside monitors inspect the fish holds for any trip that is assigned a dockside/ roving monitor beginning in FY 2011. This requirement [was intended to] enhance the enforceability of existing provisions and minimize the incentives to underreport/misreport the amount of regulated species landed." However, prior to developing protocols and training for dockside monitors to board vessels, NMFS responded to safety concerns raised by the NEFMC on samplers inspecting a fish hold, and "determined that retaining the vessel trip-end (pre-landing) hail requirement

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[14] New England Fishery Management Council. Jan. 21, 2011. Framework 45 and EA to the Northeast Multispecies FMP. http://s3.amazonaws.com/nefmc.org/110120_Final_FW_45_Resubmit.pdf

[15] "Magnuson-Stevens Fishery Conservation and Management Act Provisions; Fisheries of the Northeastern United States; Northeast (NE) Multispecies Fishery; Framework 45; Final Rule," 79 Federal Register 76 (25 April 2011), pp. 23042-23076. https://s3.amazonaws.com/nefmc.org/FW45final_rule.pdf

[16] New England Fishery Management Council. Jan. 21, 2011. Framework 45 and EA to the Northeast Multispecies FMP. http://s3.amazonaws.com/nefmc.org/110120_Final_FW_45_Resubmit.pdf

currently provides an efficient and effective means for observation and enforcement of vessel landing requirements through unannounced observation of vessel offloads at the discretion of law enforcement, which could include inspection of the hold."[17]

Summary of Public Comments on Framework 45's Final Rule, Sector Dockside Monitoring Program

A commercial groundfish industry group raised concerns regarding the utility of the DSM program, and suggested ways to improve the program. The group suggested reducing costs by only requiring roving monitors to observe offloads once (rather than observing offloads from vessel to truck and observing that offload from truck to the dealer). The group also suggested that dockside monitoring data should be allowed for use in weekly sector catch reports. NMFS responded that a streamlined and electronic format for data reports collected through dockside monitoring could improve use of the data and noted that dockside monitoring data could not replace the official record of landings collected through dealer reports.

Several group commenters (New England Hook Fisherman's Association (NEHFA), Penobscot East Resource Center (PERC), PEW Charitable Trusts) and a commercial fisherman suggested an exemption from dockside monitoring requirements for vessels fishing with Handgear A and B permits, or those vessels fishing under the small vessel exemption permit. NMFS responded that the final rule allows for such exemption for common pool vessels, not sector vessels.

Several commenters raised safety concern regarding the requirement for dockside monitors to inspect the fish hold, recommending that this task should be accomplished using NMFS Office of Law Enforcement, rather than a data collector. In addition, these commenters raised concern regarding the need to obtain insurance coverage for liability and harm, in the event that a sampler injured himself/herself while performing fish hold inspections.

Several group commenters (NEHFA, PERC, PEW Charitable Trusts) expressed the need to provide appropriate monitoring to minimize the incentive to misreport and underreport catch. As clarified in the comment response, "the dockside/roving monitoring data are primarily used for enforcement purposes, not catch monitoring."[18] NMFS planned to provide dockside monitoring coverage (based on available funding) for trips neither covered through SBRM coverage nor ASM coverage. Refer to Appendix 3.

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[17] "Magnuson-Stevens Fishery Conservation and Management Act Provisions; Fisheries of the Northeastern United States; Northeast (NE) Multispecies Fishery; Framework 45; Interim Final Rule," 138 Federal Register 76 (19 July 2011). https://www.govinfo.gov/content/pkg/FR-2011-07-19/pdf/2011-18012.pdf

[18] "Magnuson-Stevens Fishery Conservation and Management Act Provisions; Fisheries of the Northeastern United States; Northeast (NE) Multispecies Fishery; Framework 45; Final Rule," 79 Federal Register 76 (25 April 2011), pp. 23042-23076. http://s3.amazonaws.com/nefmc.org/FW45final_rule.pdf

5.2 Framework 48 – Changes to the Sector Dockside Monitoring Program

Framework 48 proposed to discontinue the requirements for the dockside monitoring program:

> "In 2011, NMFS made the determination that dockside intercepts by enforcement personnel were sufficient to monitor sector landings and reprioritized financial support for dockside monitoring to alleviate general sector operating costs."[19]

Framework 48 discontinued the Dockside Monitoring Program starting in the 2013 fishing year. The program was discontinued because the information collected through the dockside monitoring program duplicated information collected by dealers and eliminating the requirement to collect duplicative information would reduce vessel operational costs in the future. To aid its enforcement activity at the docks, NMFS maintained certain sector reporting requirements initially intended to support the dockside monitoring program, namely the requirement for sector vessel operators to submit trip start and end hails.

> "Dockside monitoring increases the operating costs of sectors. Landings information is already provided through the dealer reporting system. As long as unreported landings do not occur, the dealer reports can be used to monitor sector landings and there is little advantage to having dockside monitors verify these reports. By eliminating the program, sector operating costs are reduced, and redundant accounting is avoided."[20]

Framework 48 also clarified that "[t]he primary goal of observers or at-sea monitors for sector monitoring is to verify area fished, catch, and discards by species, [and] by gear type. Electronic monitoring may be used in place of actual observers or at-sea monitors if the technology is deemed sufficient for a specific trip based on gear type and area fished."[21]

Public Comments on Framework 48's Changes to the Sector Dockside Monitoring Program

Sector representatives, one environmental group, and one state agency commented on dockside monitoring program changes in the Framework 48 proposed rule. Some commenters supported retaining trip hail information for enforcement purposes. Sector representatives and one environmental group supported eliminating the dockside monitoring program, due to program inefficiencies (increased monitoring costs with minimal data utility and redundancy in data collection). One state fishery agency questioned whether NMFS believed the current monitoring of landings would be sufficient given the proposed termination of the dockside monitoring program. Refer to Appendix 4.

[19] "Magnuson-Stevens Fishery Conservation and Management Act Provisions; Fisheries of the Northeastern United States; Northeast (NE) Multispecies Fishery; Framework 48; Proposed Rule," 57 Federal Register 78 (25 March 2013, pp. 18188-18219. https://www.govinfo.gov/content/pkg/FR-2013-03-25/pdf/2013-06774.pdf

[20] New England Fishery Management Council. (Feb. 26, 2013). Framework 48 and EA to the Northeast Multispecies FMP. http://s3.amazonaws.com/nefmc.org/130307_FW48_Figures_Repaired.pdf

[21] Ibid.

6. Case Studies

The following section identifies a few case studies that summarize past and current dockside monitoring programs. If there is interest in a dockside monitoring program to monitor groundfish fishing activity, these case studies can provide some insight into other information collected from dockside monitoring programs in other fisheries, and the utility of data collected by other dockside monitoring programs. However, the goals for a groundfish dockside monitoring program should be clearly articulated.

Case Study #1: Groundfish Dockside Monitoring Program (2010-2011)

A. **Objective:** The purpose of the DSM Program in 2010 was to verify accurate dealer reporting. Dealer reports are one source of data used to determine a sector's in-season catch relative to the annual catch entitlement, providing the majority of landed weight information. VTRs provide non-dealer landings (e.g., catch retained for bait and home consumption), in addition to dealer landings, as well as statistical areas fished, gear used, and are used to attribute catch, by gear type.[22]

B. **Monitoring Tasks:**
   - Take copies of all VTRs filled out for the trip, with all information available (no blocked cells).
   - Record whether or not the scales are certified by the dealer's state.
   - Observe and record whether ice and box weights are tared by the dealer before the catch is added. If the dealer does not tare the box and ice, the dockside monitor must obtain the estimated weight of the ice and box from the dealer and record that weight in his/her report.
   - Ask the captain whether all fish have been offloaded, and whether any are being retained for personal use. The dockside monitor must record the captain's estimate of weight of each species being retained for home use or retained on the vessel and record the reason(s).
   - Either the dockside monitor or dealer must record the weight of offloaded fish, by species (and market class, if culled), in a report. This report must be signed by the dockside monitor, and the monitor must keep a copy of the signed report.
   - Provide accurate and complete data to the sector manager and/or any dockside monitor-designated third party, within 24 hours of the completion of the DSM event.
   - Send copies of the VTR(s), the dealer receipt(s) if separate from the dockside

[22] Labaree, Jonathon. August 2012. *Sector Management in New England's Groundfish Fishery: Dramatic Changes Spurs Innovation.* Gulf of Maine Research Institution. http://www.gmri.org/sites/default/files/resource/sector_management_in_new_england.pdf

monitor's report, and the dockside monitor's report to the sector manager or any dockside monitor -designated third party.

- Keep a copy of his/her report, which must be electronically stored by the DSM vendor.
- Inspect fish hold (Modification made in Framework 45 Final Rule, but disallowed shortly thereafter, in Framework 45 Interim Rule). This measure was disallowed, due to safety concerns regarding samplers inspecting the fish hold (Refer to Appendix 8).
- Refer to Appendix 7 for Dockside Monitoring Program Standards.

C. Summary of Program Logistics for 2010 Groundfish Dockside Monitoring Program:

- Notification to vessel regarding coverage requirement at end of trip when trip end hail is sent to service provider, and not sooner.
- Hail start and end times reported by vessels, to allow for sampler to arrive at location for sampling. Service providers notify vessels of coverage requirements when sending confirmation in response to trip end hail reported by vessel operator.
- Offloading of fish may not begin until sampler is present, if selected for coverage.
- Fish is sometimes offloaded at different dealers, with a large amount of lag time in between, which may increase costs in some instances (e.g., when sampler must observe offload to truck, and also observe the offload from the truck to the dealer).
    - For example, state regulations affect when fluke can be offloaded
    - Another example is that lobsters are typically offloaded first, and at a different dealer (in order to land live lobsters).

Fish hold inspections likely require additional insurance, which may also increase the costs (in the past, service providers were required to obtain appropriate insurance in case of injury/harm to samplers when inspecting fish holds).

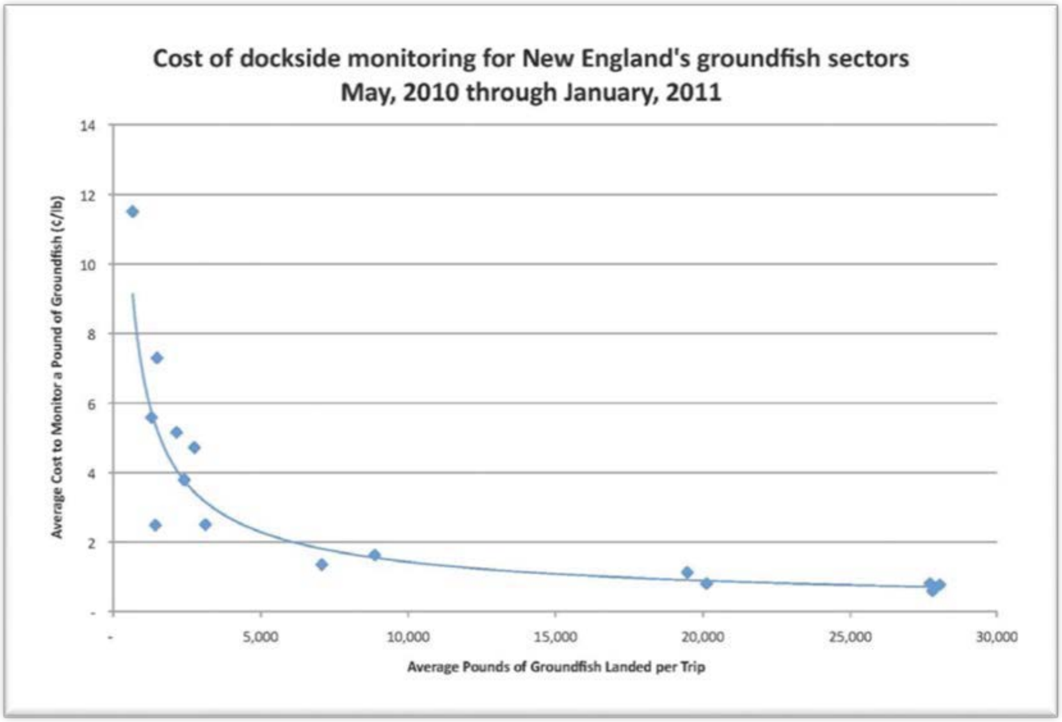
D. Program Funding (includes cost information):

Program cost information for the groundfish dockside monitoring program is provided below, based on analysis prepared by GMRI. For the 2010 fishing year, 50 percent of all trips (both trips with and without at-sea observer/monitoring) were monitored. For the 2011 fishing year, the monitoring coverage began at 100 percent of trips without at-sea/observer monitoring and was reduced to 50 percent.

GMRI administered the dockside monitoring program through a grant, which was used to reimburse vessels for dockside monitoring costs.

- Average per pound cost for all sectors ranges from $0.006/lb. to $0.12/lb., and was inversely related to volume (i.e., the more fish landed per trip, the lower the cost for DSM on a cost per pound basis; Refer to Figure 1).
- The average cost per trip across ports ranged from $97 - $212.
- The 2010 DSM Program was funded by a NMFS grant to GMRI.

Figure 1 - 2010 Groundfish Sector Dockside Monitoring Cost Information (cost per pound of fish landed)



Source: CINAR Report, Funding Sector Operations and Dockside Monitoring in Fishing Year 2011.

E. **Data Utility:** Dockside monitoring activity helped assure accurate dealer and vessel reporting of landings information (real-time monitoring of compliance with accurate dealer reporting). Hail information was used by NOAA Office of Law Enforcement to facilitate enforcement of regulations at the docks.

Case Study #2: Elements of the Archipelago Dockside Monitoring Services for the Pacific Region's Groundfish Fishery [23]

A. **Objective:** The objectives for the monitoring program include verification procedures and methods to ensure integrity of data, and the ability to correct for deficiencies in the reported data. In British Columbia, Fisheries and Oceans Canada currently utilizes four service providers to fulfill dockside monitoring requirements. Archipelago Marine Research is the approved DSM provider for the Pacific Region's groundfish fishery managed by Fisheries and Oceans Canada. There is no regional annex for the Pacific Region's dockside monitoring program.[24]

B. **Monitoring Tasks:**

- Species Verification (identify, record weight, record count);

[23] Archipelago Marine Research. 2016. *Dockside monitoring Independent, Third-Party Verification of Landed Catch.* http://www.archipelago.ca/fisheries-monitoring/dockside-monitoring/

[24] Based on electronic mail communications with the Pacific Region's monitoring programs coordinator in July 2016.

- For Hook and Line/Trap fishery all fish landed must be separated, piece counted and weighed by individual species and by product type. The only exceptions to the piece count requirement are halibut, lingcod, dogfish and sablefish landed on directed trips;
- Electronic reporting of landings information;
- Retain copies of fish log information, hail information, and other relevant information;
- Obtain fish samples and tag information for use in assessments;
- Monitor compliance with regulations for the fishery, including a fish hold inspection and on-deck inspection for remaining fish after offload is complete;
- Apply fish tags to all retained halibut; and
- Record and track individual quotas in-season for management purposes[25].

C. Program Funding (includes cost information):

Dockside monitoring in the British Columbia groundfish fishery's catch share program is paid for by the industry. In the groundfish fishery, 100 percent dockside monitoring is required. Costs are reported in Canadian dollars, which almost matched US currency during that time period. Based on estimates provided in report by Archipelago Marine Research in 2008, costs range from $65 to $500 per trip for groundfish fisheries (includes industry and government support for DSM program). The fishery has mandatory 100% observer or EM coverage. The majority of the groundfish trawl fleet uses onboard observers to observe all fishing events including landings and discards. The hook and line, trap, mid-water trawl for hake, and the small inshore groundfish trawl fishery use an audit-based electronic monitoring system. In British Columbia, the groundfish fleet is comprised of approximately 300 vessels and is valued at approximately $140 million dollars. The value of landed catch on groundfish vessels is approximately $40,000 per trip.

D. Data Utility: Enhanced regulatory compliance and protection of sustainable commercial fisheries. Dockside monitoring data is considered the primary source of landings data used to inform fisheries management. Biological data is also collected and used in stock assessments. The purpose of tagging all landed halibut is to act as an enforcement tool to decrease the amount of illegally caught halibut entering the market, and to assist in marketing Canadian halibut as a distinct and high-quality product.

Case Study #3: Massachusetts Department of Marine Fisheries (MA DMF) Portside Sampling Program of the Atlantic herring fishery

A. Objective: Collect information on catch composition, biological information and samples, for the purposes of landings verification and use in stock assessments.[26]

[25] Fisheries and Oceans Canada. 2010. *Atlantic Region Dockside Monitoring Program Policies and Procedures.*

[26] Massachusetts Division of Marine Fisheries. 2010. 2010 *Annual Report*. http://www.mass.gov/eea/docs/dfg/dmf/publications/2010-dmf-annual-report.pdf

B. Monitoring Tasks:[27]

- Collect subsamples of unsorted fish catch (beginning in 2012). Basket subsamples collected every five to seven minutes, on average.
- Record information on species composition and length frequency of fish
- Collect harvester-reported information on fishing effort (laptop, electronic VTR); and
- Refer to sample logs (Appendix #5).

C. Program Funding: Portside sampling coverage increased in 2010 due in part to a grant provided by the National Fish and Wildlife Foundation.[28] MA DMF also receives funding from The Nature Conservancy and the Atlantic Herring Research Set-Aside Program. An Atlantic States Marine Fisheries Commission grant was used to support portside sampling efforts on small-mesh bottom trawl vessels in Rhode Island. At this time, the Atlantic Herring Research Set-Aside Program supports the majority of the sampling effort (subcontracted through SMAST, who receives the funding from quota-set aside).

D. Data Utility: Information on river herring hotspots are used to inform the voluntary River Herring Bycatch Avoidance Program. All mid-water trawl vessels currently participate in the program, and the majority of small-mesh bottom trawl vessels in Rhode Island also participate in the bycatch avoidance program. Representatives of the state portside sampling program provide advice on feedback based on experience with portside sampling program, to inform management decisions regarding the development of frameworks/amendments related to fishery and bycatch concerns. Samples and length measurements from the Massachusetts and Maine portside sampling programs are used in the herring stock assessments for catch at age information and information on life history parameters. Collected samples also determine maturation stage of fish for spawning closure considerations.

Case Study #4: Maine Department of Marine Resources (ME DMR) Portside Sampling Program of the Atlantic herring fishery

A. Objective: Compare and analyze sampling results from at-sea monitoring and portside sampling data. Trips covered by observers are sampled portside to compare results due to variations in sampling schemes. Portside sampling effort currently focuses on purse seine vessels, but also include midwater trawl vessels and small-mesh bottom trawl vessels. In the future, portside sampling efforts will focus on catch estimation for the herring and mackerel fisheries to comprehensively monitor these fisheries.

B. Monitoring Tasks: Non-targeted fish are sorted and weighed. In some cases, a

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[27] Armstrong, Mike; Hoffman, Bill; and Schondelmeier, Brad. *Portside Sampling and River Herring Bycatch Avoidance.* https://www.greateratlantic.fisheries.noaa.gov/protected/riverherring/tewg/smast_madmf_portside_bycatch_program.pdf

[28] NFWF 2016 Request for proposals can be found at (proposals due June 13, 2016): http://www.nfwf.org/fisheriesfund/Pages/2016-Electronic-Mo.aspx

subsample of catch is weighed. Vessel trip report information is used to attribute landings by area and gear. All weighed fish are then measured for length information, and samples of fish are also taken. Refer to sample logs (Appendix 6).

C. Program Funding: Funding is provided by the Atlantic Coastal Cooperative Statistics Program (ACCSP). Beginning in 2016, funding provided by ACCSP was reduced to only cover travel expenses. The state of Maine's general funds support the remainder of the program.

D. Data Utility: Samples and length measurements are used in the herring stock assessments for catch at age information and information on life history parameters. Collected samples also determine maturation stage of fish for spawning closure considerations. Samples from portside sampling efforts are processed through the Maine Department of Marine Resources laboratory for catch sampling analysis and ageing.

Case Study #5: Elements of the Dockside Monitoring Services for the Maritimes Region's Groundfish Fishery

A. Objective: To provide timely third-party verification of accurate landings information to monitor fishery effort for quota management purposes. To ensure compliance with fishery regulations.

B. Monitoring Tasks: Dockside monitoring tasks for the Maritimes Region is based on Department of Fisheries and Oceans Canada National Dockside Monitoring Program Policy and Procedures, and the Maritimes Regional Annex.[29]

- Species Verification (identify, record weight, record count);
- Dockside monitors retain copies of fish log information, hail information, and other relevant information;
- Monitor compliance with regulations for the fishery, including a fish hold inspection and inspection of other areas on vessel where fish is typically stored after offload is complete. Dockside monitors are required to sign harvester logs and certify that there is no additional fish in the fish hold; and
- Certified data entry clerks enter landings information from logs of monitored and unmonitored trips, and submits the information using a landings database.

C. Program Funding: There are approximately 1,000 groundfish vessels, and these vessels land fish in remote ports. There is 20% dockside monitoring for catch less than 5,000 pounds, or less than 150 pounds of halibut (there is a small total allowable catch for halibut).

D. Data Utility: Enhanced regulatory compliance and protection of sustainable commercial fisheries. Dockside monitoring data is considered the primary source of landings data used to inform fisheries management.

[29] Fisheries and Oceans Canada. November 2012. *Maritimes Region Dockside Monitoring Annex.*

Case Study #6: West Coast IFQ Catch Monitor Program

A. **Objective:** Provide accurate, timely, and independent third-party verification of landing reports that are used to manage the fishery. To ensure compliance with fishery regulations.
B. **Monitoring Tasks:**[30] Catch monitors conduct dockside monitoring at first receivers (person or company who receives, purchases, or takes custody, control, or possession of catch onshore from a vessel that harvested fish under the shorebased Individual Fishing Quota (IFQ) Program). They monitor the sorting, weighing and recording of catch as it is received, purchased, taken custody, control, or possession of by first receivers. In general, these activities occur at shorebased processing facilities in the port of landing but may occur at other dockside facilities where catch is offloaded onto trucks that transport it to inland processing facilities.
    - Species Verification (identify, record weight, record count);
    - Verify that catch monitoring plans are being followed;
    - Written documentation of the sorting process including all operational issues that may affect the quality of catch sorting; and
    - Monitor compliance with regulations for the fishery, including a fish hold inspection if possible. Monitors record on the data sheet whether or not they were able to inspect the fish hold and confirm that all catch was offloaded, and document the reason why if they were not able to confirm.
C. **Program Funding:** 100% observer and catch monitoring coverage is required for all program participants. Both observers and catch monitors are industry funded.
D. **Data Utility:** Enhanced regulatory compliance and protection of sustainable commercial fisheries.

Case Study #7: Elements of the North Pacific Observer Program - Plant Observer for the Bering Sea/Gulf of Alaska Pollock Fishery

A. **Objective:** To monitor all Bering Sea pollock offloads for the sorting of salmon. Vessels in the directed pollock fisheries in the Bering Sea and Gulf of Alaska are prohibited from sorting salmon from their catch and must deliver all salmon to the processing plant. To verify Plant/Vessel Offload Form data and delivery weights as time permits.
B. **Monitoring Tasks:**[31] Bering Sea Pollock offload monitoring is a shared duty between the plant observer and vessel observer. Only one observer is required to be present at any given

[30] NOAA. December 2010. Compliance Guide Pacific Coast Groundfish Trawl Rationalization Program. http://www.westcoast.fisheries.noaa.gov/publications/fishery_management/trawl_program/catch-shares-guide-progr.pdf
[31] 2017 Observer Sampling Manual North Pacific Observer Program November 1, 2016. Alaska Fisheries Science Center, Fisheries Monitoring and Analysis Division https://www.afsc.noaa.gov/FMA/Manual_pages/MANUAL_pdfs/manual2017.pdf

time during the offload. The plant and vessel observers are required to be present at the beginning and end of each offload.

- Salmon retention data (identify, record weight, record count, sampling) is the data collection priority;
- Verify Plant/Vessel Offload Form data (species identity, total weight);
- Verify delivery weights as time permits. Either verify based on the weights entered on the fish ticket or by the sum of scale weights.

C. **Program Funding:** 100% monitoring is required for all pollock offloads. The fee is split evenly between the vessel owner/operator and processor or registered buyer.

E. **Data Utility:** Collect information on salmon (weights, biological sampling) retained by the pollock fishery. Enhanced regulatory compliance and protection of sustainable commercial fisheries.

7. <u>PDT Discussion: Considerations for a Groundfish Dockside Monitoring Program</u>

The Groundfish Committee tasked the PDT with investigating the tools used to monitor the groundfish fishery, including the 2010-2011 dockside monitoring program. The DSM program was discontinued in the 2010 fishing year, due to unresolved problems with the program. If the intent is to reconsider a dockside monitoring program for the groundfish fishery in the future, the PDT recommends that the former program be modified, rather than simply reinstated as previously implemented, to achieve the goals of accurate and precise reporting of groundfish bycatch and landings. The following summarizes the PDT's discussion on the topic.

Problem Statement

Accurate landings data are a critical component of total fishery removals for targeted groundfish stocks (those stocks without zero possession limits). They provide the basis for the size structure and magnitude of most of the commercial catch, ensure that sectors are in compliance with their Annual Catch Entitlements, and underpin the quota allocation mechanism. Analytical stock assessment models assume there are no biases in the age structure or with the magnitude of the catch over time. The commercial landings are assumed to be a census of the total landings. It is not an estimate with an associated error distribution similar to the recreational landings estimate. When this assumption is violated--when true catch is biased--it can contribute to problems with model performance, including retrospective errors. The loss of acceptable analytical stock assessment models due to diagnostic issues results in a reliance on overly simple empirical models that do not comprehensively integrate stock dynamics. This exacerbates uncertainty in setting catch limits. Therefore, an accurate time series of landings is a prerequisite for accurate and precise stock assessments, as well as any subsequent projections used to estimate OFLs, ABCs, and ACLs. Accurate catch reporting is also necessary to ensure that the mechanism for allocating quota between sectors provides a level playing field for all fisherman and ensures that all sector members are subject to the same constraints, thereby ensuring fairness in the governance of the catch share system and improving confidence and trust among participants. Without accurate catch data, the biological and market signals that help inform our understanding of stock conditions are at least muted, if not lost.

In any fishery regulated by output controls with a tradable quota system, where landings are strictly limited, and quota costs vary between species and even between stocks of the same species, incentives to report inaccurately exist. Currently in the groundfish fishery there is no independent verification of landings data at the offload site. Communications with NOAA Office of Law Enforcement (OLE) reveal that only a small percentage of trips are inspected for compliance. For example, in 2017 OLE inspected approximately 300 multispecies trips out of approximately 7,000 (~4%). Based on an initial review, 2% of these 300 may face enforcement actions (either at-sea or dockside). OLE reported that their recent enforcement priorities have shifted away from dockside inspections due to the self-policing construct of the sector management system, and their efforts are now primarily focused on at-sea inspections. OLE expressed concern that current monitoring efforts are insufficient to ensure that groundfish landings are reported accurately. OLE remarked that a dockside inspection, coupled with conformation of the dealer report, is required to ensure accurate landings reports. Fish hold inspections are a routine part of OLE's fishing vessel inspection, although the officer has discretion to forgo the fish hold inspection if there are safety concerns or other relevant circumstances. OLE remarked that fish hold inspections are a critical component of a monitoring program. Further, OLE indicated that they have limited resources to cover the number of trips landed, even with the JEA program as a force multiplier. Rather, OLE focus is based on egregious violations or cases initiated by actionable intelligence. OLE also conveyed that to ensure accurate reporting, a dockside inspection accompanied with confirmation of dealer reporting would be essential.

Addressing Unresolved Issues in 2010-2011 DSM Program:

1. *The details of how to do dockside monitoring in smaller, less-used ports.*

From 2010 to 2013, 91% of groundfish landings (by value) were offloaded in six New England ports (New Bedford, Gloucester, Boston, Chatham, Point Judith, and Portland). Therefore, the establishment of a dockside monitoring program at these six major ports would enable independent verification of the majority of groundfish landings in New England.

However, monitoring groundfish offloads in other ports where groundfish are landed in lower volumes and with less frequency, is an operational challenge. Canada's Maritimes Regional DSM Program may provide some guidance regarding coverage levels in smaller ports with lower volumes of groundfish landings. The Canadian Maritimes region uses the volume of groundfish landings at each port to classify a level of coverage. The premise behind this program is that monitoring levels are assigned in proportion to the risk of potential catch misreporting (by volume). Coverage levels are assigned to each port according to a four-tier system. In this case, vessels offloading at ports with low volume landings are subject to intermediate coverage levels (e.g., 25% of trips) through the dockside monitoring program. High volume groundfish vessels, or groundfish vessels offloading at ports with a higher volume of groundfish landings are subject to 100% dockside monitoring.

Under the Canadian Maritimes dockside monitoring program, vessels are required to submit a "hail-in" report at the conclusion of their trip, which details the landed weight (by species) of their catch, the port of landing, the dealer(s), and their anticipated time of arrival. For fleets/ports that don't have 100% dockside monitoring, the vessel will not know in advance if they will have an assigned dockside monitor for their offload. When a monitor is assigned, the monitor makes sure that the "hail-in" report was reasonably accurate, and if not, they can file an incident report.

A similar tiered dockside monitoring system may work well in this region. Vessels offloading at high volume groundfish ports could be monitored at a relatively high coverage level. Vessels offloading lower quantities of groundfish or offloading at ports with lower volumes of groundfish landings, could be randomly assigned dockside monitors at lower coverage levels. Because vessels already submit hail-in reports as part of their trip level reporting, the dockside monitor can compare the hail in report to the recorded offload weights to incentivize accurate reporting of landings at the species level.

2. How to pay for dockside monitoring.

One of the measures in Framework 48 was disapproved due to legal constraints regarding cost sharing for monitoring in the fishery. Cost sharing responsibilities for industry-funded monitoring programs to address monitoring needs in excess of Federal mandates (i.e., distinct from Standardized Bycatch Reporting Methodology, Marine Mammal Protection Act, and Endangered Species Act requirements) are described in the Draft Environmental Impact Statement to the Industry-Funded Monitoring Amendment (May 2016; Refer to Appendix 1 for specific rationale regarding the disapproval).

> "Department of Commerce General Counsel has advised NMFS that monitoring cost responsibilities can be allocated between industry and the government by delineating the sampling and administrative portions of the costs of monitoring. Industry would be responsible for costs directly attributable to the sampling portion of a monitoring program, and NMFS would be responsible for costs directly attributable to the

administrative portion of the monitoring program…"[32]

3. *Does DSM just produce duplicative information?*

Framework 45 removed the requirement that industry pay the costs of dockside monitoring, and it was argued that because dockside monitoring did not replace dealer reporting or VTR's, dockside monitoring did not produce a new data stream that assisted in the assessment and management of the fishery.

- The data are only duplicative **if** landings are reported accurately by the vessel and dealer.
- The primary goal of DSM is enforcement, whereas dealer reporting and VTRs are used for monitoring.
- Can dockside monitoring data be used to replace dealer data as the official landings record, for trips that are monitored dockside? If so, the information would no longer be duplicative. This is what is done in other monitoring programs (e.g., case studies 2 and 5).

4. *How monitoring and reporting will align with existing efforts.*

1. Objective(s) for dockside monitoring:

The primary objective of dockside monitoring in the groundfish fishery will be to provide independent verification of landings, in order to ensure that landings are accurately reported for all species.

Under A23, dockside monitoring may be used in conjunction with other monitoring initiatives, such as EM. The primary utility of dockside monitoring is to ensure that the landings are recorded accurately for each species. EM or ASM/NEFOP programs can be used to increase the accuracy of discard estimates, and to reduce the magnitude of stock area misreporting. Therefore, dockside monitoring can be used in combination with at-sea monitoring to increase the accuracy of catch estimates (by species and stock area).

Dockside monitoring may also allow some secondary objectives to be fulfilled, for example:

- Dockside monitoring, when used in conjunction with the at-sea monitoring provisions being considered under A23 will allow the magnitude of catch to be known with greater accuracy. This may provide managers will more flexibility

[32] NEFMC and MAFMC. Draft Environmental Impact Statement for the Industry-Funded Monitoring Omnibus Amendment. August 2018. https://s3.amazonaws.com/nefmc.org/Draft-EA-for-IFM-Amendment-August-2018.pdf

to decrease the uncertainty buffer between the Acceptable Biological Catch and Annual Catch Limit. A reduction in the uncertainty buffer would provide additional revenue opportunities to the fishery, particularly if more quota were made available for constraining stocks.

- By providing an independent, third-party verification of landed weights by species, dockside monitoring will reduce the magnitude of misreported landings in the groundfish fishery.
- Increasing the timeliness and accuracy of in-season quota monitoring for sectors.
- Dockside monitoring will give all fishery participants greater confidence that landings are being monitored and reported in an equitable manner throughout the fishery, and that all fishery participants are adhering to their quota allocations.
- Catch and discard weights by species, gear type, mesh size, fishing location, etc. Landings accuracy is not the only objective that can be satisfied by dockside monitors for the groundfish fishery. Monitoring of ACE usage is a broader objective identified in Amendment 16. An expanded dockside monitoring program could provide additional information to inform management. It may be worth exploring additional data collections that dockside monitors may be able to successfully collect, if there is interest in dockside monitoring for the fishery. More importantly, the utility of the data should be clearly articulated by both the NEFMC and NMFS prior to implementation, to ensure that the suite of monitoring options meet the FMP-specific goals.

2. Articulate a clear sampling design to meet monitoring (or enforcement) objectives.
   a. Examples:
      i. <u>Stock-specific hail requirements.</u>

Vessels are currently required to submit a "hail-in" report at the completion of their trip. The "hail-in" report includes the following information:

- Vessel name and permit number
- Intended port of landing and dealer(s)
- Landed weight of all groundfish, by species, and stock area
- Landed weight of all non-groundfish species

As part of their sampling duties, the dockside monitor will compare the "hail-in" weights for each species of fish reported by the captain to the amount of fish that is offloaded at the dealer.

Potential penalty function – for lower volume vessels that are subject to occasional dockside monitoring, their DSM coverage rate could increase if the hail-in reports are inaccurate.

ii. Inspection of fish hold, if used to monitor and improve catch accuracy.

A major issue with the previous dockside monitoring program was that dockside monitors were not allowed to inspect fish holds, primarily because of liability concerns. The PDT is concerned that fish holds must be inspected at the conclusion of an offload to ensure that all landings have been accounted for and independently verified. The PDT also notes that fish hold inspections are a mandatory component of dockside monitoring programs in other fisheries throughout the world (see case studies). The monitoring amendment should clearly articulate whether the insurance liability associated with having monitors inspect the fish hold of the vessel falls on the vessel owner, or the dockside monitoring service provider.

As an alternative to having dockside monitors physically inspect the fish hold, motion activated cameras could be used to verify that all fish have been removed from the hold at the conclusion of the offload. This option may be particularly well suited for use on vessels with EM systems.

3. Who will pay for non-administrative dockside monitoring costs, if used in the future?
    - Industry
    - Dealer
    - Combination

Appendix 1

Text from Greater Atlantic Region disapprovals regarding industry-funded monitoring

Excerpt from the Final Rule for Framework Adjustment 48 to the Northeast Multispecies FMP (78 FR 26118; May 3, 2013)

2. At-Sea Monitoring Cost-Sharing

To serve as a more long-term solution to the cost burden of at-sea monitoring to sectors, Framework 48 proposed a mechanism for sharing of at-sea monitoring costs between sectors and NMFS. Framework 48 proposed that the industry would only ever be responsible for paying the direct costs of at-sea monitoring, specifically the daily salary of the at-sea monitor. All other programmatic costs would be the responsibility of NMFS, including, but not limited to: Briefing, debriefing, training and certification costs (salary and non-salary); sampling design development; data storage, management and security; data quality assurance and control; administrative costs; maintenance of monitoring equipment; at-sea monitor recruitment, benefits, insurance and taxes; logistical costs associated with deployment; and at-sea monitor travel and lodging. This measure was intended to reduce the cost burden of at-sea monitoring to sectors and thereby increase their profitability.

NMFS has disapproved this cost-sharing measure because it is not consistent with other applicable laws as developed. Specifically, the Anti-Deficiency Act and other appropriations law prohibits Federal agencies from obligating the Federal government except through appropriations and from sharing the payment of government obligations with private entities. Framework 48 proposed to require NMFS to pay for some portion of the costs of at-sea activities, such as logistical costs generated by deployment, which are outside its statutory obligations under the Magnuson-Stevens Act. As written, this measure would also have required NMFS and sectors to share payment of obligations defined as belonging to one or the other. For example, Framework 48 proposed to require NMFS to pay some costs related to at-sea activities, such as benefits and insurance for at-sea monitors, while sectors would pay other portions of at-sea costs, like the salary for at-sea monitors. Because such action would be prohibited under the law, NMFS has disapproved this measure in Framework 48.

Although this measure was not approvable as developed, NMFS shares the Council and industry's concern about the ability of sectors to bear the full costs of monitoring in future fishing years. NMFS believes this approach to cost sharing, which defines the items that NMFS versus sectors should be responsible for, could be viable if restructured and may be worth pursuing in a future action. NMFS is already working with the New England and Mid-Atlantic Councils' joint Herring/Mackerel Plan Development Team (PDT)/Fishery Management Action Team (FMAT) to pursue cost-sharing options such as this one for those fisheries for FY 2014. The Council could consider including the NE Multispecies FMP in this joint effort to develop a workable and consistent cost-sharing mechanism for the Northeast region.

Excerpt from the Final Rule for Amendment 5 to the Atlantic Herring FMP

1. Increased Observer Coverage Requirements

As described previously, the NEFSC determines observer coverage levels in the herring fishery based on the SBRM. Observer coverage in the herring fishery is currently fully funded by NMFS. Amendment 5 proposed increasing observer coverage in the herring fishery by requiring 100-percent observer coverage on Category A and B vessels. Many stakeholders believe this measure is necessary to accurately determine the extent of bycatch and incidental catch in the herring fishery. The Council recommended this measure to gather more information on the herring fishery so that it may better evaluate and, if necessary, implement additional measures to address issues involving catch and discards. The 100-percent observer requirement is coupled with a target maximum industry contribution of $325 per day. There are two types of costs associated with observer coverage: (1) Observer monitoring costs, such as observer salary and travel costs, and (2) NMFS support and infrastructure costs, such as observer training and data processing. The monitoring costs associated with an observer in the herring fishery are higher than $325 per day. Cost-sharing of monitoring costs between NMFS and the industry would violate the Anti-Deficiency Act. Therefore, there is no current legal mechanism to allow cost-sharing of monitoring costs between NMFS and the industry.

Throughout the development of Amendment 5, NMFS advised the Council that Amendment 5 must identify a funding source for increased observer coverage because NMFS's annual appropriations for observer coverage are not guaranteed. Some commenters claim that the $325 per day industry contribution was not a limit, but a target, and that the Council intended the industry to pay whatever was necessary to ensure 100-percent observer coverage. NMFS disagrees, and does not believe the amendment specifies that the industry would pay all the monitoring costs associated with 100-percent observer coverage, nor does it analyze the economic impacts of the industry paying all the monitoring costs. The FEIS for Amendment 5 analyzed alternatives with the industry paying $325 per day or $1,200 per day (estimated sum of observer monitoring costs and NMFS support and infrastructure costs), but it did not analyze a range of alternatives that would approximate total monitoring costs. Budget uncertainties prevent NMFS from being able to commit to paying for increased observer coverage in the herring fishery. Requiring NMFS to pay for 100-percent observer coverage would amount to an unfunded mandate. Because Amendment 5 did not identify a funding source to cover the costs of increased observer coverage, the measure is not sufficiently developed to approve at this time. Therefore, NMFS had to disapprove the 100-percent observer coverage requirement. With the disapproval of this measure, this action maintains the existing SBRM observer coverage levels and Federal observer funding for the herring fishery.

Recognizing funding challenges, Amendment 5 specified status quo observer coverage levels and funding for up to 1 year following the implementation of Amendment 5, with the 100-percent observer coverage and partial industry funding requirement to become effective 1 year after the implementation of Amendment 5. During that year, the Council and NMFS, in cooperation with the industry, were to attempt to develop a way to fund 100-percent observer coverage.

During 2013, a working group was formed to identify a workable, legal mechanism to allow for industry-funded observer coverage in the herring fishery; the group includes staff from the New England and

Mid-Atlantic Councils and NMFS. To further explore the legal issues surrounding industry-funded observer coverage, NMFS formed a working group of Northeast Regional Office, NEFSC, General Counsel, and Headquarters staff. The NMFS working group identified an administrative mechanism to allow for industry funding of observer monitoring costs in Northeast Region fisheries, as well as a potential way to help offset funding costs that would be borne by the industry, subject to available funding. This administrative mechanism would be an option to fund observer coverage targets that are higher than SBRM coverage levels. The mechanism to allow for industry-funded observer coverage is a potential tool for all Northeast Region FMPs, but it would need to be added to each FMP through an omnibus amendment to make it an available tool, should the Council want to use it. Additionally, this omnibus amendment could establish the observer coverage targets for Category A and B herring vessels.

In a September 20, 2013, letter to the Council, NMFS offered to be the technical lead on an omnibus amendment to establish the administrative mechanism to allow for industry-funded observer coverage in New England and Mid-Atlantic FMPs. At its September 2013 meeting, the Council considered NMFS's offer and encouraged NMFS to begin development of the omnibus amendment. At this time, NMFS expects to present a preliminary range of alternatives for the omnibus amendment to the New England and Mid-Atlantic Councils in early 2014.

Additionally, other Amendment 5 measures implemented in this action help improve monitoring in the herring fishery. These measures include the requirement for vessels to contact NMFS at least 48 hr in advance of a fishing trip to facilitate the placement of observers, observer sample station and reasonable assistance requirements to improve an observer's ability collect quality data in a safe and efficient manner, and the slippage prohibition and the sampling requirements for midwater trawl vessels fishing in groundfish closed areas to minimize the discarding of unsampled catch.

The same measure that would have required 100-percent observer coverage, coupled with a $325 contribution by the industry, would have also required that: (1) The 100-percent coverage requirement be re-evaluated by the Council 2 years after implementation; (2) the 100-percent coverage requirement be waived if no observers were available, but not waived for trips that enter the River Herring Monitoring/Avoidance Areas; (3) observer service provider requirements for the Atlantic sea scallop fishery apply to observer service providers for the herring fishery; and (4) states be authorized as observer service providers. NMFS believes these additional measures are inseparable from the 100-percent observer coverage requirement; therefore, NMFS had to disapprove these measures too. With the disapproval of these measures, the existing waiver and observer service provider requirements remain in effect.

Excerpt from Amendment 14 to the Atlantic Mackerel, Squid, and Butterfish FMP (79 FR 10029; February 24, 2014)

1. Increased Observer Coverage Requirements

Currently, the NMFS Northeast Fisheries Science Center (NEFSC) determines observer coverage levels in the mackerel fishery based on the standardized bycatch reporting methodology (SBRM) and after consultations with the Council. Observer coverage in the mackerel fishery is currently fully funded by

NMFS. In Amendment 14, the Council recommended increases in the observer coverage in the mackerel fishery, specifically 100-percent observer coverage on all limited access mackerel vessels using midwater trawl (i.e., Tiers 1, 2 and 3) and Tier 1 mackerel vessels using small-mesh bottom trawl, 50-percent coverage on Tier 2 mackerel vessels using small-mesh bottom trawl, and 25-percent on Tier 3 mackerel vessels using small-mesh bottom trawl. Many stakeholders believe this measure is necessary to accurately determine the extent of bycatch and incidental catch in the mackerel fishery. The Council recommended this measure to gather more information on the mackerel fishery so that it may better evaluate and, if necessary, implement additional measures to address catch and discards of river herring and shad. The increased observer coverage level recommendations were coupled with a target maximum industry contribution of $325 per day. There are two types of costs associated with observer coverage: Observer monitoring costs, such as observer salary and travel costs; and NMFS support and infrastructure costs, such as observer training, data processing, and infrastructure. The monitoring costs associated with an observer in the mackerel fishery are higher than $325 per day. Upon legal analysis of this measure, the cost-sharing of monitoring costs between NMFS and the industry would violate the Anti-Deficiency Act. Therefore, based on this analysis, there is no current legal mechanism to allow cost-sharing of monitoring costs between NMFS and the industry.

Throughout the development of Amendment 14, NMFS advised the Council that Amendment 14 must identify a funding source for increased observer coverage because NMFS's annual appropriations for observer coverage are not guaranteed. Some commenters asserted that the $325 per day industry contribution was not a limit, but a target, and that the Council intended the industry to pay whatever is necessary to ensure 100-percent observer coverage. NMFS disagrees, and does not believe the amendment specifies that the industry would pay all the monitoring costs associated with 100-percent observer coverage, nor does the amendment analyze the economic impacts of the industry paying all the monitoring costs. The FEIS for Amendment 14 analyzes the industry paying $325 per day, and the DEIS analyzes the cost of vessels paying $800 per day (estimated sum of observer monitoring costs), but it does not analyze a range of that would approximate total monitoring costs. Budget uncertainties prevent NMFS from being able to commit to paying for increased observer coverage in the mackerel fishery. Requiring NMFS to pay for 100-percent observer coverage would amount to an unfunded mandate. Because Amendment 14 does not identify a funding source to cover the costs of increased observer coverage, the measure is not sufficiently developed to approve at this time. Therefore, NMFS had to disapprove the 100-percent observer coverage requirement. With the disapproval of this measure, this action maintains the existing observer coverage levels and full Federal funding for observer coverage the mackerel fishery.

In 2013, a working group was formed to identify a workable, legal mechanism to allow for industry-funded observer coverage in the herring fishery, including staff from the New England and Mid-Atlantic Councils and NMFS. To further explore the legal issues surrounding industry-funded observer coverage, NMFS formed a working group of Greater Atlantic Regional Fisheries Office, NEFSC, General Counsel, and Headquarters staff. The NMFS working group is currently exploring possibilities.

In the November 7, 2013, partial approval letter to the Council, NMFS offered to be the technical lead on an omnibus amendment to establish an administrative mechanism to allow for industry-funded observer coverage in New England and Mid-Atlantic FMPs. At its October 2013 meeting, the Council considered NMFS's offer and encouraged NMFS to begin development of the omnibus amendment. NMFS expects to present a preliminary range of alternatives for the omnibus amendment to the New England and Mid-Atlantic Councils in early 2014.

Additionally, other measures implemented in this action help improve monitoring in the mackerel fishery. These measures include the requirement for vessels to contact NMFS at least 48 hr in advance of a fishing trip to facilitate the placement of observers, observer sample station and reasonable assistance requirements to improve an observer's ability collect quality data in a safe and efficient manner, and the slippage prohibition and the sampling requirements for midwater trawl vessels fishing in groundfish closed areas to minimize the discarding of unsampled catch.

The same measure that would have required increased observer coverage, coupled with a $325 contribution by the industry, would have also required that: (1) The Council would re-evaluate the increased observer coverage level 2 yr after implementation; and (2) observer service provider requirements for the Atlantic sea scallop fishery would apply to observer service providers for the mackerel fishery. NMFS believes these additional measures are inseparable from the 100-percent observer coverage requirement; therefore, NMFS also disapproved these measures. With the disapproval of these measures, this action maintains the existing SBRM-based observer coverage provisions for the mackerel fishery.

Appendix 2

Public Comments on Amendment 16

Groundfish Dockside Monitoring

Program

1. Comment: “The Northeast Coastal Communities Sector also noted that NMFS needs to ensure that the dockside monitoring costs for all sectors are fully covered for FY 2010 and that no individual sector be allowed to carry a balance of funds into 2011 if another sector has insufficient funds to over their dockside monitoring.”
    - Response: “Amendment 16 anticipated a number of costs associated with sectors, including costs to join a sector and pay for a sector manager, and costs associated with monitoring and reporting provisions. Amendment 16 includes estimates of the costs associated with sector measures. The Council believed that these provisions are necessary to administer and effectively monitor sector operations, and that the benefits of transitioning from the current effort control system to a quota management system under sectors outweigh the costs associated with sector provisions. Under Amendment 16, the Council specified that the fishing industry would pay for the costs associated with sector provisions, and did not provide for alternative funding sources. While many of the administrative and monitoring costs associated with sector operations during FY 2010 will be paid by NMFS through Congressional appropriations dedicated to supporting Sector development, it is unclear whether such funding will remain available to support sector operations in future FYs. Additional funding has been made available from individual states, as well as from several environmental groups, to support individual sector development. If such funding from one or more of these sources is no longer available, the fishing industry will be responsible for paying these costs. Some management measures considered in Amendment 16 were not selected in part because of concerns over the costs and burdens of administering the program. The costs associated with 100- percent at-sea and dockside monitoring coverage were deemed to outweigh the benefits expected from such measures. Therefore, this action minimized costs to the extent practicable, consistent with National Standard 7. As discussed in the response to Comment 41, each individual vessel owner must choose which management regime would provide the most benefits based upon his/her intended operations. Further, if costs to join an already existing sector are considered too high, vessels may form their own sector with similarly situated vessels. The NMFS funding available to help offset costs associated with dockside monitoring during FY 2010 have been awarded by grant to a third party, GMRI, who is working directly with sector representatives to ensure the funds are distributed equitably to each sector relative to their particular monitor needs. Variables affecting dockside monitoring costs include the volume of catch, the number of trips, the need to provide service to remote ports, the need for roving monitors, or any combination of the above. However, these costs are difficult to estimate without full knowledge of how fishing operations will be executed during

FY 2010. The amount of the total grant to be distributed to sectors exceeds the current estimated total cost of dockside monitoring for all of the sectors. If necessary, funds can be shifted to optimize their effectiveness. However, should dockside monitoring costs exceed the amount of the grant, the sectors will be responsible for paying the additional costs, consistent with Amendment 16."

2. **Comment:** "The Northeast Coastal Communities Sector stated that NMFS should establish a minimum threshold requirement for dockside monitoring to ensure that vessels that land low amounts of fish for each trip are not subject to unnecessarily high dockside monitoring costs, particularly for small ports in eastern Maine where the low availability of regulated species does not result high volumes of fish being landed for each trip."
    - **Response:** "As noted above in the response to Comment 46, the costs associated with dockside monitoring are affected by several variables, including the amount of fish landed, or the amount of time the dockside monitor is required to observe landings. If dockside monitoring costs are based primarily upon these factors, it is possible that the costs will be lower for smaller volumes of fish landed by vessels operating in eastern Maine than for other vessels landing higher volumes of fish. However, Amendment 16 did not propose a minimum threshold of landings that would exempt a trip from the requirements to use a dockside monitor. Instead, Amendment 16 specified that dockside monitoring coverage will be randomly assigned to 50 percent of sector trips. Because Amendment 16 did not include a specific exemption from the dockside monitoring provisions for small volumes of fish landed, NMFS has not revised the dockside monitoring provi by this final rule."
3. **Comment:** "EDF, PEW, CLF, NAMA, and the CCCHFA indicated that additional observer coverage is necessary to effectively implement sector provisions and increase the accuracy of discard estimates in the fishery. PEW and CLF suggested that at- sea monitoring coverage should be increased to 100 percent, even if that means reducing dockside monitoring coverage. NAMA suggested that such increased coverage should be applied to at least FYs 2010 and 2011 to establish a baseline of sector operations. EDF recommended that if at-sea monitoring cannot be increased to 100 percent without delaying Amendment 16, NMFS should implement more restrictive enforcement measures that require individual vessels to pay for 100 percent observer coverage for the rest of the FY if reported discards are significantly higher or lower compared to observed trips, with positive incentives for sectors that ‘‘outperform the fleet average’’ for reporting quality. Two commercial fishermen, PEW, CLF, and CCCHFA also recommended that NMFS implement 100-percent dockside monitoring coverage. Oceana further claimed that Amendment 16 does not specify the precise level of observer coverage in the FMP, as alleged in a lawsuit brought against NMFS based on the approval of Amendment 13 to the FMP."
    - **Response:** "When the Council adopted Amendment 16, the Council neither selected the option to require 100- percent observer coverage, nor required sectors or the common pool to be subject to an at-sea monitoring program in FY 2010. However,

NMFS agrees with the basic concept advocated by the commenters that higher levels of observer coverage are more effective at collecting the data necessary to monitor groundfish landings and discards under Amendment 16 and reducing the potential of an observer effect that could potentially compromise data collected with less than 100-percent coverage. As stated earlier in the preamble of this final rule, NMFS has funding to provide approximately 38-percent at-sea monitoring coverage for sector vessels, and about 30-percent at-sea monitoring coverage for common pool vessels, in addition to fully funding 50-percent dockside monitoring coverage for FY 2010. Such coverage levels should provide sufficient information to more than meet the minimum requirements of the SBRM, while providing the additional coverage suggested by commenters to monitor sector operations under Amendment 16. Distribution of such funds was intended to accomplish the dual goals of monitoring both at-sea catch and dockside landings to ensure that discards are accurately estimated and landings data are validated. Shifting resources to emphasize one over the other would not be consistent with the objectives of Amendment 16. Additional coverage would provide more data on groundfish catch, but even if available funds were shifted to emphasize at-sea monitoring over dockside monitoring, there may not be sufficient funding to provide 100-percent observer coverage across the entire fishery. Further, there is no guarantee that such funding will be available for future years. Requiring 100-percent coverage would, therefore, cause the fishing industry to bear such costs, absent additional funding for NMFS to pay for such coverage. Individual sectors may establish at-sea monitoring programs through their yearly operations plans that provide for additional observer coverage beyond that provided by NMFS. However, no sector has proposed such additional coverage for FY 2010. Although EDF recommended implementing additional enforcement measures that would increase at-sea monitoring coverage based upon the accuracy of a sector's discard estimates compared to the fleet average, there were insufficient details provided to determine how to implement such a mechanism. Moreover, there is no enforcement authority that would allow the kind of real-time increase of observer coverage suggested by EDF. Further, it is unclear from the description whether it would even be possible for a sector to avoid triggering 100-percent at-sea monitoring coverage, as additional coverage would be required if the sector's reports were either statistically higher or lower than the fleet average. This approach could undermine incentives to accurately report discards and would, instead, create incentives to report discards that reflect the industry average. Because the Council did not include such a mechanism to increase at-sea monitoring coverage in Amendment 16, NMFS does not have the latitude to implement such a provision through this final rule. Finally, the Court's findings in the Amendment 13 lawsuit required that FMPs establish SBRM's, but did not mandate specified levels of observer coverage. Because Amendment 16 is in compliance with the omnibus amendment that implemented SBRMs for all FMPs managed in the NE in January 2008, Amendment 16 is not at odds with the Court's findings in the lawsuit referred to by the commenters."

4. **Comment:** "Two commercial fishermen, PEW, CLF, and CCCHFA recommended that NMFS utilize electronic monitoring to reduce costs, including deploying electronic monitoring in other fisheries to record NE multispecies bycatch. The APO commented that the standards for approving electronic monitoring technology are not clear and that the public should be involved with any decision to approve such technology."
   - **Response:** "NMFS has not yet determined whether electronic monitoring technology is sufficiently developed to be applied in the NE multispecies fishery. Criteria to evaluate such technology are currently being refined by NMFS based upon existing research and pilot programs. Any electronic monitoring technology to be applied in the NE multispecies fishery will be subject to rulemaking consistent with the Administrative Procedure Act."
5. **Comment:** "Three commercial fishermen, the AFM, and the Sustainable Harvest Sector recommend that dockside monitors should not be required for trips in which either an atsea monitor or fishery observer is deployed. They suggested that such a practice is redundant and a waste of resources."
   - **Response:** "NMFS disagrees. The roles for dockside monitors and at-sea monitors are different; dockside monitors are intended to verify the landings of a vessel and certify that landings weights on the dealer report are accurate, while at-sea monitors are responsible for verifying area fished, catch, and discards by species and gear type. Furthermore, the responsibilities of a fishery observer differ from those of an at-sea monitor, in that observers are also required to collect biological samples and more comprehensive data on the interactions with protected species and marine mammals. Moreover, because both at-sea monitors and observers do not have the capacity to operate 24 hr per day, and are often required to sub-sample portions of the catch, data from at-sea monitors or observers do not represent a complete accounting of every pound of fish that is retained by a vessel, unlike dealer reports, and cannot be used to validate dealer reports. Finally, the Council did not differentiate in Amendment 16 between trips monitored by an at-sea monitor or observer for the purposes of defining dockside monitoring coverage levels. Therefore, because the purposes of dockside monitors and at-sea monitors and observers are different, the associated data for each entity are not directly comparable, and because the Council did not consider the exemption requested by the commenters, NMFS is not implementing such an exemption through this final rule."

Appendix 3

Public Comments on Framework 45's Proposed Rule

- Changes to the Sector Dockside Monitoring Program

1. **Comment:** "The NSC questioned the utility of dockside/roving monitoring requirements, suggesting that FW 45 should eliminate such requirements completely. The NSC believes the current requirements to be highly inefficient, representing an unsustainable and unjustified cost to the fishing industry. Further, they suggested that NMFS should allow sectors to use dockside monitoring data as a proxy for dealer data in the weekly sector catch reports submitted to NMFS to increase the utility of the dockside/roving monitoring program. Finally, NSC indicated that roving monitors should not have to observe offloads to a truck and also to a dealer, asserting that roving monitors should only be required to observe offloads from the vessel to a truck, to increase the efficiency and reduce costs associated with these provisions."

    - **Response:** "The Council considered completely eliminating dockside/roving monitoring requirements during the development of FW 45. However, due to lingering concerns over the ability to enforce existing provisions to monitor sector ACE and minimize incentives to misreport catch, the Council retained dockside/roving monitoring requirements in FW 45. NMFS may only approve or disapprove measures proposed in FW 45, and may not change or substitute any measure in a substantive way. Therefore, NMFS cannot eliminate dockside/roving monitoring requirements through this final rule. During the development of Amendment 16, it was anticipated that sectors would rely upon dockside/ roving monitor data to document sector landings immediately following a vessel's offload until the official dealer reports become available approximately a week later. This practice has been discussed with sector managers through several sector workshops held during 2009 and 2010. NMFS recognizes that dockside/roving monitoring data cannot currently be reported as part of the weekly sector catch reports submitted to NMFS based upon existing guidance and database structures. To date, many dockside/roving monitoring data are not systematically collected in a format that can be easily transferred to a catch monitoring database. Instead, they are often merely scanned images of a dockside/roving monitor report. NMFS has the regulatory authority to accept dockside/roving monitoring data in the future and may reconsider the acceptance of dockside/roving monitoring data if such data become available in an acceptable electronic format. Further, dealer landings, as documented through official dealer reports, have been the standard by which landings are monitored for many years, and were used as the basis for the calculation of potential sector contributions and, therefore, sector ACE. Accordingly, even if dockside/ roving monitor data could be considered as a proxy for dealer landings in weekly sector catch report, dealer landings data would continue to be the official record of species landed by each federally permitted vessel. The Council required sectors to develop and implement an independent third-party weighmaster system satisfactory to NMFS for monitoring landings and utilization of ACE. The original intent of dockside/roving monitoring coverage was to verify landings of a vessel at the time it is weighed by a dealer to certify the landing weights are accurate as reported on the official dealer report for compliance purposes. Therefore, NMFS implemented regulations under Amendment 16 that require that a roving monitor must observe the offloads from a vessel to a truck and again from the truck to a dealer, unless the vessel offloads directly to a dealer. These regulations were based upon a pilot program and existing dockside/ roving monitoring programs developed in other regions and in Canada. During sector implementation workshops conducted in 2009 and 2010, and ongoing communications with sector managers, NMFS indicated that it would allow a roving monitor to only observe offloads from a vessel to a truck, provided a representative from the dealer ultimately receiving the fish was present at the time of the offload, and that all fish were weighed at the time of the offload. This ensures that the weight of fish offloaded corresponds to the weight of the fish recorded in the official dealer report, consistent with the intent of Amendment 16. Thus, existing regulations and protocols already allow for the behavior requested by the NSC in their comment."

2. Comment: "The NEHFA, PERC, PEW, and one commercial fisherman supported exempting vessels issued a limited access NE multispecies Handgear A or a Small Vessel Exemption permit or an open access NE multispecies Handgear B permit that is fishing in the common pool from the existing dockside/roving monitoring requirements. They stated that dockside/roving monitoring costs may be more than the value of fish landed on a particular trip and would make the operation of such permits economically unviable. The NEHFA also noted that many handgear vessels are launched and retrieved at public boat ramps, thereby creating logistical difficulties for waiting for the dockside/roving monitor to arrive because a boat may be forced to move off of the dock to accommodate the launching of other boats. This group also contended that the current system of monitoring landings is sufficient for these vessels due to the small amount of fish landed on each trip. Finally, PERC suggested that handgear vessels fishing in sectors should also be exempted from the dockside/roving monitoring requirements."

   - Response: "NMFS agrees that the costs associated with the existing dockside/ roving monitoring requirements could make fishing with a Handgear A, Handgear B, or Small Vessel Exemption permit uneconomical for the reasons noted above and specified in FW 45. Therefore, NMFS implements the proposed exemption from the common pool dockside/roving monitoring requirements for these permit categories through this final rule. Because the Council did not adopt a provision that would have exempted sector vessels fishing with a handgear permit from the dockside/roving monitoring requirements as part of FW 45, NMFS cannot implement such a provision through this action."

3. Comment: "Three commercial fishermen and two commercial fishing industry groups (AFM and NSC) opposed the proposal to require dockside/roving monitors to inspect the fish holds of vessels offloading groundfish. AIS, Inc., a dockside/roving monitoring service provider, also expressed concerns that the proposed requirement for dockside monitors to inspect fish holds presents safety issues. All commenters highlighted the risk of serious injury from having dockside/ roving monitors board vessels, climb down ladders into the fish holds, and inspect the holds or other compartments for fish that have not been offloaded. AIS noted that there are no standards in FW 45 that address potentially dangerous conditions in inspecting holds, or requirements for vessels to provide a standardized safe boarding system. AIS also stated that there is no guidance as to how to inspect fish holds, including whether dockside monitors must inspect piles of ice or look for fish in other compartments, giving the impression that dockside/ roving monitors may be acting as enforcement personnel instead of data collectors. Several commenters suggested that this potential risk will force vessel owners to buy more insurance to ensure that they are adequately covered for any potential liability lawsuits that might result from this provision. In doing so, they contested that this would contradict the FW 45 economic analysis that indicates that this measure should not impact either vessel owners or service providers. They noted that, even if the dockside/roving monitoring service providers had sufficient insurance coverage, vessel owners might still be sued and face financial liability from the injury claims of individual dockside/ roving monitors. Further, they claimed that the proposed rule does not provide any rationale that enhanced enforceability is needed, or that underreporting is occurring. They contested that the existing provisions that require dockside/roving monitors to ask vessel operators if all fish have been offloaded, and classify providing false statements to dockside/roving monitors as a violation, should be sufficient to enforce this provision. They recommended that NMFS Office of Law Enforcement should inspect fish holds, instead of dockside/roving monitors."

    - Response: "As noted throughout the development of Amendment 16 and FW 45 by both fishing industry representatives and NMFS, the transition to expanded sector management and ACLs increases incentives to misreport or under report catch and landings. Dockside/roving monitoring programs established in other regions of the United States and Canada that are managed by harvest quotas are considering, or have required, dockside/roving monitors to inspect fish holds to ensure that all fish are offloaded. The potential for dockside/roving monitors to inspect fish holds was explicitly discussed throughout the development of Amendment 16 as part of both the Council process and parallel meetings to discuss the development of sector measures sponsored by the Gulf of Maine Research Institute. Section 4.2.3.5.4 of the Amendment 16 FEIS documents this discussion and clearly indicates that to be approved as a dockside/roving monitor, a dockside/ roving monitor must meet several criteria, including: ‘‘Physical capacity for carrying out the responsibilities of a dockside/roving monitor pursuant to standards established by NMFS such as being certified by a physician to be physically fit to work as a dockside/roving monitor. The physician must understand the monitor’s job and working conditions, including the possibility that a monitor may be required to climb a ladder to inspect fish holds.’’ Therefore, the general public, including both vessel owners and dockside/roving monitoring service providers, were well aware of the potential that dockside/ roving monitors might be required to inspect fish holds and the risks that such activity might incur. However, no comments opposing this practice were raised to NMFS during the public comment period on the Amendment 16 proposed rule. The final rule implementing Amendment 16 measures did not require dockside/roving monitors to inspect the fish holds based, in part, on a pilot dockside/roving monitoring program conducted in the summer of 2009. Similar to comments received on this action, some safety concerns were identified with inspecting fish holds during the pilot program, even though fish holds were actually inspected as part of that pilot program. As a result, in the Amendment 16 proposed (74 FR 69382; December 31, 2009) and final rules, NMFS intentionally included language in the dockside/roving monitoring program operational standards at § 648.87(b)(5)(ii)(B)(1) that allow individual dockside/roving monitors or service providers to inspect fish holds if they elect to do so. Section 311 of the Magnuson-Stevens Act provides the Secretary of Commerce with the general authority to enforce the provisions of the Magnuson-Stevens Act. NMFS acknowledges that existing dockside/roving monitoring provisions make it a violation for a vessel operator to provide false statements to a dockside/roving monitor about whether all catch is offloaded. However, that is just one of many ways to ensure compliance with existing regulations. NMFS does not agree that such measures are completely sufficient to ensure that all catch is offloaded. The only way to validate statements made by a vessel operator is to actually inspect fish holds. NMFS Office of Law Enforcement personnel already have the authority to board and inspect vessels. However, requiring dockside/roving monitors to also inspect fish holds, as anticipated during the development of Amendment 16, provides another means to ensure that vessel operators are complying with existing requirements, and that all fish that are landed are recorded in dealer databases or other data sources such as dockside/roving monitor reports. Dockside/roving monitors are not enforcement personnel, but their observations, including the reports summarizing the offloads of individual trips, are available to law enforcement personnel, as described in Section 4.2.3.5.4 of the Amendment 16 FEIS and the existing regulations at § 648.87(b)(4). The training provided to dockside/roving monitors by NMFS explicitly states that it is the dockside/ roving monitor’s responsibility to account for all catch, whether or not it is properly weighed or recorded by other parties. Monitors must record any species that is not weighed in their incident report to facilitate compliance with existing requirements. Therefore, based on the need to ensure that NMFS is accurately monitoring the amount of fish landed, NMFS has retained the requirement that dockside/roving monitors must inspect fish holds as part of this final rule. NMFS recognizes that dockside/ roving monitors must proceed with caution when conducting inspections of fish holds. As part of the dockside/ roving monitoring training curriculum and certification process overseen by NMFS, individual dockside/roving monitors are trained and tested for competency in safety procedures, including slips, trips, and falls; electrical safety; climbing stairs and ladders; overhead dangers; unstable items; and fire. In addition, NMFS will likely require all previously certified dockside/roving monitors to attend a refresher safety training session on issues specific to boarding vessels and inspecting fish holds. Based on examples in other U.S. and Canadian fisheries, NMFS is currently developing standardized protocols that outline the major elements that dockside/roving monitors must comply with when inspecting fish holds. These elements include, but are not limited to, requesting permission from the vessel captain to board a vessel, following the instructions of the vessel's captain and crew to safely enter and exit the fish holds, and inspecting only areas of the vessel that would normally be used to store fish. Such standards will be integrated into the dockside/roving monitoring training curriculum developed and conducted by the Northeast Fishery Observer Program. The dockside/roving monitor service provider approval standards adopted in Amendment 16 explicitly included the requirement for service providers to have adequate insurance to cover injury, liability, or accidental death that might befall dockside/roving monitors. NMFS recognizes that despite such coverage, individual dockside/roving monitors still have the capacity to bring a lawsuit against vessel owners for any injuries incurred while inspecting fish holds. NMFS encourages sectors and dockside/ roving monitor service providers to seek agreement on how to best address the issues and problems raised by the comment. As to whether FW 45 sufficiently considers possible increases in cost for liability insurance for inspecting fish holds, NMFS does not have sufficient information to do so. While NMFS has information on the amount and type of insurance dockside/ roving monitoring service providers have purchased, it would be difficult for NMFS to speculate on the costs of additional insurance for individual vessels. However, NMFS is committed to reviewing the requirement to inspect fish holds and the costs associated with it over time as more information becomes available."

4. Comment: "Two industry groups (AFM and NSC) supported the proposal to delay the industry's responsibility for dockside and at-sea monitoring costs until FY 2013. They stated that this accurately reflects the fishing industry's inability to pay for the high costs of such monitoring at this time. However, the NSC cautioned that the economic viability of the fishing industry is not likely to improve sufficiently to enable sectors to cover such monitoring costs in FY 2013. Accordingly, they recommended that the Council and NMFS

should consider further postponing industry responsibility for such costs until the fishing industry is profitable again. In contrast, PEW suggested that sectors should be in a better position to assume monitoring costs in FY 2013. PEW offered that the proposed delay would help ensure the success of the established sector program, arguing that the long-term benefits of fishing under sectors outweigh any potential impacts associated with reduced dockside monitoring in the short term. Oceana opposed delaying industry responsibility for dockside and at-sea monitoring costs, claiming that NMFS does not have the authority to modify sector monitoring provisions in a FW action because such a measure would be a fundamental change in the FMP and that implementing this delay through a FW action would circumvent the public process. Citing a recent court case (Oceana, Inc. v. Evans, 384 F. Supp. 2d 203, 255 (D.DC 2005)), they contended that such measures can only be modified through an amendment, with an associated NEPA document. They also suggested that the proposed delay would undermine the Magnuson Stevens Act requirements to monitor bycatch and implement measures to ensure accountability for ACLs, especially considering the concerns expressed by NMFS in a November 15, 2010, letter to the Council highlighting concerns about the potential limitation of NMFS funding in 2012 to support dockside and at-sea monitoring. FWW echoed this concern, noting that this might cause a ‘‘gap in the necessary enforcement required due to increased incentives for high-grading, misreporting, and underreporting.’’ They recommended that delaying or removing monitoring costs should be based on vessel size/capacity, or an individual business's revenue."

- Response: "NMFS recognizes that the costs of requiring the fishing industry to pay for sufficient at-sea monitoring coverage could reduce profitability. However, a FMP must continue to maintain measures that prevent overfishing and promote the long-term health and stability of the fishery, as required by section 303(a) of the Magnuson-Stevens Act. As noted above, NMFS is concerned that relying exclusively on available NMFS funding for at-sea monitoring coverage during FY 2012 may reduce the amount of atsea monitoring coverage available during that FY due to the yet uncertain amount of available NMFS funding for FY 2012. NMFS agrees that delaying industry responsibility for paying for at sea monitoring coverage may reduce the amount of at-sea monitoring coverage during FY 2012 and undermine efforts to obtain accurate information regarding catch in the fishery. Therefore, NMFS has disapproved the proposed measure to delay industry responsibility for the costs at-sea monitoring coverage during FY 2012. NMFS expects at least some funding that will offset at least some of the at-sea monitoring coverage costs during FY 2012. Accordingly, the fishing industry would only be responsible for the costs of at-sea monitoring coverage that is not accounted for by available Federal funding. As noted in the FW 45 EA, delaying industry responsibility for funding dockside/roving monitoring coverage in FYs 2011 and 2012 will immediately reduce operational costs to industry, without reducing the availability of landings information. This is because the dockside/roving monitoring data are primarily used for enforcement purposes, not catch monitoring. The trip-end hail report, in conjunction with the requirement for dockside/roving monitors to inspect fish holds implemented by this final rule, is intended to provide sufficient information to ensure compliance with existing regulations. Moreover, NMFS is expected to have sufficient funding in FY 2011 to continue the levels of observer and at-sea monitoring coverage for both sector and common pool trips implemented in FY 2010, and to augment that with sufficient dockside/ roving monitoring coverage for trips not monitored by observers or at-sea monitors. Even if insufficient funding available to NMFS results in a shortterm reduction in dockside/roving monitoring data, NMFS agrees that such reductions in data would likely be offset by long-term benefits of fishing under sectors. Therefore, NMFS is approving the delay in industry responsibility for dockside/roving monitoring costs through this final rule. Further changes could be considered by the Council through a future management action, but because NMFS does not have the authority to revise measures adopted by the Council in FW 45, NMFS cannot unilaterally postpone industry responsibility for such costs beyond FY 2012 through this action. NMFS disagrees that the proposed postponement of industry responsibility for dockside/roving and at-sea monitoring costs represents a fundamental revision of the FMP and would circumvent the public process. First, the fundamental dockside/roving and at-sea monitoring provisions implemented by Amendment 16 are retained. The only aspect of these provisions that changes through FW 45 is the entity paying for the costs of such monitoring. Although NMFS will pay for at last some of the costs of dockside/ roving and at-sea monitoring coverage for FYs 2011 and 2012, and will endeavor to achieve the coverage requirements specified in Amendment 16 for industry-funded dockside/roving and at-sea monitoring coverage, these changes do not constitute a fundamental change to the FMP requiring an amendment to the FMP. Second, the Council fully anticipated that measures adopted under Amendment 16 could be revised in the future through a FW action. This is documented in the Amendment 16 FEIS's executive summary when it states, ‘‘The periodic adjustment process is modified so that all measures adopted can be adjusted on a framework action’’ (see page 10 of that document) and in Section 4.2.8. This was codified in the regulations at § 648.90(a)(2)(iii) and (c)(1)(i). Both the Amendment 16 FEIS and the proposed regulations to implement Amendment 16 measures were made available for extensive public comment. Therefore, because the fundamental aspects of the Amendment 16 sector and common pool monitoring measures are not affected by the proposed delay in responsibility for monitoring costs, and that the public was afforded substantial opportunity to comment on the ability of the Council and NMFS to revise existing management measures through a FW action as part of the Amendment 16 proposed rule, NMFS has not remanded this provision back to the Council for implementation through an amendment to the FMP."

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Appendix 4

April 9, 2013

Mr. John K. Bullard, Regional Administrator
NOAA Fisheries – National Marine Fisheries Service
55 Great Republic Drive
Gloucester, MA 01930

RE: Framework 48 to the Northeast Multispecies Fishery Management Plan
NOAA–NMFS–2013–0050

Dear Mr. Bullard:

On behalf of Conservation Law Foundation (CLF), I am writing to provide comments on the rule proposed by NOAA Fisheries for Framework 48 (FW 48) to the Northeast Multispecies Fishery Management Plan.[1] We recently submitted joint comments with the Pew Charitable Trusts to NOAA Fisheries on the related sector operations plans rule.[2] CLF focuses here on our particular concerns with Framework 48, most particularly the proposal to authorize a procedure that would allow sectors to access the year-round groundfish closed areas through their annual sector operations plan approval process.

We would note initially three contextual circumstances that surround the series of framework adjustments and sector ops plan approvals that are being promulgated in such a rushed manner this spring with significantly foreshortened public review and comment periods. First, there is a crisis with a number of groundfish stocks including both cod stocks, GOM haddock, and a number of flounder stocks. Many of the stock assessments exhibit significant retrospective patterns and the assessment scientists have already cautioned that their estimates may be optimistic in terms of predicted the actual condition of those stocks. With cod, age structure is significantly truncated and weights at age are low. Many of these stocks are in crisis as a direct result of the failure to curb overfishing and are now further burdened by worsening environmental factors.

There is no rational reason to place these stocks at any greater risk of further collapse. Although there are a number of significant quota cuts, there are also a number of quota increases in the fishery. Moreover, few, if any, multispecies permit holders are dependent on revenues from the

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[1] Northeast (NE) Multispecies Fishery; Framework Adjustment 48; Federal Register / Vol. 78, No. 57 / Monday, March 25, 2013 / Proposed Rules / pages 18188-219.
[2] Letter to Alison Murphy, NOAA-Fisheries, from Pew Charitable Trusts and the Conservation Law Foundation dated March 28, 2013:
NOAA_NMFS_2013_0007_Sector_Plans_Pew_CLF_0328_2013 (1jx-84gi-fimp).

stocks with quota cuts, having diversified to a broad range of other species for some time. What is at risk by the measures proposed in Framework 48 as well as several of the other management actions being taken in this period is the long term future of a number of critical stocks and as well as the related fisheries that unavoidably catch these stocks as bycatch, thereby threatening long term risks of substantially greater social and economic harm.

The second overarching circumstance framing the Framework 48 action is the Omnibus EFH Habitat Amendment (Omnibus Amendment). The Omnibus Amendment has been slowly moving through the management process for close to a decade, despite the fact that protection of essential fish habitats from fishing activities was one of the primary legislative purposes of the Sustainable Fisheries Act of 2006. Significant technical analysis has been done in support of the current thinking underlying the Omnibus Amendment but none of that analysis has been presented to the public in a final form and the gaps in that analysis with respect to a consideration of the full range of benefits that EFH provides to species productivity are well know. Much of the work that is currently underway by the Closed Area Technical Team (CATT) is focused on improving that analytical framework and coming to a better understanding of the relationships between essential fish habitats and species productivity and management actions to mitigate or avoid deleterious effects. Each meeting of the CATT produces new information and insights into the multiple ways in which these closed areas are benefitting managed groundfish species, well beyond the mortality reduction benefits.

That analysis, however, is not complete. The documentation, alternatives analysis, and mitigation measures have not been fully reviewed; and the public has had no opportunity yet to understand and respond to the complex set of issues that will be addressed in the Omnibus Amendment. Any material or points of view about the relative contributions of various parts of the existing closed or open areas to improved productivity that are included in those documents are preliminary from a legal point of view. Nevertheless, even the language that is being used in Framework 48 to distinguish “mortality closures” from “habitat closures” reveals that the agency is already making decisions to promote opening existing closed areas on the basis of that preliminary analysis, prejudging the final decision document and environmental analysis. The agency’s action constitutes a classic segmentation of the environmental review process that is fundamentally against the principles and law of the National Environmental Policy Act (“NEPA”).

The negative impacts of the NEPA segmentation are exacerbated by the fact that all these decisions are being made in a foreshortened and confusing public comment period that stretches across four separate regulatory actions: the sector operating plan regulations, Framework 48, Framework 50, and then whatever form the later action takes on approving sector access in some or all of the closed areas later this year. This is the sort of chopped up, incoherent, and disjointed federal environmental review that routinely is found to violate NEPA. The agency here is already on record with the position that if this very same set of questions were to be raised together, there would be no question that an extended and integrated environmental review would be required.

The proposed solution of breaking the decision into smaller pieces is being proposed by the agency for the explicit purpose of avoiding that result. Such an approach is antagonistic to the principles of broad public participation and reasoned, integrated decision making that NEPA is intended to bring to all major federal decisions.

Finally, CLF strenuously objects to the framework process by which the existing closed areas are being made available for access for fishing. This is virtually the same approach that was rejected by the Federal District Court for the District of Columbia in Oceana, Inc. v. Evans, 384 F. Supp. 2.d 203, 254, order clarified, 389 F. Supp. 2d 4 (D.D.C. 2005). In Oceana, the court set forth the following standard: "[a] framework adjustment that truly adjusts management measures according to specifications in the FMP might well be lawful, whereas so-called adjustments which in fact undermine or contravene key provisions of an FMP would not." Oceana, Inc. v. Evans, 384 F. Supp. at 254.

In the instant case, Amendment 16 is the controlling last amendment and it specifically indicated that access to the year-round closed areas was not available to the sectors through their annual operating plans. CLF can find no support in the record of that action that would suggest that opening of any and all of the year-around closures was to be a proper subject of a framework action. Framework 48 directly undermines and contravenes that prohibition in Amendment 16 and is not a proper subject for a framework amendment. To make the situation even more untenable legally, Framework 48 itself does not even frame out or elucidate what the extent and type of access sectors will be allowed. Those sets of decisions are being delegated to yet another action, which seems to not even have the formal status of a framework: a later approval process with unspecified parameters or scope or even timing.

We will now turn to the provisions of Framework 48 itself and provide comments in the order the issues are identified in the document:

1. Status Determination Criteria for SNE/MA Yellowtail

It is difficult to understand a "best-available-science" assessment for SNE/MA yellowtail flounder that the stock could either be fully rebuilt and not overfished and not experiencing overfishing or that it is experiencing overfishing, is overfished, and the productivity of the fish population is so low that it might not ever rebuild even if fishing mortality were held to zero. While the evidentiary split of 60:40 suggests that the assessment scientists certainly considered it was a close call, it nonetheless seems a true Hobson's choice. Perhaps SNE/MA yellowtail is just another indicator of a heavily disturbed system coupled with inadequate analytical tools for management.

2. SNE/MA Windowpane Flounder sub-ACLs

Given the recent significant exceedance of the total ACL limits for two years, we are pleased to see a new set of reactive and proactive accountability measures for this stock.

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3. Scallop Fishery sub-ACLs for GB Yellowtail Flounder

These provisions make sense and we think the incentive structure provided by the FY2014 sub-ACL is appropriate.

4. Small-Mesh Fisheries sub-ACL for GB Yellowtail Flounder

At 100mt, the small-mesh catch of GB yellowtail flounder is significant and it is important that effective AMs are developed to control mortality in this fishery within prescribed limits. The proposed regulation requires subsequent action to be effecting and the public should know when adequate AMs will be developed in the small-mesh fisheries.

5. Recreational Fishery AM

CLF supports the requirement in the law that there should be proactive accountability measures available to the Administrator to ensure that the recreational sub-ACL is not violated.

6. Commercial Groundfish Fishery AMs

CLF supports the proposal in this framework to increase the effectiveness of the AMs by accelerating implementation in the fishing season after the overage is believed to have occurred. We also support the promulgation of rules setting area-based AMs for Atlantic Halibut, Atlantic wolfish, and SNE/MA winter flounder. We also support the revised AMs for SNE/MA windowpane flounder, including specifically the area-based AMs.

7. Commercial Fishery Minimum Sizes

The goal of these proposals is to reduce regulatory discards and increase revenue from the catch. These proposals are troubling however because they will have a tendency of encouraging fishermen to target small fish that have barely become sexually reproductive. Discards are wasteful and inefficient. However, because discards are counted against the catch but produce no financial return, the current size limits provide a natural disincentive to catching fish just entering the fishery. This action would remove that disincentive and likely still produce large discards of sub-legal fish. The 16" haddock size limit seems designed to promote the targeting of the latest large year class, a year class that might be vital to the future of the fishery if it were allowed another season or two. We have been told and we believe that a number of fishermen also are encouraged to fish illegally with net liners and other devices to prevent the escape of any legal-sized fish, even at the expense of high discards of undersized, sexually immature fish. With continued low levels of observer coverage coupled with the ACL cuts, it is reasonable to expect that such behavior might increase. Lowering sizes will produce more discards, not fewer. This might be less of a problem if full retention were required of all catch; at least then a more accurate picture of the bycatch problem might be documented. But the Council has not elected to do that.

8. Sector Monitoring Program

A. At-Sea Monitoring

Monitoring the New England groundfish fishery has become a troubling flash point and the quality and quantity of the data inputs to the stock assessment models threatens the very foundations of the public's confidence in fishery management. There is an industry perspective that can be seen in Framework 48 that it is the public's responsibility to pay for any monitoring as evidenced by the following sort of statement: "Framework 48 proposes to delay the industry's responsibility for at-sea monitoring costs to FY 2014…. Coverage levels would instead be set at the level that NMFS can fund."[3] The failure of the Council and federal managers to manage these fisheries at sustainable levels has produced the apparent consequence that the scientists and manager are either stuck with inadequate data of the actual catches or fishing businesses that are financially burdened by the low quota levels are forced out of business by the burden of any marginal monitoring costs. We say "apparent" because it remains unclear to CLF what is the broad financial condition of the multispecies permit fleet. Many of the aggregate numbers neither support the notion that there is an economic crisis for vessel owners nor the notion that many multispecies permit holders are currently economically dependent on the stocks that will be experiencing quota cuts in FY2013. The industry has to bear its burden of monitoring if it wants to continue to pursue these fisheries. Raiding the scarce federal funding available for the process of approving electronic monitoring for this fishery in order to cover short-term monitoring costs is one of the worst proposals from a cost-benefit perspective that we can imagine in this area.

This monitoring directly bears on the managers' ability to understand what is actually going on with the various stocks of fish at sea. Monitors provide critical data that supports *increases* in quota as well as *decreases.* The assessment scientists seem to have formed a broad consensus that the persistent retrospective patterns they have seen in many of their groundfish models is a result of missing significant mortality in the fish at sea.

The Council's proposal in Framework 48, like the related provisions in the Sector Operations Plans Proposed Rule (NOAA—NMFS 2013-0007), does not meet applicable legal or regulatory thresholds. They preclude accurate monitoring of sector-level catch and thus undermine the meaningfulness of any of the sector-based accountability measures. These problems have been identified in extensive and thorough detail in the Sector Operations Plan Proposed Rule comments of Oceana. We have attached the Oceana comments to this letter and hereby adopt and incorporate them by reference as if fully set forth herein. The agency should reject the Framework 48 monitoring proposal.

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[3] Northeast (NE) Multispecies Fishery; Framework Adjustment 48, Supplemental Information at 26.

B. Dockside Monitoring

CLF supports the elimination of the dockside monitoring program as long as the dockside monitoring hail requirements and an effective dockside intercept system are in place, operational, and demonstrably effective.

C. General Monitoring Comments

With respect to the principle objectives of sector monitoring programs, it is becoming apparent that catch is being misidentified as to the stock area where it is being caught. This is a major problem for assessments and for inshore boats that are disproportionately dependent on particular stocks of fish. Accurate and timely identification of catch by stocks and by place is essential to the fishery and must become a much higher priority for the sector monitoring programs. Of course, without sufficient and appropriate sector/stock monitoring and stratification, all of these principles are meaningless.

We also remain very concerned that the monitoring protocols seem to result in too many monitoring trips on smaller boats that catch a diversity of species but are not responsible for a significant portion of the groundfish species of concern. On the other hand, many of the larger vessels that are targeting these species—and have a greater capacity to support the costs of monitoring—are not being targeted by the monitoring effort. CLF also strongly objects to the qualifying language—"to the extent practicable"—in the rulemaking associated with sector monitoring. Monitoring needs to be adequate to its purpose. Fisheries, or sectors within fisheries, that cannot meet appropriate performance standards should not open.

The rationale for reducing ASM on monkfish DAS trips seems to be sound in a world of constrained monitoring, and the protocols associated with the proposal seem appropriate. There is no reason, however, why electronic monitoring and full retention policies have not been developed and implemented in New England fisheries. These large mesh fisheries are perfect examples of where such programs would be very cost effective, produce valuable catch data, and promote regulatory compliance. Lowering the monitoring requirements works against this goal and is likely a false savings. The program will have to be carefully managed so that significant groundfish discards are not hidden by this loophole from normal coverage requirements.

9. GB Yellowtail Flounder Management Measures

The primary problem at this point in time with GB yellowtail management is the recent revelation that potentially wide-scale misreporting of the areas where GB yellowtail are being caught is taking place. This proposal, while understandable on its face, seems likely to create even more misreporting by unobserved boats. Until NMFS develops a better understanding of the extent of catch misreporting and implements measures to reduce the practice, this finer scale tuning of discard rates should not be approved.

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10. List of Allowable Sector Exemption Requests

This section of the proposed rules eliminates the prohibition set out in Amendment 16 that sectors may not request access to year-around closed areas. The two rationales driving this change are eliminating the redundancy of catch limits and mortality-based closed areas and allowing the multispecies permit fleet access to areas where they could target redfish, pollock and GB haddock. The assumptions underlying these rationales are that the existing closed areas are closed purely to limit fishing mortality and that there are populations of haddock, redfish and pollock in these areas that are otherwise not accessible to the groundfish fleet. Both assumptions are invalid.

With respect to the fishery management functions being served by the existing closed areas, it is apparent from a review of the record that they were all closed for multiple reasons, not just to reduce mortality on groundfish populations. The Framework 48 comment letter submitted by the Pew Charitable Trusts and the appendix attached to that document lay out a detailed history of the closed areas. The Pew comment letter and its appendix are attached to these comments and we adopt and hereby incorporate them by reference as if fully set forth herein. CLF agrees with all the facts and the conclusions in those materials.

With respect to the rationale that access is needed before the Omnibus Amendment is completed in order to provide access to GB haddock, redfish and pollock, the analysis conducted by the CATT completely undercuts that justification. Redfish populations are not significantly identified with any of the existing closed areas and the ACL is fully accessible to the fleet without any opening of closed areas. The only analysis that suggests that additional pollock might be available if a closed area were to be open focuses on the proposed thin box on the eastern side of the Western Gulf of Maine Closed Area. Irrespective of this analysis, the entire pollock ACL appears to be readily accessible within currently open areas, thus obviating the need to reopen area for access to pollock. As for haddock, there already exist SAP programs that are designed to allow access to potential haddock in the Georges Bank closed areas but that issue seems almost academic given the fact that the fleet has caught such a low percentage of its ACL in FY2012. There is no evidence from the trawl surveys or observer data that those haddock are hiding out in CA I or CAII.

Indeed, looking objectively at the situation, the economic analysis of the proposed opening of the existing closed areas concluded that there was a chance of “neutral”—no benefits—to slightly positive benefits associated with allowing access into those areas with significant chances of major long term negative economic consequences. CLF believes that the characterization of the CATT literature search and economic analysis provided in the supplement information associated with Framework 48[4] puts a positive spin, if not an outright exaggeration on the positive side of the presentations CLF observed on this topic at the CATT. In the actual words of

[4] Northeast (NE) Multispecies Fishery; Framework Adjustment 48 at 40-41.

the economist who conducted the analysis: "there is potential for much greater costs if the exemptions place fishing pressure on critical life stages or greater gear interactions ensue, which would result in a negative net benefit of undetermined magnitude."[5]

Others have commented on the increased impacts on protected marine mammals if these significant areas were to be re-opened to fishing as well as conflicts between recreational fishermen in the western GOM closure area. All those comments are meritorious and counsel against opening access to these areas.

A. Framework 48 Does Not Comply With the National Environmental Policy Act (NEPA)

As a federal agency proposal to modify the terms of an existing FMP, Framework 48 constitutes a major Federal action under NEPA that triggers the requirement to assess the environmental impact of such the proposed changes to the multispecies regulatory regime. 42 U.S.C.A. § 4332(2)(C). *See, e.g., Greenpeace v. Nat'l Marine Fisheries Serv.*, 55 F. Supp. 2d 1248, 1257 (W.D. Wash. 1999). NEPA imposes a requirement that federal agencies "will have available and will carefully consider detailed information concerning significant environmental impacts" before a project is approved. *Winter v. Natural Res. Def. Council, Inc.*, 555 U.S. 7, 23 (2008) (quoting *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 349 (1989). *See also City of Alexandria, Va. v. Slater*, 198 F.3d 862, 866 (D.C. Cir. 1999).

An environmental impact statement (EIS) must include a detailed statement of the environmental impact of the proposed action, any adverse environmental effects which cannot be avoided should the proposal be implemented, alternatives to the proposed action, the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented. 42 U.S.C. § 4332(2)(C)(i)-(v). If it is unclear whether a full EIS is required, an agency must at a minimum prepare an environmental assessment (EA). 40 C.F.R. § 1501.4(b).

While an EA is not as comprehensive as an EIS, an EA must take a "hard look" at potential environmental consequences and consider reasonable alternatives. *See Cape Hatteras Access Pres. Alliance v. U.S. Dept. of Interior*, 731 F. Supp. 2d 15, 34-35 (D.D.C. 2010), and *Flaherty v. Bryson*, 850 F. Supp. 2d 38, 71 (D.D.C. 2012). More specifically, an EA must discuss the need for the proposal, identify alternatives to the proposed action, and describe the environmental impacts of both the proposed action and the alternatives, including direct, indirect and cumulative impacts. *Nat'l Trust for Historic Pres. in the U.S. v. U.S. Dept. of Veterans Affairs*, CIV.A. 09-5460, 2010 WL 1416729 (E.D. La. Mar. 31, 2010). If, following this "hard look" at a proposed action and its potential effects, an agency determines that the action will not result in any significant environmental impacts, the agency may issue a "finding of no significant impact"

[5] DePiper, October 25, 2012 at 5.

(FONSI) and is excused from preparing an EIS. *Id.* However, if the record does not support a FONSI, the agency must issue an EIS. *Id.*

In this case, the record reflects that the NOAA Fisheries has not previously analyzed the potential environmental consequences of the proposed use of a sector operations plan exemption to re-open areas that are currently closed to fishing for groundfish. Amendment 13 to the Northeast Multispecies Fishery Management Plan, published on April 27, 2004, described the procedure for establishing sectors, identified a list of management measures that may be adjusted through a framework action, and specifically provided that the Regional Administrator may not grant exemptions to year-round closure areas. §648.87(b)(1)(xvi). The prohibition on granting exemptions to NE multispecies year-round closure areas was reiterated in Amendment 16. §648.87(c)(2)(i). Because the re-opening of closed-areas was characterized as a prohibited act, such action was not analyzed in either an EIS or an EA nor, consequently, was a FONSI issued pertaining to such action. In light of this history, the fact that much of the area being proposed for access to sectors has been closed to groundfishing for over a decade and that this federal action authorizing a process to allow access to such areas will have a significant impact on the affected marine environment, NOAA may not re-open the closed-areas without conducting an EIS.

Moreover, the agency's actions are clearly an attempt to "segment" the larger Omnibus Amendment action that is intended to comprehensively address the status of all closed areas in New England. This separation from the Omnibus Amendment of this intended subcomponent of that action is designed to avoid NEPA review requirements. This practice of "segmenting" major Federal actions into smaller units for the purpose of avoiding preparation of an EIS and, thus, consideration of overall environmental impacts violates NEPA. *See Coal. on Sensible Transp., Inc. v. Dole*, 826 F.2d 60, 68 (D.C. Cir. 1987), *Taxpayers Watchdog, Inc. v. Stanley,* 819 F.2d 294, 298 (D.C.Cir.1987). Courts have identified standards that Federal actions must meet in order to avoid illegal segmentation. These include whether the proposed segment (1) has logical termini; (2) has substantial independent utility; (3) does not foreclose the opportunity to consider alternatives, and (4) does not irretrievably commit federal funds for closely related projects." *Taxpayers Watchdog, Inc. v. Stanley*, 819 F.2d 294, 298-99 (D.C. Cir. 1987) (citing *Piedmont Heights Civic Club, Inc. v. Moreland,* 637 F.2d at 439). The proposed Framework 48 action to establish a process to exempt sectors from the prohibition on fishing in closed-areas would violate at least two of these requirements as it does not have substantial independent utility and it would foreclose opportunities to consider alternatives in the Omnibus Amendment and other future processes.

In 2011, NOAA issued an NOI for the Omnibus Amendment by which it merged into the Amendment a determination as to the functions and values of the groundfish closed areas and as to any future access to those areas. In so doing, NOAA conceded the lack of independent utility of any action to consider re-opening these areas. These are not discrete areas that can be understood or analyzed in isolation; they have interactive effects in the regional marine ecosystem that have to be approached systemically and in an integrated fashion. The absence of independent utility of these various proposed closed area openings is further emphasized by the economic analysis referenced above that concludes that any benefits of re-opening these areas are highly speculative, if they exist at all.

Additionally, if the areas proposed for new sector access are approved, the opportunity to utilize the Omnibus Amendment to advance alternatives that maintain the existing high quality habitat within the closed areas would obviously be foreclosed as the gear impacts and catch of larger females and other productivity components in the closed areas would be rapidly lost. As noted above, the Omnibus Amendment is designed to fully consider the functions and values of existing and proposed habitat and groundfish closures and to assess the benefits of management measures for alternative areas. Any action that forecloses the very purpose of an ongoing, parallel management effort would be counterproductive and would violate NEPA.

Because NMFS has not prepared an EIS, and because interim consideration of opening areas that are presently closed would constitute improper segmentation under NEPA, NMFS should refrain from implementing any openings outside of the Omnibus Amendment currently underway.

B. The Framework 48 Process Must Comply With the Endangered Species Act

The Endangered Species Act makes it unlawful to take a threatened or endangered species. 16 U.S.C.A. § 1538(a)(1). The term "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. 16 U.S.C.A. § 1532(19). Any decision by NOAA to open areas that are presently closed would subject listed endangered species such as right whales and leatherback turtles to ship strikes, entanglement and other forms of takes. NOAA is obligated under the ESA to insure that any action authorized, funded or carried out by the agency is not likely to jeopardize the continued existence of any listed species. 16 U.S.C. § 1536(a)(2). As such, the agency must undertake a detailed consultative process for determining the biological impact of any proposed reopening. *Leatherback Sea Turtle v. Nat'l Marine Fisheries Serv.*, 99-00152 DAE, 1999 WL 33594329 (D. Haw. Oct. 18, 1999). That consultation process must culminate in the issuance of a biological opinion (BiOp) in which the agency states whether it believes that the activity is likely to jeopardize the continued existence of a particular species and, if so, the agency must suggest reasonable and prudent alternatives or devise plans to reduce the risk of a take. *Id.* (citing 16 U.S.C. § 1536(b)(3)(a)). Any action that may authorize groundfishing in the closed areas creates the risk of irreparable harm to endangered species. Consequently, prior to any such action there must first be a full consultative process and the development of a BiOp associated with access to the closed areas.

conservation law foundation

11. Requirement to Stow Trawl Gear While Transiting Closed Areas

CLF strenuously objects to this proposal that was adopted by the Groundfish Committee against the advice of the Council's VMS/Enforcement Committee, which recommended more modest changes targeted at safety and effectiveness. CLF believes that this fishery continues to have a significant and underreported problem with illegal fishing activity and misreporting of catches.

12. Correction to Eastern U.S./Canada Quota Monitoring

CLF does not think that the agency has the authority to make this change to the regulation without Council action. The fact that a different approach based on the agency's interpretation of Council intent might have been included in the Amendment 16 Preamble does not convert that interpretation into a Council action. Moreover, CLF is concerned that the recent reports and substantiation of misreporting of catch by multispecies permit boats on Georges Bank makes the VTRs inherently unreliable as an allocation mechanism. The current regulation should stay as is and NMFS should begin implementing it according to its terms until and unless the Council decides to change the allocation approach after debate and public comment.

Framework 48 is a step backward for the New England Fishery Management Council. The proposed program compromises data quality by failing to require adequate and appropriate monitoring; it attempts to authorize allowing widespread access to the closed areas despite the Council's awareness that the risks to future productivity are great and the short term benefits are marginal and short-lived at best; it continues a recent pattern of risk-positive management action in the face of great uncertainties about the status of a number of the stocks; and it violates both the spirit and the letter of the National Environmental Policy Act and the Endangered Species Act.

Thank you for this opportunity to offer these comments.

Submitted on behalf of the Conservation Law Foundation.

Sincerely,

Peter Shelley

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April 8, 2013

Mr. John K. Bullard
Regional Administrator
National Marine Fisheries Service
55 Great Republic Drive
Gloucester, MA 01930

Re: FW48 Proposed Rule (NOAA-NMFS-2013-0050)

Dear John:

We offer the following comments on your proposed rule Framework 48 and begin by requesting you to review the GOM cod presentation given by Northeast Fisheries Science Center (NEFSC) scientist, Michael Palmer, (*Gulf of Maine Cod: From Bankers' Hours to Bankruptcy and the Role of Fine-Scale Spatial Dynamics on Stellwagen Bank*).

FW 48 efforts to mitigate for FW 50 "potential negative economic impacts" should consider the frailty of GOM cod in particular. Dr. Palmer's presentation will assist that consideration; i.e., mitigation that ignores the fine-scale spatial distribution of cod will deteriorate stock status and the overall health of the GOM "stock." We highlight this presentation as part of our comments on your proposal to allow sectors to petition NMFS for access (albeit limited) to groundfish "mortality" closures and your dropping the cod minimum size by three inches.

Minimum fish sizes

The Council has decided to decrease minimum size limits for cod (22 → 19"), haddock (18 → 16"), gray sole (14 → 13"), yellowtail flounder (13 → 12"), plaice (14 → 12"), and redfish (9 → 7"). We opposed this action. Pollock (19"), halibut (41"), and winter flounder (12") are to remain the same. Vessels fishing in sectors will be required to land all allocated groundfish meeting the minimum size requirements. The "logic" for these changes is: "*These changes would be made to reduce regulatory discards and to allow many fish to reach spawning age before being caught, not to facilitate the targeting of smaller fish…The minimum size limits…are based on an analysis of the size of discarded fish in trawl gear in recent years and the* length at 50% maturity *(our emphasis). The* *minimum sizes…would be expected to reduce many discards due to minimum size restrictions under the gear requirements in place in 2009-2011…"*

Because the status of many of our groundfish stocks is so poor (e.g., GOM and Georges Bank cod), it is counterintuitive to move away from minimum sizes where percent maturity is greater than 50%. For cod you propose to drop the minimum by 3 inches approaching 50% maturity. With our learning more about cod spawning behavior and the importance of repeat spawners for increased spawning success (not just for cod), targeting 50% maturity is not defensible. DMF research of which you are very aware is very relevant to our arguments.

The Council with NMFS in support has concluded it's acceptable to target cod and other groundfish even when the target size (as a minimum) is about 50% immature. We should be promoting fisheries sustainability through protection of age structure and accounting for spatial distribution with an emphasis on letting far more individuals become first-time, but better yet, second-time spawners.

As a member of the Sanctuary Advisory Council and aware of the contents of the Sanctuary's Management Plan (June 2010), we know the Sanctuary might revise its designation document on or before 2015 (See Executive Summary page iii) to give it authority to set regulations for fisheries within its boundaries. Weakening protection of cod and other Sanctuary resources heavily fished within the Sanctuary is ill-advised. Consider the following Plan conclusion: *"…fishing – especially commercial fishing impacts and pressures every resource state in the sanctuary. On an annual basis, virtually every square kilometer of the sanctuary is physically disturbed by fishing. Fishing has removed almost all of the big old growth individuals among biological important fish populations, and reshaped biological communities and habitats in the process…"* The Sanctuary, of course, would support any measure that reduces discards (such as increased mesh and strategically placed closures), but promoting the targeting of smaller fish with likely increased discarding of even smaller fish will cause justifiable concern.

Will the reduced minimum sizes "facilitate the targeting of smaller fish?" The Council and NMFS assumption that reduced minimum sizes will not change fishermen's behavior is a very risky assumption. After having participated at most of the Council's ABC Risk Policy Workshop designed to develop advice to the SSC about the acceptable probability of overfishing when setting ABCs, we conclude that the likely "severity of consequences" (one aspect of risk) from targeting smaller fish is too high and unacceptable.

By comparison you use the "full retention" approach as the way to conclude you will *"minimize the likelihood that vessels will target smaller fish."* You compare this option to the minimum size reductions. A far better and legitimate comparison would have been against status quo: "no change in sizes."

Moreover, by decreasing minimum sizes, NMFS will put sector fishermen at too high a risk. The Commonwealth, and perhaps other states, may not our minimum sizes for the aforementioned reasons, i.e., we are risk averse regarding the negative consequences of lowering the sizes. In our case, the Commonwealth's Marine Fisheries Advisory Commission recently opposed the size reductions, and its approval is needed before any reductions can be adopted.

Consequently, if NMFS lowers the sizes without garnering state support, you do so with the understanding that sector fishermen are held jointly liable for discarding legal-size groundfish. Your rule will force them to discard legal fish according to your definition, but illegal by ours. We appreciate the need to have everything in place for May 1; nevertheless, so far, there have been no important discussions with us about minimum size reductions – just a Federal Register announcement and two weeks to comment. States partner with the federal government on inter-jurisdictional fisheries issues, yet that partnership seems lacking when it comes to this pending groundfish action.

We support status quo. Note your rationale for status quo, i.e., make no changes: *"Since implementation in 1986, the Northeast Multispecies FMP has used minimum size limits in conjunction with gear requirements to reduce catches of sub-adult fish. When adopted the purpose of this measure was to* ***provide opportunities for fish to spawn before harvest, as well as to reduce the incentive to use illegal mesh to increase catches*** *(our emphasis)."*

The Council has abandoned this rationale in favor of reducing regulatory discards even though decreasing the minimum size likely will motivate fishermen to use illegal mesh. Witness recent examples given to the Council by Law Enforcement about use of net liners. Regrettably, we seem to be moving away from creating incentives for fishermen to use larger mesh and/or to avoid smaller fish.

We ask you to explain what is meant by a decrease in minimum sizes *allowing many fish to reach spawning age before being caught.* This appears to be a non sequitur. More smaller fish will be caught; therefore, how will many more fish reach spawning age before being caught. A better alternative is larger mesh or required use of square versus diamond mesh depending on the situation.

Also, consider the following FW 48 analysis of impacts of biological impacts: *"…the biological impacts of changing minimum size requirements are a function of whether the change leads to a different selectivity in the fishery. If the catch of small fish as a proportion of the total catch increases, then changes in yield per recruit, status determination criteria, and rebuilding progress could result…there would likely be reductions in yield per recruit, MSY, and slower rebuilding progress."* GOM cod is provided as an example. *"A shift in selectivity of one year reduces the YPR 9.4% for GOM cod. The value of F40 declines 18.5%."* The analysis highlights that biological impacts are difficult to predict because impacts will depend on fishermen's behavior.

Understand that we appreciate the subtle and unstated benefit of lowering minimum sizes, ostensibly to reduce regulatory discards; i.e., sectors' ACES effectively increase: less assumed discarding means more to land. We suspect that's why many fishermen, including Council members, especially those involved with sectors, favor the full retention approach that is still "on the table." Full-retention will be very difficult to support without far greater at-sea monitoring and law enforcement. Furthermore, states will have to rescind all minimum sizes, an unlikely scenario. Also, recreational fishermen will find that rescinding for the commercial fishery to be very at odds with their having to live with minimum sizes.

Currently, real or assumed discards caused by that sector reduce each sector's ACE(S). Consequently, a sector fisherman can find his catch portfolio reduced to account for discards even when he doesn't fish, i.e., other sector fishermen's discards count against each member's allocation (PSC, percent sector contribution). By assuming reduced discards with lowered minimum sizes, fewer fish are subtracted from sector ACEs; therefore, more can be landed. If you decide to reduce the minimum sizes, *how will NMFS adjust fishermen's portfolios? This must be clarified now rather than later.*

Finally, consider your own conclusion regarding reducing the minimum sizes: "*…there could potentially be unforeseen consequences from targeting smaller fish that could have long-term negative impacts on future landings and revenue…*" This is an important admission fraught with risk. We counter that the consequences can be and are "foreseen."

Mitigating negative impact of FW 50

Preparing as best we can for the severe socioeconomic impact of FW 50 is sensible; however, to properly address mitigation, the Council and NMFS must focus on individuals and not on classes of vessels or gear types. That has not happened. Therefore, NMFS' (Council) claim that fishing opportunities will increase and profitability in the groundfish fishery will improve thereby mitigating negative economic impacts anticipated for groundfish vessels and their communities, is specious.

Consider that you make a very important and risky assumption regarding allowance of exemption requests from sectors to year-round closures and changes to minimum size restrictions. You say: ***"Assuming all impacts to vessels are also applicable to ownership entities, all of the alternatives have the potential to impact a large number of small entities, and while some of the options may significantly alter profitability, none of them would have a disproportionate impact on small entities."*** This is a profound and vital assumption not supported by FW 48 analyses, unless major, untested assumptions are made.

Consider your statement pertaining to sector vessels and operating costs associated with at-sea and dockside monitoring in FY 2013, absent any funding assistance from NMFS: *"…the highest percent reductions in net revenue were expected to occur in the 30-50 ft vessel category.* ***Since profitability of individual vessels is unknown*** *(our emphasis), the effects of this option [sector monitoring] on participation levels could not be* *estimated, but it is likely that vessels operating close to the margin would be forced to exit the industry or lease their quota…"* NMFS admits the likelihood that small vessels will suffer the greatest impact, contrary to the aforementioned conclusion about no disproportionate impact on small entities. NMFS should explain this seeming contradiction.

We intend to submit comments on FW 50. Those comments will focus on a better way to mitigate. For example, rather than "tweaking rules" in a risky way to give greater operational flexibility to sector fishermen, it will be far better to provide more catch, i.e., extraordinarily precautious ACLs create extreme adverse socioeconomic impacts affecting sector and common pool fishermen – some far more than others. Caution is important, but layers of precaution cause inordinate sacrifices by vessel owners, fishermen and processors, shore-side infrastructure, etc.

Recreational Fishery AMs

NMFS proposes to proactively modify recreational fishery AMs prior to the start of each fishing year. NMFS intends to *"consult with the Council, or the Council's designee, and would tell the Council, or its designee, what recreational measures are under consideration for the coming year."*

We emphasize that NMFS should consult with states, not as Council members, but as separate partners having to consider state regulatory changes to support NMFS. The consultation should be more than telling states what NMFS intends to do. Groundfish recreational fisheries occur in state waters as well as in federal waters, perhaps more so in state waters; therefore, with states having saltwater recreational fishing licenses and working closely with NMFS on marine recreational fishery surveys (MRFSS & now MRIP), close coordination and reciprocal cooperation are key.

Sector Monitoring Programs

You note that Sectors were required by Amendment 16 to *"implement a dockside monitoring program to validate dealer-reported landings…Dockside monitoring was also set to be implemented for common pool vessels in FY 2012…"* Then you note: *"Through Framework 45, the Council suspended the dockside monitoring requirements until FY 2013 and required dockside monitoring only to the extent NMFS could fund it."* With these dockside programs now being completely eliminated, we ask for a better description of what exactly convinced NMFS in 2011 that sector landings were "sufficiently monitored." You indicate, *"dockside intercepts by enforcement personnel were sufficient to monitor those landing."* Is this still true?

We understood then that reliance on law enforcement was a fallback position because limited funds had to be reprogrammed "to alleviate general sector operating costs." The central question now becomes: How will sector landings be sufficiently monitored?

Regarding current dockside monitoring hail requirements, you ask whether those requirements should be maintained. We believe they should be kept because, as you state, *"hails have become a useful tool for both NMFS and sector managers to monitor* *sector vessels' activities, including use of certain sector exemptions, and to facilitate dockside intercepts by enforcement personnel…"* Additionally, we ask if NMFS and Law Enforcement have adequate capability to check hails versus observed landings to monitor sector and common pool landings versus ACEs and quotas.

On a related monitoring issue, you propose to *"revise the regulatory text at §648.87(b)(1)(v)(B) to read that coverage levels must at least meet the CV standard at the overall stock level and be sufficient to monitor sector operations, to the extent practicable, in order to reliably estimate overall catch by sector vessels."* We ask for more clarification, i.e., what do you mean by "to the extent practicable."

Furthermore, in the referenced section, you state: *"coverage must be fair and equitable, and distributed in a statistically random manner among all trips such that coverage is representative of fishing activities by all vessels within each sector and by all operations of vessels operating in each sector throughout the year."* We support your approach, but are concerned that your "to the extent practicable" will result in coverage that isn't satisfactory especially for statistical purposes and accurate accounts of catch and discard.

Confounding this important issue is the decision to *"delay industry responsibility for at-sea monitoring costs to FY 2014 to mitigate the expected negative economic impacts of lower trip limits in FY 2013. Coverage levels would instead be set at the level that NMFS can fund."* We support your decision to delay and realize there is no other option to consider, and we understand why. However, by relying on the Council to *"further modify this requirement in the future as more information becomes available on the appropriate monitoring levels, costs of these programs, and implementation of electronic monitoring systems,"* NMFS really means it's willing to accept a Council likely decision in 2013 to delay that responsibility to 2015 or beyond.

We also support your approach that sectors *"must provide detailed trip-by-trip catch data to NMFS for the purposes of auditing sector catch monitoring data based upon guidance provided by the Regional Administrator."* However, the "if requested" part of your proposal should be understood as a consistent requirement, not just when requested that could very well be occasionally.

<u>Sector Access to Closed Areas</u>
You state, *"…sectors are subject to a hard TAC that limits overall fishing mortality resulting from sector operations, making certain other mortality or effort controls redundant…"* This is a mistake. For example, it doesn't consider that mortality on aggregations of fish, such as cod, subject to fishing without trip or possession limits (i.e., sector vessels fishing as they will with original allocations enhanced through leasing) can create very high, localized fishing mortality dramatically reducing the size of aggregations and/or interfering with pre-spawning and spawning behavior. Reflect on Dr. Palmer's analyses of the Stellwagen Bank area and very localized fishing caused by fine-scale distribution of cod.

You state that our concerns will be "evaluated by NMFS in the consideration of any specific sector requests for each fishing year." We request those evaluations be made available to the Council and public for review before specific exemptions are granted. You indicate a "rigorous analysis" will be necessary, and we agree and ask if the Council's PDT will be involved. It should be.

We appreciate NMFS is abiding by the Council decisions on access. For example, sectors will not be allowed access in Closed Areas I and II from February 16 through April 30 to protect spawning groundfish. However, we're uncertain as to whether those are the correct dates, and we ask if the NEFSC will comment on these access dates to be modified by you if access timing is incorrect, e.g., should access be denied during some part of late fall and early winter when cod are also spawning. As you noted, the analyses must be rigorous.

Finally, we appreciate your treatment of the Council's Closed Area Technical Team analysis of access to the closed areas. The CATT did a fine job and had some important conclusions such as: *"Due to data limitations and the fact that sector fishing effort is driven more by Catch Per Unit of Effort (CPUE) and market conditions than effort controls, the CATT was unable to quantitatively model potential changes in fishing effort."*

For this and other reasons you've decided to *"consider sector requests for exemptions to closed areas in a separate rulemaking from the general approval of sector operation plans for 2013, if the proposed change in FW 48 is approved. The closed area exemption requests would be considered as amendments to the sector operations plans through a proposed and final rule that would be available for public comment with an accompanying National Environmental Policy Act (NEPA) analysis."* This suggests any access could be no later than this fall. Sector fishermen likely will want access as soon as possible, and we all appreciate the sense of urgency. Nevertheless, this access is very controversial and requires the approach you have selected.

<u>Status Determination Criteria GOM & GB Cod and SNE/Mid-Atl Yellowtail Flounder</u>
We always appreciate the hard work of the NEFSC and the effort given to complete the many important stock assessments. However, there are times when we wonder about the outcomes. For example, we have two approved assessment models with one providing a biomass target of 54,743 mt (assumed natural mortality of 0.20). The other target is 80,200 mt ("ramped-up" natural mortality to 0.40 not expected to remain "in perpetuity"). Both models provided a fishing mortality threshold of 0.18. For each GOM cod scenario we are overfishing, and the stock is overfished. You now ask for comments on the two choices.

However, you offer no guidance as to what option is preferred and why, although with the SARC concluding that natural mortality is not expected to remain at 0.40, it seems you're favoring the 54,743 mt. Considering the fishery failure officially effective on May 1 and a revised rebuilding schedule the Council will develop, it makes sense to choose the lower target.

The key will be to reduce fishing mortality to the 0.18 threshold or below. With that said, we wonder why the SARC did not conclude natural mortality is as high as 0.40, if not higher. Consider the photograph in a recent front-page Boston Globe issue. An estimated 15,000 gray seals clustered at a haul-out on Monomoy Island suggests natural mortality has increased and will be much higher than expected for some time to come. This does not bode well for the groundfish fishery and for other stocks on which these seals and other predators (e.g., spiny dogfish) prey.

Finally, for yellowtail once again we wonder. The SARC concluded that the evidence was 60:40 (quite a call) in favor of a "recent recruitment" scenario assuming that a *"possible change in productivity has reduced the size of incoming year-classes since 1990."* Therefore, the stock is not overfished and overfishing is not occurring; thus, we are rebuilt, yet the new target is a very low 2,995 mt. The fishing mortality threshold is a modest 0.31, a bit higher than we would have expected.

We ask NMFS to reconcile the conclusion that for yellowtail there has been a "possible change in productivity," but for cod that doesn't seem to be case. Furthermore, calling yellowtail "rebuilt," although technically correct, has a hollow ring to it. If productivity has changed so dramatically as to cause such a dramatic reclassification of yellowtail, why hasn't GOM and GB cod been affected by changed productivity as well? We consider this to be an unanswered key question pertaining to the direction in which the Council and NMFS are headed, i.e., ecosystem-based fishery management.

<u>Conclusion</u>

We always appreciate the opportunity to comment on Council decisions and NMFS proposals, especially when those decisions and proposals are not supported by DMF. Of course, there are many we do support and helped develop as a Council member.

The task before us all is how to assist the groundfish fishing industry survive these very difficult times of low ACLs, poor prospects for groundfish rebuilding, and changes in ocean productivity contributing to low to poor year-classes. Our other task is to address industry consolidation and excessive shares – a task made even more difficult due to our fisheries failure.

Mitigation is extremely important, and we will support legitimate mitigation approaches. However, mitigation cannot be allowed that potentially will deteriorate groundfish resource conditions even further. This is the attitude reflected in all of our aforementioned comments and our previous ones on sector operations plans.

Sincerely yours,

David E. Pierce, Ph.D.
Deputy Director

cc
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John Bullard
Northeast Regional Administrator
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April 9, 2013

Dear Regional Administrator Bullard:

As commercial groundfish fishermen using fixed gear to fish within the Gulf of Maine, we wanted to take this opportunity to directly respond to one aspect of the Framework 48 proposed rule, the Halibut accountability measures (AM), and express our concern regarding the northern location of the fixed gear closures associated with this AM. We understand and support the need for an accountability measure for the Atlantic Halibut fishery in cases where the total allowable catch is exceeded. However, with the current location of the northern area for the fixed gear exclusion area, there is a high likelihood that our summer fishery will be eliminated and that inshore fishermen from Maine will be disproportionately affected.

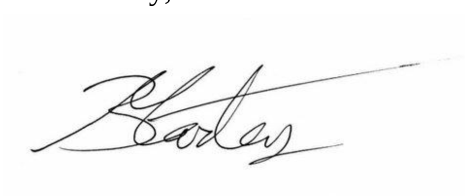
This past season we observed high numbers of Atlantic Halibut that were just below the minimum size. We are concerned that the total allowable catch has a high likelihood of being exceeded next fishing year, following the trends of the past two fishing seasons of exceeding the TAC by 29% and 57% respectively, and that the accountability measures will go into place for the majority of our 2014 fishing season or in a worst case scenario, 2013.

Additionally, we have significant economic concerns with the impact of eliminating fixed gear in these accountability areas. The justification for the accountability measure in Framework 48 states that approximately $1 million in estimated revenues come from the fixed gear areas, and that the majority of the effort in that area is from vessels with homeports in Chatham, Massachusetts. Though the economic loss may be largest to these vessels, the Maine Coast Community Sector represents some of the boats with the largest landings at the Portland Fish Exchange, and those boats fish primarily around Platts Bank in the summer when our fishing season is in full swing. Losing access to these grounds would significantly impact fishing businesses within the sector without a corresponding benefit to the Atlantic Halibut resource.

Through observations, we have witnessed higher rates of Atlantic Halibut catch early in the fishing season in this area from targeting monkfish with tie-down gillnets. To better serve and restore the health of the halibut resource installing seasonal closures, or more specific gear restrictions may have a better outcome for the fishing resource while increasing the potential to still target healthy stocks in the area given the added economic pressures next fishing season with the extremely low allocations. We fear that this accountability measure, as written for the fixed gear area, will have severe unintended consequences without having an adequate benefit for the Atlantic Halibut fishery. Additionally, but putting this AM in place for FY 2013, it does not give our sector the opportunity to develop any exemptions that may allow our fishermen to fish in this area using a specific gear-type. We are currently involved in two projects we fell may help us avoid halibut, one is to develop technology to track bycatch, share with other vessels, and ensure there is limited future catch and the second is a gear modification that allows for large panel mesh in the bottom of the gillnet which we believe would decrease halibut interactions. Without time to continue to test these programs and build a comprehensive emption our gillnet fishermen will be removed from an important area without having the ability to develop a plan to deal with this AM.

Thank you for the opportunity to provide comments on the fixed gear accountability measure for Atlantic Halibut. We are very concerned with the current placement of the northern fixed gear area, and hope that future discussions can include local fishermen to determine an area, or time of the year to restrict effort, in a constructive manner that will benefit the resource and still provide fishing opportunities to allow MCCS members to continue to fish.

Sincerely,



Ben Martens
MCCS Sector Manager

April 9, 2013

John K. Bullard
Regional Administrator
NOAA Fisheries
55 Great Republic Drive
Gloucester, MA 01930

Re: Comments on the Proposed Rule for Framework Adjustment 48 to the Northeast Multispecies Fishery Management Plan [Docket No. 120814336-3249-01 RIN 06848-BC27]

Dear John,

The Northeast Seafood Coalition is a non-profit organization representing over 250 commercial fishing entities, which hold over 500 limited access groundfish permits, on political and policy matters affecting their interests in the federal groundfish fishery. Collectively, NSC members represent the full diversity of the groundfish fishery. NSC members fish on small, medium, and large vessels from ports across the northeast and they employ all groundfish gear types. NSC fishing members are enrolled in the Northeast Fishery Sectors (NEFS).

Today, the Northeast Seafood Coalition (NSC) submits the following in response to the request for comments to the regulatory measures for the groundfish fishery proposed under Framework Adjustment 48.

1) Status Determination Criteria for GOM Cod, GB Cod, SNE/MA Yellowtail Flounder and White Hake

- ***Estimates of Fmsy***

NSC reiterates the specific concerns it expressed in its January 17, 2013, memo to the Council regarding the use and specific choice of Fmsy proxies for groundfish stocks below. As a more general observation, however, the current management process employed by the Council and agency does not provide managers with sufficient information, understanding or opportunity to consider alternative scenarios for directly estimating Fmsy or choosing among proxy alternatives. In many respects, these choices are a matter of policy based on management objectives and acceptable risk and can have profound implications for specific stock management. Such choices should be made by managers, not stock assessment scientists, through a far more transparent and deliberative process that ultimately provides guidance to such scientists.

The current process for selecting Fmsy proxies is essentially the reverse. As noted below, current policy is based on advice generated more than a decade ago that was itself based on literature published a decade earlier than that. Absent any deliberate process by managers to reconsider this policy, it has simply been carried-forward in each stock assessment and consequent management action – including Framework 48. During this time there have been improvements to both the understanding of such population dynamics as stock-recruitment relationships that may provide for direct estimates of Fmsy, as well as improvements to the relevant analytical and modeling approaches for selecting the appropriate Fmsy proxy.

Thus, notwithstanding statements to the contrary in Framework 48, it is likely that the current use of the Fmsy proxy of F40%msp as the basis for managing nearly every groundfish stock does not meet the statutory standard for using the best scientific information available.

NSC's January 17, 2013 memo to the Council can be found at the conclusion of these comments. NSC urges the Agency under this present rule-making to seriously consider the two recommendations presented at the end of the memo. These recommendations request a more thorough review by the Science and Statistical Committee (SSC) and policy decision by the Council as follows:

> *"With these questions in mind, NSC respectfully recommends that the Council submit the following requests to the SSC to be addressed as soon as possible:*
>
> ***1) Where possible, provide direct estimates of Fmsy for all groundfish stocks.***
>
> ***2) Where not possible to provide direct estimates of Fmsy, reevaluate the current Fx%msp proxy taking into consideration of what percentage of MSP is most likely to achieve the specific management goals for each applicable stock. This should include an evaluation of the consequences of this choice on the rebuilding target for each stock, and a comparison to available data."***

2) SNE/MA Windowpane Flounder Sub-ACLs

NSC supports the proposed action to allocate a sub-ACL of SNE/MA windowpane flounder to the scallop fishery and rename the other sub-component the "other fisheries sub-ACL".

3) Scallop Fishery Sub-ACL for GB Yellowtail Flounder Based on Estimated Catch

Consistent with NSC's input to the Council during their vote on November 14, 2012, NSC supports the proposed action for two reasons.

1. The TMGC accepted an extremely low TAC for 2013, one that the NSC has great concerns with. At this level and at any level below a 1,000 mt US share, the directed groundfishery is untenable. For this reason, NSC conceded that to destroy both the scallop and groundfish fishery, on paper, in advance of the start of the fishing years, should be avoided if possible. Discussions between groundfish and scallop fishery representatives resolved that the amount of catch estimated for bycatch would represent 40% of the US share of 215 mt in fishing year 2013.

2. NSC cannot overemphasize the need to have each substantial component of a fishery held fully accountable to their catch. Status quo policy does not do this adequately. NSC strongly supports allocating sub ACL's as a percentage of the total ACL in a manner that reflects the historical use and need for the stock by each stakeholder, with the directed fishery afforded the highest priority. Unfortunately, to date, existing policy places the directed fishery, which has suffered the greatest economic loss for the shrinking GB YT ACL, as the lowest priority--essentially receiving the leftovers after all "other" and "more important" fisheries have been receiving between 90 and 100 percent of their need. This policy was overlooked when the US / CA shared TAC was at or about 2,000 mt and the US was receiving at least 75 percent of the TAC. But at such low levels the stock must be allocated according to historical shares.

   To be clear, NSC's support for the 40% is limited to 2013 for the reasons mentioned above. The spirit of this temporary 2013 sub-ACL formula was to allow the scallop fishery time to adjust to a sub ACL based on historical shares of 16%. NSC supports 16% in 2014 and beyond and will be strenuously opposed to any disingenuous effort that attempts to modify this critical decision. NSC support for this measure is entirely conditional upon the full three year policy being carried out as prescribed in this proposed rule. (40% 2013, 16% 2014, 16% 2015).

4) Small-Mesh Fisheries Sub-ACL for GB Yellowtail Flounder

NSC supports the proposed action to allocate a sub-ACL of 2 percent of the U.S. ABC for GB yellowtail to the small-mesh bottom trawl fisheries.

5) Recreational Fishery AM

NSC strongly supports a healthy and vibrant fishery comprised of both commercial and recreational stakeholders, however, NSC has grave concerns with the approach taken by the Council and Agency regarding recreational fishery accountability measures (AM). To us, there appears to be a stark inconsistency in the manner that MSRA is being implemented by the agency in terms of the approaches applied to deal with enormous cuts in fishery wide ACLs for GOM cod and haddock.

On the one hand, commercial fishermen are not allowed access to the “groundfish closed areas” for the purpose of “protecting groundfish and to promote rebuilding”, while on the other hand, a component of the fishery that argued for and succeeded in receiving 34% and 38% allocation of GOM cod and haddock respectively, is allowed to fish those allocations almost entirely within the “groundfish closed areas”.

The commercial fishery is fishing under an output controlled system with weekly or daily reporting from the sectors. VTR’s are submitted within 24hrs of offloading and all VTRs submitted to NMFS every week. Sector vessels have at sea monitors or NEFOP observers on 22% to 38% of all trips. Comparatively, private and “for hire” commercial / recreational fishermen have little or no monitoring, are not under a directly controlled output but are instead managed through effort controls, and their reporting is sparse VTR data coupled with zero quota accounting in-season which leaves the fishery wide opened to a possible overage that would not be detected for months or even years after it occurred.

This double standard of applying AMs is inexcusable and it is questionable whether it is legal under MSRA. The implications to the fish stocks subject to strict rebuilding plans and the economic consequences to commercial fishermen dependent upon these stocks are significant. The recreational component of the fishery has been granted a substantial component of the ACL, a sub- ACL which is harvested largely in closed areas, with limited monitoring and reactive AMs.

But the double standard of management policy continues. Rather than proposing responsible measures for effectively monitoring and controlling fishing in the recreational sector in response to ACL reductions as large as 77 percent, Framework 48 actually proposes to insert new authority for the RA to "loosen" recreational measures in-season if that sector is "projected" to be unable to achieve their sub ACL. NSC struggles to understand what data would be used that could reliably support such an in-season management response. Would the Agency consider allowing commercial vessels access to the GOM mortality closures if the commercial sub ACL was not being achieved? At least the Agency would know, at any point in time and with great precision, just how much has been harvested and how much is remaining, in stark contrast to what the Agency will have to make the decision to loosen recreational measures for harvests inside the groundfish closed areas.

This approach is tantamount to the Agency being compelled to open the WGOM and eliminate the April rolling closure this year to allow the commercial sector to harvest their GOM cod and GOM haddock that is being under-harvested FY 2012. Instead, the commercial fishery operating under strict hard TAC requirements, real time reporting and monitoring remains constrained by effort controls during a period of low catchability. Recently, the Agency has claimed the under harvest and low catchability has been evidence of low abundance and justification for unthinkable reductions in 2013 ACLs. Contrast that thinking with the proposed action for adjusting measures for the recreational sector and the double standard approach is quite clear to NSC.

6) <u>Commercial Groundfish Fishery AMs</u>

- ***Change to AM Timing for Non- Allocated Stocks***

In general, NSC does not support the proposed action because the data that will be used to make these decisions is known to be unreliable for use in the short term. The subjectivity of the evaluation of "should **<u>reliable</u>** information be available" is of particular concern since this determination could be made very late in the current fishing which would leave the fishery with little warning that an AM will be triggered at the start of the following year. This can have tremendous negative business effects on the fishery. Although NSC acknowledges the positive aspects of removing the AM if new information determines the AM should not have been implemented in the first place, it is little consolation as compared to the risk that having this policy in place will compel the agency to react when it believes it has "reliable" information when we all know that level of accuracy in the data does not exist in real time for non-allocated stocks. At this point, it is difficult to identify anything that is reliable in groundfish science or management.

Further, NSC notes that the timing of the AM's was not an issue addressed by the Court. Instead, as stated in the proposed rule preamble, NMFS recommends that AM's should be imposed 'as soon as possible' after the overage occurs. The Agency does not explain why and what the biological or management downside is of implementing such AMs in the third year. NSC seriously questions whether that downside would justify the severe impacts on business planning and operations if the agency mistakenly implemented an AM in the second year and had to reverse itself some months later. The potential chaos caused by this scenario argues strongly against putting the Agency in a position to make a subjective judgment as to when data is sufficiently reliable to implement these AMs in the second year. This is just looking for more problems. The groundfish fishery desperately needs reliability and stability—and one small way to achieve that is by continuing to implement these AMs in the third year.

In the event the Agency decides to ignore comments to the contrary and implements this change to the AM timing for non-allocated stocks, NSC supports the Agencies intent to use the start of the fishing year as the trigger point so that the entire fishing year is under one regime unless new information is revealed that could undo an AM if one has been triggered.

- ***Area-Based AMs for Atlantic Halibut, Atlantic Wolffish, and SNE/MA Winter Flounder***

In general, NSC does not support the proposed action because the data that will be used to make these decisions is known to be unreliable for use in the short term.

- ***Revised AM for SNE/MA Windowpane Flounder***

NSC supports SNE / MA Windowpane flounder sub-ACLs and the proposed AM applying to trawl vessels using codend greater than 5"

7) Commercial Fishery Minimum Fish Sizes

Species	Current Rules	Proposed changes for FW 48
Cod	22	19
Haddock	18	16
Pollock	19	No change
Gray sole	14	13
Yellowtail flounder	13	12
Dabs	14	12
Redfish	9	7
Winter Flounder (BBs)	12	No change

NSC strongly supports the proposed action as presented above. One way to help mitigate the huge reductions in ACL is to ensure as little wasted ACL to discards as possible. This measure was carefully analyzed by the PDT with the intent to convert the greatest portion of known discards into landings. Furthermore, these sizes were carefully considered in relation to the maturity and biology of fish stocks. The Council's final vote on the minimum fish sizes presented above is in some cases greater than the sizes originally presented by the PDT.

8) Sector Monitoring Programs

- ***Delay Industry At-Sea Monitoring Cost Responsibility***

NSC supports the Council's request to delay industry At-Sea Monitoring Costs Responsibility. Further, NSC notes that the current FY2013 Continuing Resolution enacted in March reallocates nearly $120 million in revenues from the Saltonstall-Kennedy fund to cover the agency's costs for several critical functions including "Survey and Monitoring Projects".

- ***At-Sea Monitoring Cost-Sharing***

NSC understands the Agency's concerns and we support including the NE multi-species FMP in the joint effort with FMAT to develop a workable and consistent cost-sharing mechanism for the Northeast Region.

- ***Eliminate Dockside Monitoring***

NSC supports elimination of the dockside monitoring program at this time. NSC has maintained that this program was not well designed or contemplated in a manner that made the data timely or useful. It caused numerous logistics and costs issues without commensurate benefits. NSC has always maintained that Dockside Monitoring should either be 100% or 0% if the program's intent is to ensure equitable enforcement of dealer activities throughout the region. NSC agrees that the trip start and end hails offer vastly improved windows of opportunity for enforcement intercepts and that the requirement should be kept available for the Agency to implement on an "as needed" basis. However, NSC must point out that our experience with handling the traffic coming via VMS and through the various government and third party servers proved completely unreliable for fishermen to receive confirmation of hails returned to the vessels in a timely manner. This problem, unless resolved, will create enforce abilityof hail requirements.

Consistent with NSC long record of promoting efforts to reduce redundancy and packaging data inputs to serve multiple purposes, NSC supports NMFS intent to clarify the regulatory text so that hails may be modified in the future to be streamlined with other reporting requirements that collect similar fishery data, such as Vessel Trip Reports (VTRs) and Vessel Monitoring System (VMS) catch reports.

- ***Sector Monitoring Goals and Performance Standard***

NSC supports the agencies proposed regulatory language to more explicitly state Sector Monitoring Goals and Performance Standards.

- ***Reduce At-Sea Monitoring for Monkfish Trips***

NSC supports this proposed action to implement a lower at-sea coverage rate for sector vessels fishing on a monkfish day at sea in the SNE Broad Stock Area with extra-large mesh gillnets.

9) GB Yellowtail Flounder Management Measures

NSC does not support the proposed action. Splitting this area into two strata will do little towards achieving the intended result. The only thing it will do is add complexity without benefit. NSC's comment during the Council deliberations was minimal to none because we struggled to understand how the benefits outweighed the costs or the likelihood of unintended results. NSC favored an approach to consider defining a more discreet area of historical GB YT catches for the purpose of allowing a greater area of GB to be accessed without assumed discard rates constraining access to the vast areas known to be sparse for YT presence. The propose action is far too broad in defining the two areas which we fear will result in no management benefits but will only add administrative burdens to the industry, Sectors and the Agency.

10) List of Allowable Sector Exemption Requests

NSC strongly supports the proposed action to broaden the list of allowable exemption requests. NSC agrees with the Agency's rationale for doing so, sectors are subject to a hard TAC that limits overall fishing mortality resulting from sector operations, making certain other mortality or effort controls redundant. Since hard TAC management was implemented by Amendment 16 in 2010, NSC has commented numerous times on the apparent disregard to remove regulatory artifacts associated with the old input control managed fishery.

11) Requirement To Stow Trawl Gear While Transiting

NSC strongly supports the proposed action to remove the gear towage requirement for trawl vessels while on a groundfish trip. NSC agrees VMS requirements are sufficient to monitor and enforce transiting requirements.

12) Correction to Eastern U.S./Canada Quota Monitoring

NSC supports the agency's proposed removal of the FW42 language inadvertently left in the regulations at § 648.85(b)(8)(v)(C). NSC participated directly in all Amendment 16 development meetings as well as the numerous data and technical workshops held to develop reporting tools and methodologies. If not explicitly, certainly implicitly, this Framework 42 artifact was being entirely replaced with sector level accountability to every distinctly managed stock or stock unit such as eastern and western cod and haddock in the US / CA areas. As the owner and developer of Fishtrax reporting tool, NSC was intimately involved in constantly modifying the software parameters for the automated onboard Fishtrax tool to ensure compliance with the regulatory methodology. NEVER was there an instance, either at a Council meeting or other meeting, where NSC was informed that eastern stocks were going to be required to be MISREPORTED under sector management. Had this ever been questioned or discussed by the Council during the development of Amendment 16, NSC and others would have commented extensively about the inconsistency this requirement poses for reporting and accountability of sector quota.

It is important to NSC that we continue to strive to create offshore opportunities to harvest GB haddock. Canadian haddock TAC utilization has been over 80% to as high as 98% while U.S. is barely harvesting 10%. It would be counterintuitive to artificially constrain U.S. fisherman by essentially requiring them to misreport catch which would result in premature shutdown of access to the very stock the U.S. is already disadvantaged relative to our Canadian counterparts.

Furthermore, since GB cod is one stock, and the eastern / western distinction is purely a management distinction for the benefit of the US / CA resource sharing agreement, there is no real biological issue regarding cod mortality but instead, there is a potential management issue IF misreporting of cod catch occurs on trips that are fishing eastern and western areas. NSC would argue that there would need to be overwhelming and convincing evidence that misreporting is occurring at a level that warrants further dismantling of any chance that the U.S.

can participate on par with the Canadians in the Transboundary Resource Sharing Understanding.

NSC completely agrees with the Agency's interpretation of Amendment 16 intent as this was certainly our understanding as a substantial stakeholder and participant in the Council process.

NSC appreciates the opportunity to provide comments on these important regulatory measures for the groundfish fishery. We will be submitting comments for the Proposed Rule for Framework Adjustment 50 in the coming days.

Sincerely,

Jackie Odell

Jackie Odell
Executive Director

NORTHEAST SEAFOOD COALITION

DATE: January 17, 2013

TO: New England Fishery Management Council

CC: Science and Statistical Committee

RE: Estimation of Fmsy for Groundfish Stocks

Implementation of the Magnuson-Stevens Act requirements to end or prevent overfishing according to the National Standard 1 guidelines requires the determination of Fmsy or, if a direct estimate cannot be determined, a proxy thereof.

Efforts to estimate Fmsy in groundfish assessments have typically applied methodologies that rely in part on an adequate understanding of the stock – recruitment relationship for each stock. In practice, stock-recruitment relationships are difficult to determine for many fish stocks. Accordingly, a range of approaches have been developed to estimate Fmsy, including biomass-based production models, theoretical stock-recruitment models, more generalized stock-recruitment models, and empirical stock-recruitment models.

Nevertheless, instead of presenting the results from different methods to the Council, the 2002 *Final Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish* chose to simply establish a proxy for Fmsy for groundfish stocks. This choice has had a substantially limiting influence on all future groundfish stock assessments and the advice provided to the Council.
http://www.nefsc.noaa.gov/publications/crd/crd0204/crd0204.pdf

The default proxy chosen by the 2002 Working Group for Fmsy was the Shepherd model (a combination of stock-and-recruitment theory and yield-per-recruitment theory). The Shepherd model is based on a specification of the 'maximum spawning potential' (MSP). Although a range of MSP values are possible, the Working Group chose only 40% MSP.[1] So, in other words, although a large range of alternatives is possible, the Working Group presented the Council with only one method and only one of the many possible versions of the method.

It should be noted that MSP-based proxies for Fmsy assume the stock is in equilibrium. These stocks are not in equilibrium. Several more realistic alternatives exist for estimating Fmsy using non-equilibrium methods. Indeed, the scientist who performed the simulations in 1992-3 on which the 2002 Working Group based its advice for using F40%msp as a proxy has since raised his own questions about this methodology. Indeed, although those simulations were for west coast fish stocks, managers of those fisheries have since adopted F35%msp as their proxy for Fmsy.

The GARM III Working Group was unable to define stock-recruitment relationships for most groundfish stocks. Instead of using production models or other available methods that do not require any understanding of the stock-recruitment relationship to directly estimate Fmsy, the Working Group chose to apply the F40%msp proxy for Fmsy for all stocks (ignoring F30%, F20%, etc.), except redfish, for which F50%msp was applied. The GARM III report specifically cites the 2002 Working Group report as justification for their choice.
http://www.nefsc.noaa.gov/saw/garm/Garm%20III_BRPs_report_6june2008_finalCorrected.pdf

Further, the choice to adopt the F40%msp proxy for Fmsy by the GARM III Working Group has subsequently been cited as the "best scientific information available" in Amendment 16 and subsequent framework actions adopted by the Council including proposed Framework 48. It is clear that the Council was not fully advised of the implications of this approach or the potentially more desirable and scientifically sound alternatives available when making these decisions. As can be seen, the limited advice provided in the 2002 Working Group Report cited above has been perpetuated throughout the groundfish stock assessment and management process.

Two serious questions emerge for the Council's consideration—

1) **Was the specific choice of F40%msp as the proxy for Fmsy appropriate for most groundfish stocks and does it represent the best scientific information available?**

[1] The fishing mortality rate associated with 40% of the MSP of the stock. MSP is defined as the 'spawning stock biomass per recruit in the absence of any fishing' —i.e., when F=0. Thus, the F40%msp proxy means the fishing mortality rate that would reduce spawning stock biomass per recruit to 40% of the unfished level (maximum).

- The choice of 40% of MSP as opposed to some other percentage of MSP in setting a proxy for Fmsy (overfishing) is inherently arbitrary. It also often generates much greater rebuilding targets that may exceed Bmsy, which may be very difficult if not impossible to achieve within arbitrary MSA rebuilding timeframes. Managers need to understand the important implications this choice has for the specific management goals for each stock.

2) **Is *any* MSP-based proxy for estimating Fmsy appropriate for groundfish stocks and does that represent the best scientific information available? (ie. should we use direct estimates of Fmsy instead)?**

- Overfishing is legally defined according to Fmsy, and technical guidance from NOAA is that Fmsy proxies should only be used when Fmsy is not estimable.
- Since 2002 considerable additional data has been obtained that may support an understanding of the stock-recruitment relationship for some groundfish stocks (including Georges Bank yellowtail flounder) that is adequate to support the direct
- estimation of Fmsy for specific stocks (but a production model approach does not require assumptions about the stock-recruitment relationship).
- Even when stock-recruitment relationships cannot be determined as is often the case for groundfish stocks, valid production models based on age-aggregated biomass dynamics can be used to provide direct estimates of Fmsy for these stocks.
- MSP-based proxies for Fmsy are not appropriate for groundfish stocks that are not at equilibrium, and alternative non-equilibrium methods are more appropriate.

With these questions in mind, NSC respectfully recommends that the Council submit the following requests to the SSC to be addressed as soon as possible:

1) **Where possible, provide direct estimates of Fmsy for all groundfish stocks.**

2) **Where not possible to provide direct estimates of Fmsy, reevaluate the current Fx%msp proxy taking into consideration of what percentage of MSP is most likely to achieve the specific management goals for each applicable stock. This should include an evaluation of the consequences of this choice on the rebuilding target for each stock, and a comparison to available data.**

Appendix 5

MA DMF 12/2012

MA DMF Portside Bycatch Study Data Log

Land Date: _________________	**Scales Used: Large** ___________ TARE: _____	**DMF TRIP ID:**____________
Vessel Name: ______________	**Small** ___________ TARE: _____	Sampler(s): ______________
Vessel Hail: ________________ (mts, lbs, trucks)	Subsample Basket scheduled every _____ minutes	Offload Site: ______________

Sub-Sample #	Time (24-hr)	Basket Weight (kg)	Species 1 (Target)	Species 2	Species 3	Species 4	Species 5	Species 6	**Notes** (Truck #/size, pump/offload notes, LF sample, problems...)
Page SUM (add columns for each page)									After adding all columns verify that **Basket Weight = SUM of all Species Weights**
Trip SUM (add Page SUMs after last basket of trip)									**Note:** If using tube scales add to .1 kgs, if using digital scale add to .01 kgs.

If **SUM of RH/S** (Alewife, Blueback Herr, Am.Shad) **= 1.5% OR MORE of total basket weight**, immediately text msg RH% to MA DMF

Appendix 5

MA DMF SMALL PELAGIC PORTSIDE BYCATCH SURVEY

Species				Species				Species				Species			
Tot Wt (kg)				Tot Wt (kg)				Tot Wt (kg)				Tot Wt (kg)			
Sub Wt (kg)				Sub Wt (kg)				Sub Wt (kg)				Sub Wt (kg)			
Lt (cm)		Frequency	Sub Wt	Lt (cm)		Frequency	Sub Wt	Lt (cm)		Frequency	Sub Wt	Lt (cm)		Frequency	Sub Wt
	0		(kg)		0		(kg)		0		(kg)		0		(kg)
	1				1				1				1		
	2				2				2				2		
	3				3				3				3		
	4				4				4				4		
	5				5				5				5		
	6				6				6				6		
	7				7				7				7		
	8				8				8				8		
	9				9				9				9		
	0				0				0				0		
	1				1				1				1		
	2				2				2				2		
	3				3				3				3		
	4				4				4				4		
	5				5				5				5		
	6				6				6				6		
	7				7				7				7		
	8				8				8				8		
	9				9				9				9		
	0		Notes		0		Notes		0		Notes		0		Notes
	1				1				1				1		
	2				2				2				2		
	3				3				3				3		
	4				4				4				4		
	5				5				5				5		
	6				6				6				6		
	7				7				7				7		
	8				8				8				8		
	9				9				9				9		

MA DMF SMALL PELAGIC PORTSIDE BYCATCH SURVEY

Species ______
Tot Wt (kg) ______
Sub Wt (kg) ______

Lt (cm)		Frequency	Sub Wt (kg)
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	0		Notes
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		

Species ______
Tot Wt (kg) ______
Sub Wt (kg) ______

Lt (cm)		Frequency	Sub Wt (kg)
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	0		Notes
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		

Species ______
Tot Wt (kg) ______
Sub Wt (kg) ______

Lt (cm)		Frequency	Sub Wt (kg)
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	0		Notes
	1		
	2		
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	4		
	5		
	6		
	7		
	8		
	9		

Species ______
Tot Wt (kg) ______
Sub Wt (kg) ______

Lt (cm)		Frequency	Sub Wt (kg)
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	0		Notes
	1		
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	9		

Appendix 6

DMR PORTSIDE BYCATCH STUDY **Samplers:**

Basket # Total Kg	Basket # Total Kg	Basket # Total Kg
Basket # Total Kg	Basket # Total Kg	Basket # Total Kg
Basket # Total Kg	Basket # Total Kg	Basket # Total Kg
Basket # Total Kg	Basket # Total Kg	Basket # Total Kg
Basket # Total Kg	Basket # Total Kg	Basket # Total Kg
Basket # Total Kg	Basket # Total Kg	Basket # Total Kg
Basket # Total Kg	Basket # Total Kg	Basket # Total Kg

Link #
BCS #
Date
Target Species
Lot Weight

Catch Location
Gear Code
Depth Ftm
VTR #
Observer

Entered
Comments

Appendix 7

Sector Dockside Monitoring Program Standards

May 25, 2009

PURPOSE STATEMENT*: This document reflects a collaborative effort by sector organizers to capture a baseline protocol of a Dockside Monitoring Program for both 100% and less than 100% Dockside Monitoring Program. Acknowledging that individual sectors present unique technical challenges, participants in this process opted to articulate protocols they felt should be meet by all sectors at a minimum. However, while it will be the responsibility of individual sectors to design a Dockside Monitoring Program that achieves these protocols, the approach taken by an individual sector will vary based on the unique circumstances of their sector.*

I. HAIL

1. Upon departure, sector vessels will HAIL OUT, meaning notify the Sector Manager (SM) and Dockside Monitoring Vendor that he is departing on a Groundfish (GF) Trip. The HAIL OUT will include basic identifying information. Basic identifying information includes vessel name (or other data that uniquely identifies the vessel) and sector name.

2. Transmission of the HAIL will be either via Vessel Monitoring System (VMS) or some other electronic method as determined by the Sector.

3. At an appropriate time before landing, (determined by sector and Dockside Monitoring Vendor) the sector vessel will HAIL IN, meaning notify the Dockside Monitoring Vendor of his specific offload location, estimated time of arrival, and estimated volume or weight of GF on board. Whether the captain needs to estimate volume of GF on board, broken down by species, will be determined by whether there is 100% or less then 100% Dockside Monitoring for the sector.

    a. **If there is 100% Dockside Monitoring**, meaning a Dockside Monitor (DM) or Roving Monitor (RM) will be present for the offloading of every sector vessel groundfish trip, then the HAIL IN will include the following:
        i. Vessel name, Captain's name, permit number, sector name, VTR# and Trip ID #.
        ii. Specific offloading location, estimated time of arrival, and estimated volume or weight of all species combined on board.
        iii. The DM vendor will send a confirmation to the vessel that the HAIL was received.
        iv. If the DM has an emergency and cannot meet the vessel as required, the DM vendor will notify the vessel, the sector manager and the Office of Law Enforcement.

    b. **If there is less than 100% Dockside Monitoring,** (meaning any specific GF trip may or may not have a DM or RM present to witness offloading), then the vessel will be notified by the DM Vendor (when they send their confirmation) that:
        i. They will have a DM/RM present, OR
        ii. They are issued a DM Waiver for the trip, (meaning no DM or RM will be present to witness the offload).

c. **If there is less than 100% Dockside Monitoring:** Regardless of whether the vessel gets a waiver or not, the HAIL IN will include everything required for 100% DM coverage, but will also include an estimated volume of each species on board.

II. Responsibilities of the Dockside Monitoring Vendor

1. The DM Vendor must be able to receive HAILs on a 24/7 basis and must be able to send a confirmation of the HAIL back to the vessel. The confirmation system may be automated, but must indicate completeness of the required information.

2. The DM Vendor may keep a running list of 'open trips' so they are prepared to cover landing events and for other purposes (safety).

3. Upon receiving a HAIL IN, the DM Vendor will respond by sending the vessel and the Sector Manager a confirmation that includes confirming that a DM will be at the unloading station at a time certain; (or be able to communicate with the vessel to coordinate a time for offloading to commence). This can be any time agreeable to the unloading facility, the vessel and the DM.

4. The DM/RM will be required to sign the dealer receipt to document that the offload was observed.

5. The DM Vendor will be required to keep a record of each offload for auditing purposes and for any other reasons that may be stipulated in the private contract between vendor and Sector. This may also be needed to satisfy NMFS compliance concerns.

6. If there is less then 100% DM required, then the DM Vendor will notify the Sector Manager and NMFS Law Enforcement with the complete HAIL IN information (including a breakdown of species to be landed and estimated weight of each species on board) and whether the vessel will have a DM present at offloading or not.

7. The DM/RM must provide accurate and complete data to the SM and/or any third party immediately upon completion of weighing to give the Sector Manager or third party with enough time for the SM to ultimately produce an accurate and complete weekly report to NMFS.

8. The DM Vendor will be responsible for establishing an acceptable randomized methodology for determining allocation of DMs/RMs and waivers if less than 100% coverage level is chosen.

9. The DM Vendor will be responsible for working with Sector Managers to establish an acceptable process for Safe Harbor situations when a sector vessel is unable to follow normal dockside monitoring protocol due to an emergency situation.

III. Actual Monitoring of Offload at Dealer

1. The vessel may enter port and tie at safe berth but no offloading can commence until the DM/RM is present.
    a. Under limited circumstances vessels may be allowed to land non-allocated stocks for example lobsters or scallops, but will be required to notify NMFS Enforcement with enough notice to enable enforcement to be deployed if desired.

    b. **If 100% Dockside Monitoring is required:**
        i. The DM will take copies of the VTR(s) with all information available (no blocked cells).
        ii. The DM will verify the scales are certified and record the weight of offloaded fish by species or market class.
        iii. The DM will check the vessel to ensure that all fish have been offloaded.
        iv. The DM will sign the dealer receipt.
        v. The DM will collect copies of the VTR(s), and the dealer receipt.
        vi. The DM will electronically send his copies of the VTR(s), the dealer slip and his report to the sector manager … if the sector has contracted with a third party to collect and process their data, then the DM will send all three documents to that third party.
        vii. The DM will keep a copy of his report and it shall be stored by the DM vendor.

    c. **If less then 100% DM is required and the vessel will get a waiver:** The DM Vendor, when confirming that they have received the HAIL IN, will notify the vessel that they are receiving a waiver from DM for this trip. It will be the responsibility of each vessel operator to provide electronic copies of the VTR and dealer report to the Sector Manager or if applicable a contracted third party data company.

    d. **If less then 100% DM is required and the vessel will have a DM or RM,** then the process for 100% DM will be followed.

IV. Offloading to a Truck / Roving Monitors

1. The vessel will HAIL IN as described for all Dockside Monitoring.

2. It will be the responsibility of each individual sector to specify what remote unloading facilities Sector members will be allowed to offload to trucks at in their operations plans.

3. All trucked fish must be weighed, either at the offload site by a licensed dealer (in which case it is treated as a dockside monitoring event) or at the dealer when the truck offloads.

4. **If 100% DM is required**:
    a. The DM vendor will be responsible for ensuring a Roving Monitoring will be at the offload site when the vessel arrives to offload. All landing events at remote ports will be required to have a RM present to witness offload activities as well as a DM present at dealer to certify weigh-out.

b. Copies of the VTR(s) need to be available at the truck offload for the DM.

5. **If less than 100% DM is required:**
   a. The HAIL IN will include the captain's estimate of weight of each species on board.
   b. The vessel will be notified by the Dockside Monitoring Vendor (when they send their confirmation) that
      i. they will have a RM present OR
      ii. they are issued a DM Waiver for the trip
      iii. the DM vendor will notify the Sector Manager and NMFS Law Enforcement with the complete HAIL IN information (including a breakdown of species to be landed and estimated weight of each species on board) and whether the vessel will have a DM present at offloading or not.
   c. Offloading of landings at remote ports and weigh out of landings at dealer facilities will be considered two separate events. DM will be responsible for establishing a selection process that randomly selects remote port offloads that will be monitored by a RM and weigh out of trucked landings at dealer facility by DM.

V. Actual Monitoring of Offload at a Remote Port

1. The vessel may enter port and tie at safe berth but no offloading can commence until the RM is present.
   a. The RM will take copies of the VTR(s) with all information available (no blocked cells).
   b. If there are scales, then the RM will verify the scales are certified and record the weight of offloaded fish by species.
   c. If there are no scales at the offload site, then the RM will record the number of totes of each species with the Captain's estimate of weight of each tote.
   d. The RM will check the vessel to ensure that all fish have been offloaded.
   e. The RM will ensure that each tote is labeled with the appropriate information including but not limited to:
      i. Vessel name, Captain's name, permit number, sector name, VTR# and Trip ID #, date of offload, RM name, tote number and species;
   f. The RM will confirm that the driver's manifest includes an accurate list of all totes, the species they hold, the vessel and permit each tote came from, and the RM's name/contact info.
   g. The RM will electronically send his copies of the VTR(s) and his Offload Report to the sector manager, and if the sector has contracted with a third party to collect and process their data, then the RM will send both documents to that third party.
   h. The RM will keep a copy of his report and it shall be stored by the DM vendor.

2. Final RM protocols and requirements will be determined by the DM vendor and the individual Sector, detailed in the Sector's Operations Plan, and must be approved by NMFS.

New England Fishery Management Council
50 WATER STREET | NEWBURYPORT, MASSACHUSETTS 01950 | PHONE 978 465 0492 | FAX 978 465 3116
John Pappalardo, *Chairman* | Paul J. Howard, *Executive Director*

May 10, 2011

Ms. Patricia A. Kurkul
Regional Administrator
National Marine Fisheries Service
55 Great Republic Drive
Gloucester, MA 01930

Dear Pat:

The Final Rule implementing Framework Adjustment 45 included a requirement that dockside monitors inspect the fish hold for any trip assigned a dockside or roving monitor. At the April Council meeting, the following motion was passed without an opposing vote (12/0/2):

> *"request that the Council write a letter to NMFS expressing our concerns on the requirement to have dockside monitors go down in the fish hold."*

The Council is concerned that this requirement poses an unacceptable safety risk for dockside monitors. There are no generally accepted standards that describe access from an offloading site to a fishing vessel. While at some locations there may be a boarding platform or gangway between the dock and the vessel, it is far more common for access to be by jumping or clambering from one to the other. Given the high tides in some areas of New England there may be a large vertical distance between the pier and the vessel, and as a result access may be via a poorly maintained, slippery, and, in winter, ice-encrusted ladder. There are numerous examples of experienced fishermen falling in the water between the vessel and the pier, often with tragic results. To expose dockside monitors to these risks without a clear benefit is unacceptable.

Once on-board a vessel the number of hazards does not decrease. Dockside monitors are being asked to inspect fish holds; access to a hold can be nearly as hazardous as that between the dock and the vessel. There are also safety concerns with entering fish holds do to the possibility of poor or non-existent ventilation. These personnel operate independently, with no safety observer or backup should they encounter a problem. There is a very real possibility that an accident could be undetected for a considerable length of time.

These safety issues are likely to increase the potential liability for both dealers or dock owners and the fishing vessels. As a result insurance companies may increase premiums. These increased costs will only dissipate the economic benefits of the catch share system.

Even if the safety issues can be resolved, there are other questions concerning the role of the monitors that have not been addressed. Are they to move ice or other gear to ensure all fish has been offloaded?

How do they respond if they do find catch that is not offloaded, since they do not have enforcement authority? Will this requirement delay the offload of multiple vessels at busy offload sites? What will be the response if a vessel captain does not give permission to board their vessel? Can a dealer refuse to allow a monitor to board from its dock because of safety issues?

In sum, the Council believes its concerns warrant revisiting this requirement. We urge you to reconsider this decision in light of the serious safety and practical issues that have been raised. Please contact me if you have any questions.

Sincerely,

Paul J. Howard
Executive Director

Amendment 23

To the

Northeast Multispecies Fishery Management Plan

Appendix III

Electronic Monitoring Programs in the Northeast Multispecies (Groundfish) Fishery

Electronic Monitoring Programs in the Northeast Multispecies (Groundfish) Fishery

The utility of fishery-dependent data for catch monitoring hinges on the collection of accurate information, and electronic monitoring (EM) is a general framework of tools for helping achieve this goal. Amendment 23 to the Northeast multispecies (groundfish) fishery management plan aims to improve monitoring while reducing costs and EM may be one tool to achieve this objective with a properly designed program.

To explore the implementation of EM in the groundfish fishery, the Northeast Fisheries Science Center (NEFSC) and the Greater Atlantic Regional Fisheries Office (GARFO) have coordinated with interested stakeholders on multiple Exempted Fishing Permit (EFP) projects since fishing year (FY) 2016. These EFPs were designed to allow commercial vessels to use EM as part of official catch monitoring protocols, facilitating the development of fleet-wide implementation. At the core of the protocols is a multi-camera video system used to record vessel operations that follow predefined catch handling procedures. The recorded video is then reviewed by trained video reviewers to determine whether the catch handling procedures were followed (e.g., regulatory compliance) and, for audit-model protocols, to annotate the size/weight of groundfish species discarded. Vessel captains are required to report haul-level effort and catch information (including discards) through electronic Vessel Trip Reports (eVTRs), producing fine-scale fishery-dependent data useful for science and management.

The two primary approaches to EM that have been developed for groundfish include:

1) Audit model
2) Maximized retention

The audit model approach is suited to vessels with small amounts of discards where individual fish can be displayed to a camera for measurement, and documented by the captain on the eVTR. Subsequently, a video reviewer watches the video footage of the trip and independently records all discards. This information is used to verify, or audit, the discards reported by the captain on the eVTR. The maximized retention approach is better suited to larger volume vessels where discards for undersized fish (e.g., haddock) are more easily estimated by retaining the catch and sampling it at the dock as part of a dealer transaction. While the video footage is used to track compliance for both approaches, it is not currently used to estimate discards for vessels participating in maximized retention.

The catch accounting processes used by GARFO have differed both within and between the approaches as each have developed over time. Additionally, modifications to the catch handling, reporting, and reviewing procedures have been made to accommodate various contingencies discovered as participation and the total trip number have increased.

1) Audit Model (project leads: The Nature Conservancy, Maine Coast Fishermen's Association, and Cape Cod Commercial Fishermen's Alliance)

- Participants from groundfish sectors use EM to meet at-sea monitoring requirements and account for quota-managed groundfish discards. On a subset of EM trips, vessels also carry federally-funded NEFOP fisheries observers. This project entered its 4th year in FY 2019.
- Project collaborators: Gulf of Maine Research Institute (GMRI), Teem Fish (EM service provider), GB Cod Fixed Gear Sector, Maine Coast Community Sector, Northeast Fishery Sectors II, V, and XI, and Sustainable Harvest Sector 1.
- Project Goals: 1) Evaluate third-party video review for catch accounting; 2) Develop audit methodology by using discards seen on video footage to verify fishermen's eVTRs; and 3) Refine catch handling and video review protocols.
- Groundfish Audit Model: EM is running on either ASM-selected trips (5 participating vessels, 27 total trips) or 100% of all declared groundfish trips (17 participating vessels, 369 total trips).
- Video review occurs at the trip level.
    - In FY18, 100% of trips were reviewed.
    - In FY19, we are reviewing less than 100% of trips to test a "true" audit approach.
        - The current audit level for the primary review is 50%.
- Under the audit-model, vessels are assigned one of four discard sources for each trip: NEFOP, eVTR, EM discard report, or a discard rate.
    - Trips with NEFOP observers are assigned the discards reported by the observer, consistent with the fishery as a whole.
    - Trips that are not selected for audit, and do not carry a NEFOP observer, are assigned the discards reported by the vessel on the eVTR.
    - For trips that are selected for audit, NMFS compares the discards reported by the captain on the eVTR to the discards reported by the video reviewer on the EM discard report. If the eVTR and the EM discard report match within a given tolerance, the trip is assigned discards as reported on the eVTR. If they do not match within a given tolerance, the eVTR cannot be verified and the trip is assigned discards based on either the EM discard report or a program-specific discard rate.
- FSB performs a secondary review on a portion of these trips in an effort to develop standards for EM data review and provider performance.
- Groundfish: ~200 active vessels; 25 vessels are operating under the current EFPs (see below for MREM EFP).
- NEFSC/GARFO are developing business practices necessary to support an operational EM program including; data analysis protocols and design for the audit-model (i.e., percentage of video reviewed, pass/fail criteria, development of subsampling and volumetric sampling approaches).

2) Maximized Retention (project lead: Gulf of Maine Research Institute)

- Three participating vessels (96 total trips) from groundfish sectors retain all catch of allocated groundfish in accordance with maximized retention requirements, and use EM to verify compliance. These vessels run cameras on 100% of their groundfish declared trips. The EFP supporting this project was issued for two years and the project is entering its second year.
- Project collaborators: GMRI, Integrated Monitoring (EM service provider), and Sustainable Harvest Sectors 1 and 3.
- Project Goals: 1) Examine feasibility of discard compliance monitoring in a mixed-species fishery; 2) Test maximized retention; 3) Develop a pilot dockside monitoring program to collect catch data and monitor potential changes in size distribution.
- Participants retain 100% of allocated groundfish, while discarding unallocated groundfish and halibut in excess of one fish per trip; EM is used for monitoring catch retention compliance.
    - All allocated groundfish is reported by dealers for catch accounting purposes, including NO SALE catch. Participating vessels receive a discard rate of zero for allocated groundfish on these trips.
- On a subset of EM trips, vessels carry at-sea monitors (ASMs) to collect information on unallocated groundfish and non-groundfish species. All trips are exempted from NEFOP coverage (non-normal sampling).
    - Data collected by ASMs are used to develop program-specific discard rates. These discard rates are used to estimate catch of unallocated groundfish and non-groundfish species on these trips.
- All trips have mandatory dockside monitoring coverage (managed by FSB). Dockside monitors have three primary functions: (1) Inspect fish holds to ensure complete offload of catch; (2) conduct biological sampling on undersized groundfish catch; and (3) verify dealer weights.
- FSB performs a secondary review on a portion of these trips in an effort to develop standards for EM data review and provider performance.
- NEFSC/GARFO are developing business practices necessary to support an EM program including; data analysis protocols and dockside monitoring protocols.

Amendment 23

To the

Northeast Multispecies Fishery Management Plan

Appendix IV

Groundfish Plan Development Team Monitoring Analyses and SSC Sub-Panel Peer Review Report

Modelling Discard Incentives for Northeast Multispecies (Groundfish) Stocks

4/12/2019

Anna Henry, Chad Demarest, and Melissa Errend

Introduction

Quantifying total removals is an important data requirement for successful fisheries management. Primarily, total removals are important for determining what future stock sizes will be, and for quota-managed fisheries, to ensure catch is within total catch limits. However, it is easier to measure catch that is retained than catch that is discarded at sea. Catch may be discarded for a variety of reasons, including low market value, regulations prohibit retention, or quota limits have been reached. In some fisheries discarded catch can comprise a significant portion of total removals, so it is important to accurately estimate discards. In U.S. fisheries, this is typically accomplished by deploying human observers on some, or all, fishing trips.

In fisheries with less than 100 percent observer coverage, managers and scientists allocate significant resources to estimate unobserved discards. Often, though, we lack the terminology to communicate precisely what we are estimating. This is particularly problematic in multispecies fisheries where regulations simultaneously require discarding specific species or sizes of fish but also prohibit discarding of other species or sizes of fish. Such is the case in the Northeast Multispecies groundfish fishery.

The fishery includes 17 quota allocated stocks and 5 non-allocated stocks occurring in three distinct ecosystems, delineated by managers into four broad stock areas including: Gulf of Maine (GOM), southern New England/Mid-Atlantic (SNE/MA), and both western and eastern areas of Georges Bank (inshore, and offshore GB). Minimum size limits require discarding undersized fish; yet the fishery as a whole is managed by a quota-based system that requires landing all fish above the minimum size to determine when catch limits are met. Yearly observer coverage ranges from 14% to 32% meaning in some years up to 86% of trips are unobserved (GARFO 2019, Table 1).

Discard rates on observed trips are used to estimate discards on unobserved trips but, importantly, a primary observer duty is to estimate legal discards, i.e., undersized fish and prohibited species. We suggest the term “mandatory discards” to describe this estimate. An ancillary observer duty is to report instances of non-compliance for subsequent NOAA Office of Law Enforcement (OLE) action. Because of this compliance role, illegal discarding of legal-sized fish (termed here “prohibited discards”) is generally assumed not to occur on observed trips, though instances have been reported (NOAA OLE, 2019; see Attachment 1). Without observers onboard, it is very difficult to enforce mandatory landing requirements since sufficient evidence, such as fish length, is rarely acquired before a fish is thrown overboard. Enforcement cannot always make this determination even if they are on scene (NOAA OLE, 2019). The lack of compliance enforcement leaves unobserved trips vulnerable to an unknown level of voluntary compliance with landing requirements.

Prohibited discarding may severely undermine efforts to estimate total removals and ensure catches stay within limits, but this behavior may be economically rational. This is because in any quota-based fishery there exists some incentive to discard legal sized fish, perhaps to highgrade or avoid constraints imposed by small quota allocations (Arnason 1994). In tradeable quota programs, this incentive is a function of the costs and benefits associated with the retention of each individual fish based largely upon differences in quota prices and expected landing prices. Therefore, the focus on estimating mandatory discards has consequences on the precision and accuracy of total discard and total catch estimates given that the costs and benefits of prohibited discarding on observed trips may not be the same as those on unobserved trips. Theoretically, this stems from the economics of crime that suggests that, among other factors, the willingness to engage in illegal activities is a function of the likelihood of being caught and the severity of punishment (Becker, 1968).

When an observer is not on board, the likelihood that illegal discarding might be detected is thought to be very small, which reduces any potential 'cost' of this illegal activity (NOAA OLE, 2019). Therefore, when benefits of discarding are large, catches may be underreported as result. Furthermore, when fishermen are not accountable to their limits and can evade quota constraints by discarding, this undermines the effectiveness of the quota lease market, particularly for those who are less able, or less willing, to discard illegally.

Here, we describe the economic factors that influence a fisherman's decision to discard illegally by adapting previous theoretical models (Arnason 1994, 2001) to describe the Northeast Multispecies fishery. We then parametrize the model using information from fishing trips 2007-2017 in order to explore how discard incentives change year to year and across stocks. We use results to inform a discussion about what factors influence discard incentives most, and how the discard incentive model might be used retrospectively or prospectively as an indicator of biased catch data.

Methods

We model the incentive to discard a pound of stock *i* on a trip *k* (Id_{ik}) on unobserved trips as the difference between the costs associated with landing one additional pound of fish (q, in live pounds) and the costs associated with discarding that unit, standardized by the total ex-vessel value (Equation 1).

$$Id_{ik} = \left[\left(Cl_i(q_i) - Cd(q_i)\right)/(pf_i * q_i)\right]_k. \quad [1]$$

Costs of landing (*Cl*, Equation 2) include the cost of leasing quota for that unit of fish[1] (*pq*), sector and landing fees (*sf*, and *lf*, respectively), and any costs associated with on board handling such as the labor of properly gutting and icing the fish, which all together are per unit costs of labor (*Cll*). In the model, we specify sector fees by sector (sectors 5, 22 and 26 do not have fees, other sectors' fees range between $.035 and $.075 per pound) and landing fees are a constant at $.05 per pound, a typical fee charged dockside by dealers. The cost of labor associated with landing is also modeled as a constant at $.01 per pound. It is difficult to approximate the true marginal labor cost of landing (which includes all pre-processing, such as gutting, dressing, and putting on ice) realistically this would vary by trip depending on realized crew shares, the total pounds landed, trip duration, and even target species since roundfish and flatfish stocks require different amounts of pre-processing (such as gutting). Murphy et al. (2018) report that between years 2007-2015 the value of the median crew share ranges from $0 to $665 per crew member per day depending on vessel size, but the fleetwide median has been relatively stable at $400 per day. In addition, average groundfish landings per day absent are approximately 2,600 pounds. One groundfish observer estimated that one hour per every twelve hours fishing is spent pre-processing. Combining these pieces of information, our approximation of marginal labor costs appears to be reasonable, since this back-of-the envelope calculation would estimate that if all 2,600 fish were pre-processed in one hour the marginal pre-processing cost could be approximated as $.013/lb. In 2015, the highest crew shares were observed for the largest vessel size class would yield a marginal labor cost of landing of $.02/lb.

$$Cl_i(q_i)_k = \left\{pq_i * q_i + (1-\delta_k)\left[\left(\sum_{j=1}^{n} pq_j * r_j\right) * q_i\right] + Cll(q_i) + sf * q_i + lf * q_i\right\}_k, \qquad [2]$$

In addition, we also include a term that represents the cost of quota for all other stocks associated with landing an additional pound of fish. In New England, on unobserved trips a discard rate is applied based on observed discards within each strata (sector, gear, stock). Therefore, we model this as the proportion of unobserved tows (δ, set at 0 for unobserved trips) multiplied by the discard ratio (*r*) which are back calculated by stock and trip using the year end imputed rate as the discards of all stocks within the same broad stock area ($disc_j$) over the quantity kept landings on trip k (q_k, Equation 3).

$$r_j = disc_j / q_k. \qquad [3]$$

Costs of discarding (*Cd*) include the revenue forgone when not landing one unit of fish (ex-vessel value), as well as the labor costs associated with discarding the fish (*Cdl*). As we focus on illegal discarding, we add the probability of detection (*p(d)*) and the magnitude of sanction associated with illegally discarding fish (*s*, Equation 4). Labor costs of discarding are assumed to be near zero because there are very few marginal costs associated with discarding outside of sorting, which occurs whether a fish is landed or discarded. We set this at a conservatively high value at $.005 per pound. The probability of detection and sanction are modeled together as a

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1 We commonly refer to quota prices and quota costs throughout this work but this only includes the costs of leasing quota. Permanent sale of quota is not allowed except through the sale of the entire fishing permit.

constant, which we set at a combined cost of $5 for stock landings more than $20 and $0 for any landings less than $20—simply because on trips with low landings this parameter becomes strongly influential. We believe this is conservative granted that the probability of detection for illegally discarding legal sized fish at sea is likely zero or close to zero on unobserved trips, which counteracts even a high possible sanction, noting that here this could represent a sanction of $20,000 with a 0.25% probability of being detected. King and Sutinen (2010) found that for the NE groundfish fishery in 2006 the average sanction for all violations was $20,000, but the average settlement fine was around $10,000. In addition, according to OLE, out of 12 reported incidents of prohibited discarding on both observed trips and unobserved trips (out of which 8 were generated by observers), the strongest action taken has been 1 written warning over the last two years. This supports other information from OLE that even on observed trips it is very difficult to acquire enough evidence to issue violations (NOAA OLE, 2019), and supports our rationale for including a low expected cost for prohibited discarding.

$$Cd_i(q_i)_k = [pf_i * q_i + Cdl(q_i) + p(d) * s]_k \qquad [4]$$

Incentives are estimated separately for each allocated groundfish stock and each groundfish trip over fishing years 2007-2017. Trip information is selected for trips from the GARFO DMIS database. Ex-vessel prices are calculated at the NESPP4 (market/grade) level from information of total value and landed pounds for each grade on a given trip. Landed stocks with ex-vessel prices greater than $10 or less than $.05 per pound for each of the 17 allocated stocks were removed as outliers from the dataset.

Quota lease prices are estimated with a hedonic price model using methods described in Murphy et al. 2018. For fishing years 2011-2016 quota prices are estimated by stock for each quarter of the fishing year using inter (between) sector and intra (within) sector trades of both fish for fish and fish for cash as reported in sector end of fishing year reports. For quarters with minimal trading volume, the model estimates a quota price of zero. In cases with non-zero prices in adjacent quarters we adjust estimated prices by substituting prices from the surrounding quarters in the same fishing year (Table 2). In other instances, such as where estimated quota prices appear anomalous (e.g., high prices for low utilization stocks), prices were adjusted to the median reported cash trade value. Prices for fishing year 2010 and 2017 are estimated annually due to fewer reported trades and no information on within sector trades[2]. The value of quota for fishing years 2007-2009 (pre sectors) is assumed to be zero.

Sector NEFS IX trips were excluded from results because vessels in this sector were found guilty of strategic misreporting and therefore landings information is known not to be accurate. Strategic misreporting likely affected the quota market as well, but we did not attempt to adjust for this.

[2] 2017 quota prices will be updated to quarterly modeled prices (including inter sector trade data) after sector year end reports are submitted.

Model assumptions:

The discard incentive model assumes that:

- landings are representative of underlying discard incentives (e.g. the model will not estimate discard incentives for stocks that are not reported as landed);
- landings data are known without error (e.g. no species substitution or other misreporting);
- modeled quarterly inter- and intra-sector quota prices adequately capture the instantaneous quota cost faced by fishermen during a trip;
- quota price encapsulates the marginal value of quota, where
- the marginal value of leased quota is equal to that of allocated quota (e.g. not incorporating an “endowment” effect);
- expectations of landed fish prices are adequately captured by ex-vessel prices received on each trip.
- quota prices and ex vessel prices are unaffected by illegal discarding or misreporting; (the benefit of discarding includes the marginal value of quota for that stock and the discards associated with landing an additional unit of fish, noting that this does not explicitly include the marginal value of landing any fish accessible in the future and enabled through discarding the fish in question);
- the probability of detection and the associated sanction are perceived by fishermen to be low;
- costs of labor of discarding and labor of landing are constant; and
- there is no shadow value of biomass, i.e., discarded catch cannot be harvested again.[3]

Results:

Modeled quota prices follow general trends in single stock cash reported trades (Figure 1). Instances where these diverge are due to the influence of fish for fish trades and/or basket trades, where numerous stocks are included with one overall cash price. Price estimates for 2010 may be biased high due to a lack of data on within sector trades. Generally, estimated quota prices increase for stocks and years with higher quota utilization rates (Figure 2) following expectations from general economic theory.

Our model shows that discard incentives for many stocks increased with the implementation of the sector system (fishing year 2010), reflecting the influence of non-zero quota costs (Figure 3). Stocks which have not seen much change in discard incentives include several lower-value or low-utilization stocks such as both GB haddock stocks, pollock, and redfish (see Figure 6 for

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[3] Arnason (1994) believed this was negligible.

trends in ex-vessel prices, Figure 7 for trends in utilization). However, for other stocks trends since have not been consistent, due primarily to the interactions of fluctuating ACLs, quota prices, and ex-vessel prices. The imputed cost of quota for sublegal discards, which for most stocks is somewhere between 0 to 3 cents per pound of landed stock, contributes somewhat less to the incentive to discard legal-sized fish. Other model parameters we estimate as constants likely do not affect changes over time, such as the probability of detection and associated sanction, labor costs, or landing fees because cumulatively these are nearly negligible in contrast to ex-vessel and quota price (all other costs of landing, besides the cost of quota, sum to roughly 10 cents per pound, regardless of stock).

Between 2010 and 2017, almost every year had at least one stock that was landed with a positive discard incentive. In 2010, approximately half of all GB yellowtail flounder landings were modeled to have a positive discard incentive (Figure 4) and the ratio was nearly as high for the SNE/MA yellowtail flounder stock, for which mean quota prices nearly matched mean ex-vessel prices in that year. In 2011, sub-ACLs were increased for all three yellowtail stocks, as well as several other stocks with relatively low allocations, including witch flounder, plaice, and winter flounder. Highly-utilized stocks including GOM cod also saw sub-ACL increases in that year, resulting in very low quantities landed with positive discard incentives (Figure 4) and relatively few trips landing any stock with a positive discard incentive (Figure 8). In 2012, quota prices jumped for the eastern GB cod stock as well as GB yellowtail flounder, resulting in about 20% of landings in that year with a positive discard incentive. From 2013 to 2015, discard incentives are estimated to be highest for yellowtail and cod stocks, with around 20% of landed GOM cod having a positive discard incentive between 2015 and 2017. Starting in 2016, quota for GB cod west was allowed to be converted to GB cod east quota, and in 2014 a similar provision allowed GB haddock west quota to be converted into GB haddock east quota (FW 55 and 51, respectively). The quota conversion for GB cod west is likely reflected in the increase in quota price, and the corresponding increase in discard incentive, in recent years. Other stocks with positive discard incentive landings include witch flounder, plaice, and in some years, GB and GOM winter flounder. GOM haddock also sees higher discard incentives, generally corresponding to years where the difference between ex-vessel price and modeled quota prices are smallest.

Overall, the model suggests that the percentage of trips landing at least one stock with a positive discard incentive has increased since 2010 (Figure 6). This is most true for trips landing GOM cod, noting a particularly strong increase in discard incentives for trips in 2015 (Figure 7). In addition, between 20 to 30 percent of landings between 2014 and 2017 had a positive discard incentive for GOM cod (Figure 4). Comparing quota prices and ex-vessel prices over time, trends seem to match well, with higher proportions of positive discard incentive stocks appearing when average annual quota prices exceed 40 to 50 percent of ex-vessel price (Figure 5, Figure 6).

The discard incentive model may have advantages over other metrics of constraining stocks. When comparing utilization trends with modeled discard incentives, utilization alone does not describe our results, reflecting the imperfect relationship between quota price and utilization. For example, American plaice has been nearly fully utilized since 2012, yet landings and trips with a positive discard incentive have increased over time. Changing ACLs may also serve as another indicator since highly utilized, low allocation stocks may be inferred as constraining—but we see that for example, in 2013 witch flounder experienced a drop in its ACL and was near fully utilized, but discard incentives did not change much from 2012. This illustrates that while utilization and the total allocation certainly are related to quota prices, the exact nature may be difficult to predict, complicating expectations of how discard incentives might change in a given year.

Discussion:

Our results show that under sectors, cod and yellowtail flounder stocks have had the highest discard incentives overall, but incentives vary considerably year to year. These stocks are also currently considered to be experiencing overfishing, and are overfished (GARFO, 2019, Table 3). Discard incentives change by stock and fishing year, therefore any bias in catch data resulting from illegal discarding of legal sized fish is unlikely to be consistent in either direction or magnitude over time (Figure 3, Figure 4). Quota prices and ex-vessel prices are primary drivers of discard incentives in any year, therefore an understanding of these two factors are important considerations for the design of management measures seeking to reduce inaccuracies in true catch. Improved tracking on inter- and intra-sector quota prices and individual quota holdings may assist with enforcement as noted by OLE (NOAA OLE 2019).

These findings beg the question: if it was not economically rational to land 20% of all GOM cod in 2016, why were they landed? Assumptions and generalizations in our model may overestimate discard incentives for those who do not lease in much quota or who receive higher ex-vessel prices, and at the margin where labor costs are over or underestimated, but our model also misses other, non-economic reasons that fishermen may choose to comply with regulations even when it is less profitable to do so. Social determinants of compliance include sense of morality, peer perceptions, and judgments about the rules in place (Jagers, Berlin, and Jentoft 2012). However, King and Sutinen (2010) in a 2007 survey found that these normative factors play a weak role in the groundfish fishery; fishermen were found to doubt justifications for management decisions, and believed schedules and rebuilding targets to be arbitrary and unfair. Furthermore, they found that fishing violations, such as fishing illegally, were detected and prosecuted at low enough levels that the economic incentive *not* to comply with regulations was $4,334 per trip. Therefore, it may be reasonable to assume that our estimates of landings with positive discard incentives represent the lower bound of the total discard-incentivized catch.

Finally, our model may *underestimate* (and rather significantly, at that) the true incentive to illegally discard legal sized fish, for two reasons. First is the endogeneity problem noted in the model assumptions: the very problem the model aims to detect is self-attenuated by discarding all of a given stock, eliminating that trip from our results, and also by the feedback loop created by the fact that illegal discarding reduces demand for quota and consequently impacts quota prices. The second reason is that our model focuses on the marginal incentive for each fish in isolation. In fact, a pound of fish discarded obtains a benefit equal not only the quota value of that pound of fish and the other marginal parameter contributions, but also obtains the benefit of allowing access to covariate stocks on future tows and trips. The value of this additional fishing opportunity obtained by discarding is difficult to incorporate into a marginal model such as this, but is likely another primary driver of prohibited discarding.

The current model may be a useful indicator of risk, but more work is needed to fully characterize the magnitude of noncompliance in the northeast groundfish fishery. Updating previous work on attitudes about compliance would be helpful to better balance normative motivations against strictly economic incentives, as well as ground truth assumptions in our model about perceptions about probability of detection. Furthermore, predictive models of catch would permit comparisons of catch compositions for at-risk stocks over time in order to estimate underreported catch. This work is needed to accurately estimate the impact of noncompliance on total catch estimates.

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Figures and Tables

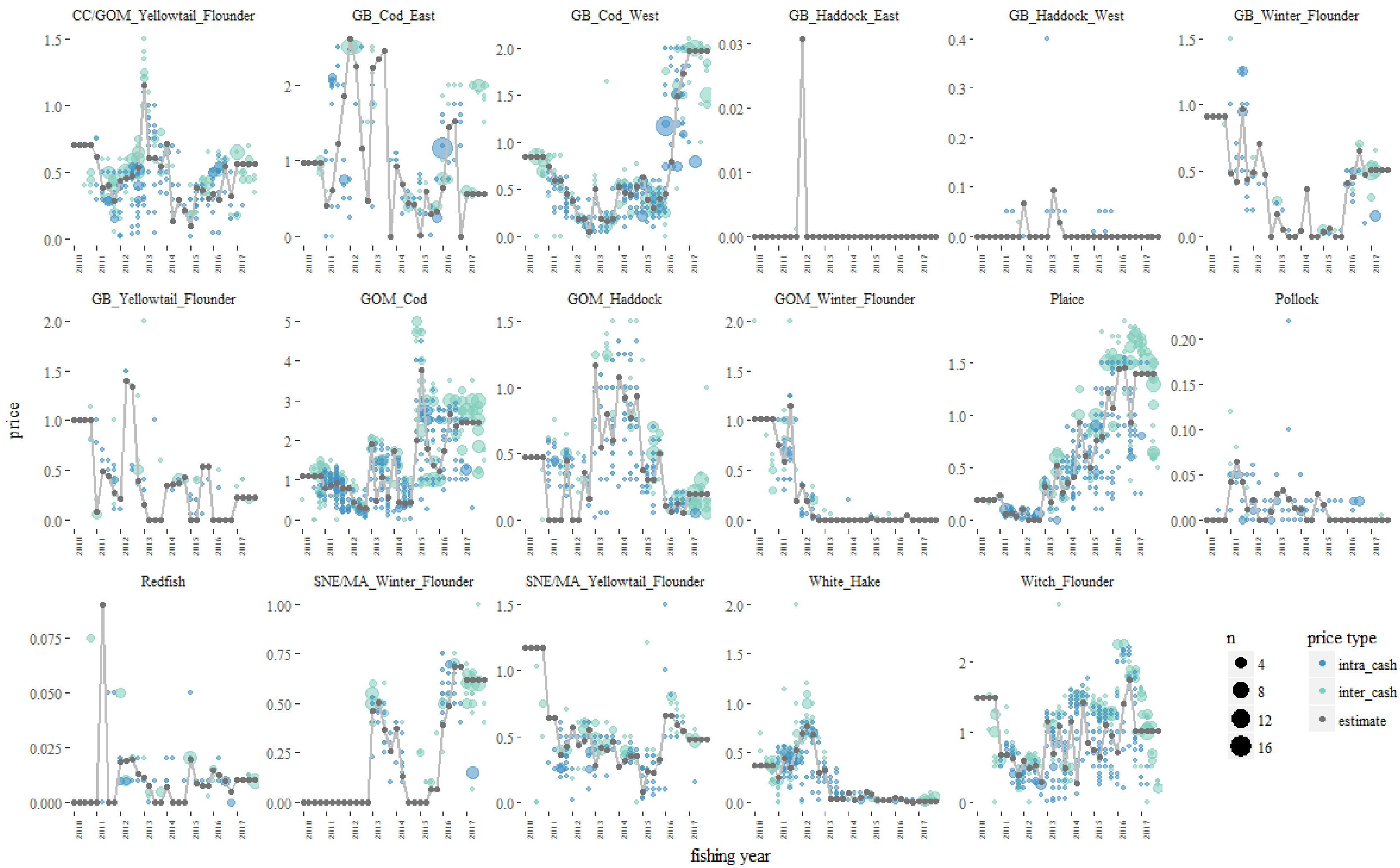

Figure 1. Estimated quota prices and sector reported single stock fish for cash trade prices by fishing year, quarter. Note that the Y-axis values differ for each stock.

Figure 2. Percent of quota caught and estimated quota prices.

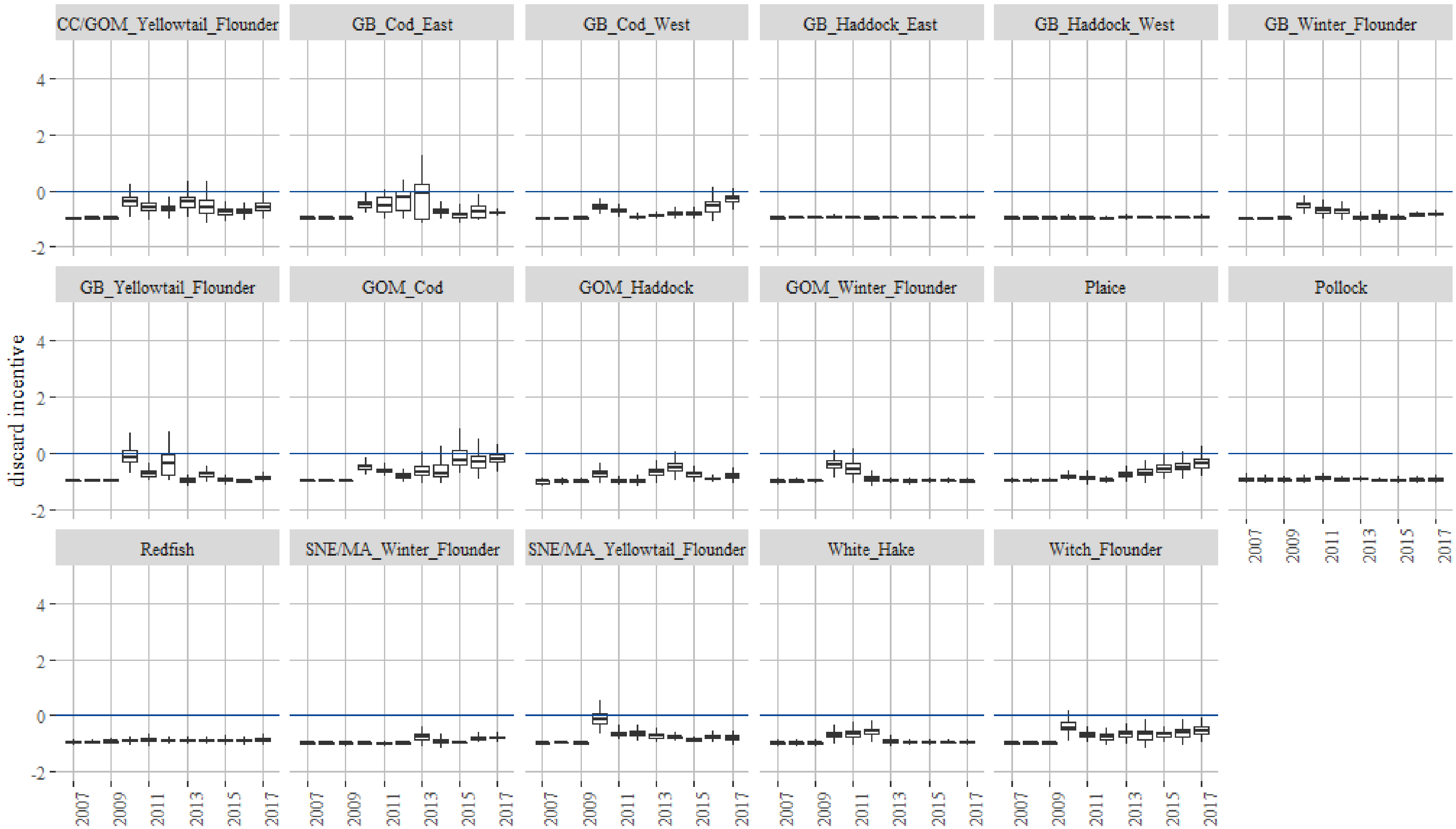

Figure 3. Estimated discard incentives for all unobserved trips fishing years 2007-2017. The boxplot 'box' shows the median, 25th percentile and 75th percentile of the distribution, the whiskers show the "min" and "max" values (defined as 1.5x the upper or lower quartiles), outliers (anything beyond 1.5 times the interquartile range) not shown for clarity.

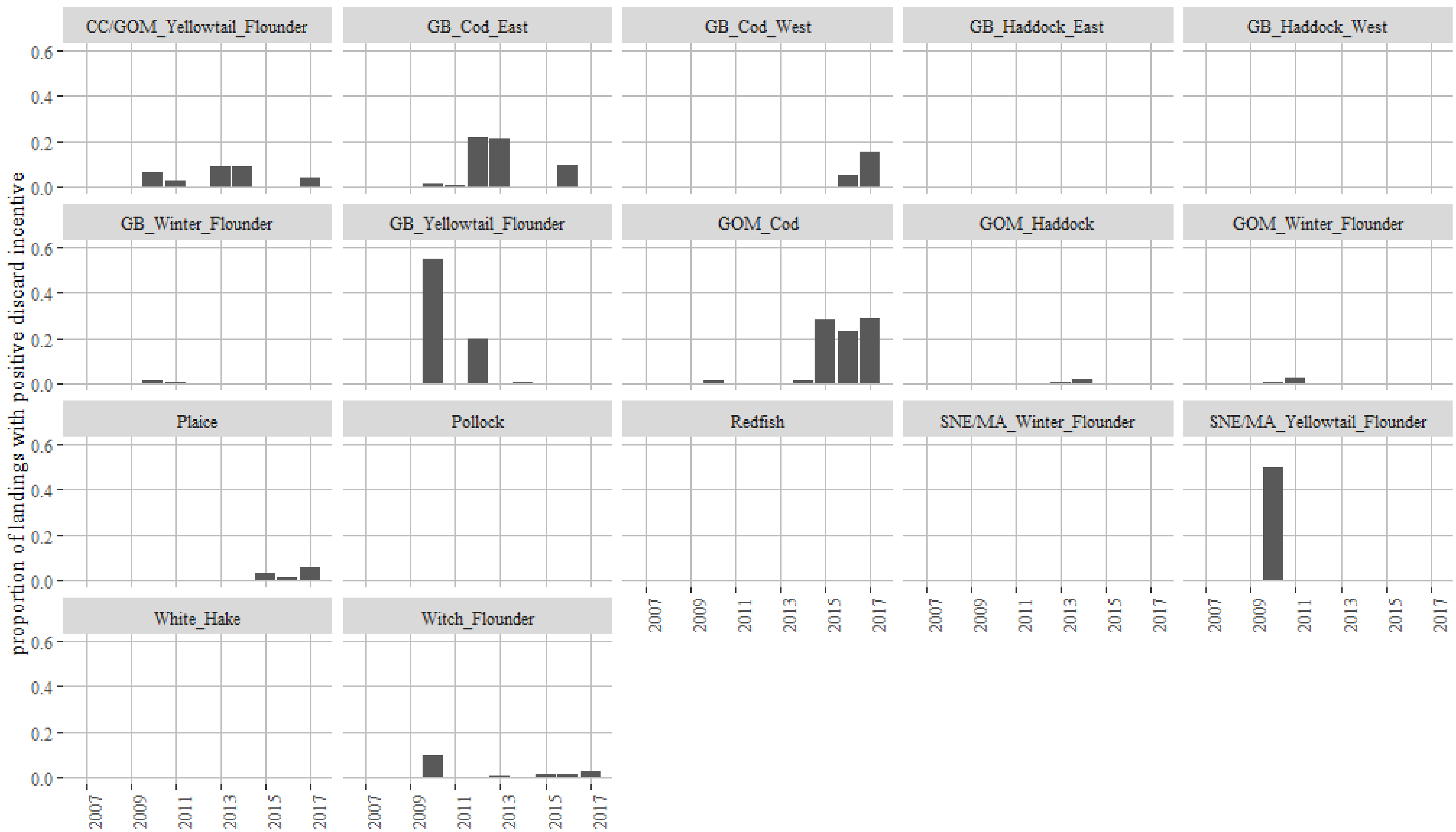

Figure 4: Proportion of landings with a positive discard incentive in each year 2007-2017 and for each allocated stock.

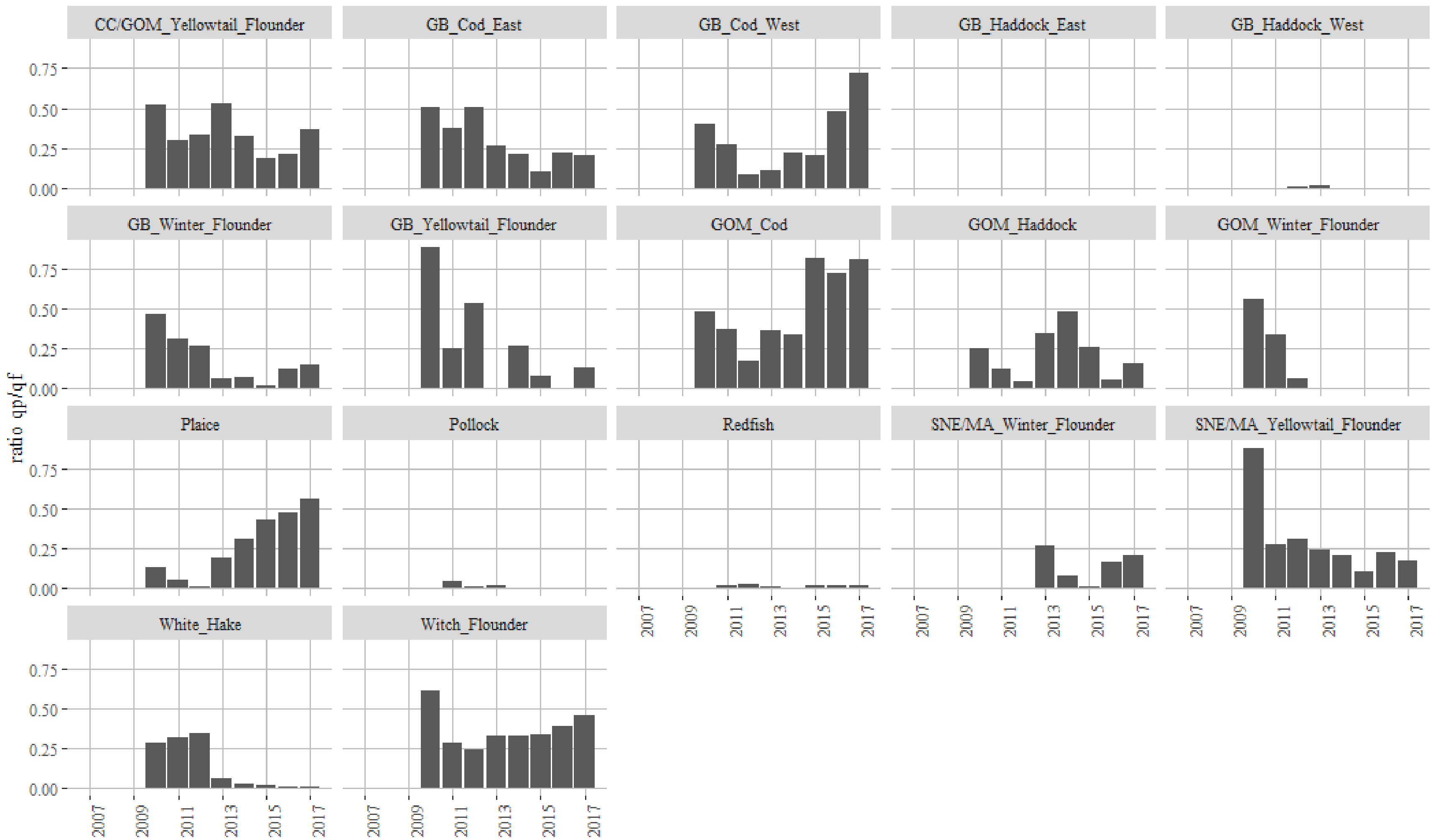

Figure 5: Ratio of modelled average annual quota price to ex-vessel price for each stock and year 2007-2017. *starting in 2016 quota for GB cod west was allowed to be converted into GB cod east quota, and in 2014 a similar provision allowed GB haddock west quota to be converted into GB haddock east quota (FW 55 and 51, respectively).

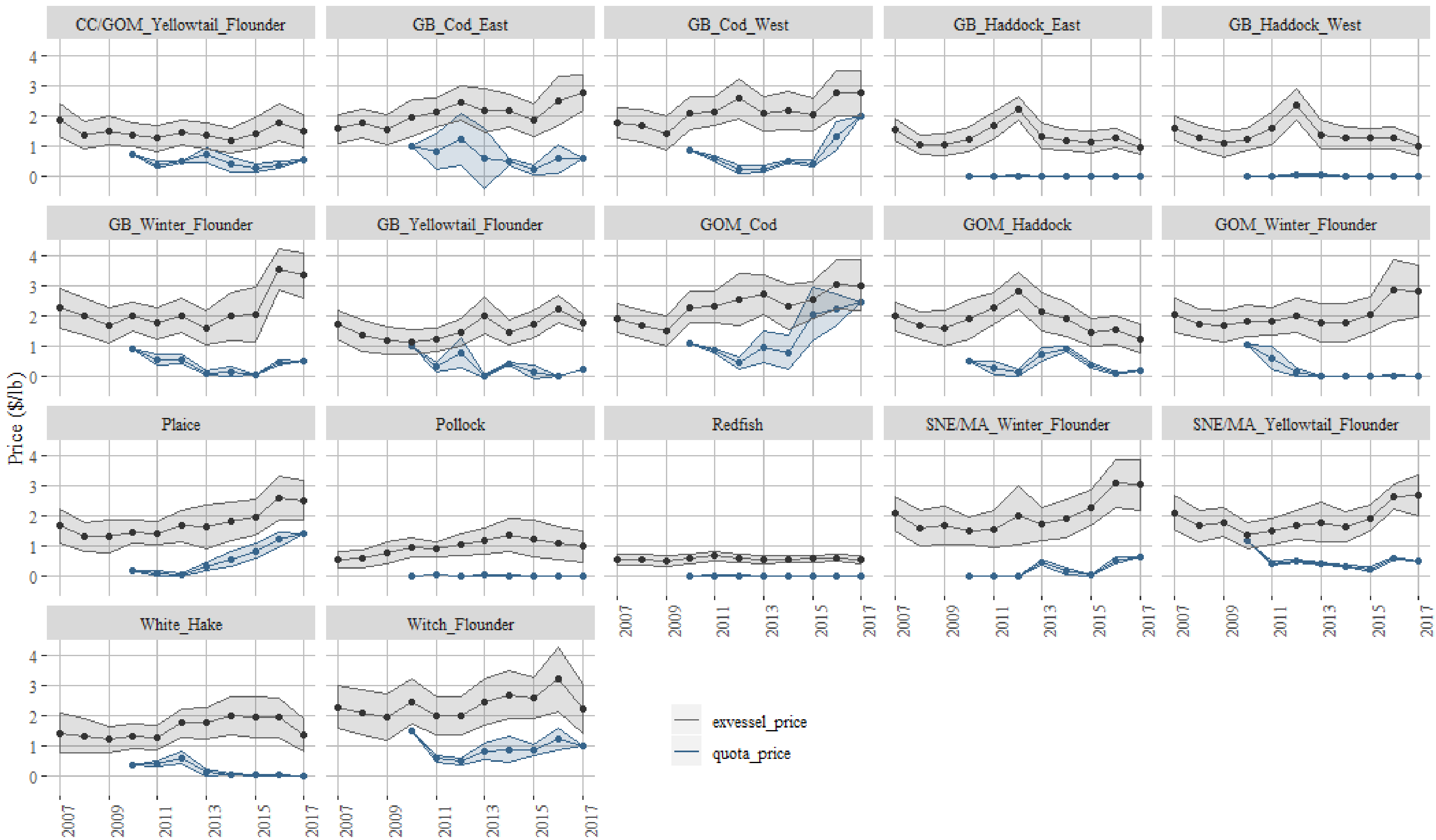

Figure 6: Mean annual ex-vessel price and quota price trends over time 2007-2017.*starting in 2016 quota for GB cod west was allowed to be converted into GB cod east quota, and in 2014 a similar provision allowed GB haddock west quota to be converted into GB haddock east quota (FW 55 and 51, respectively).

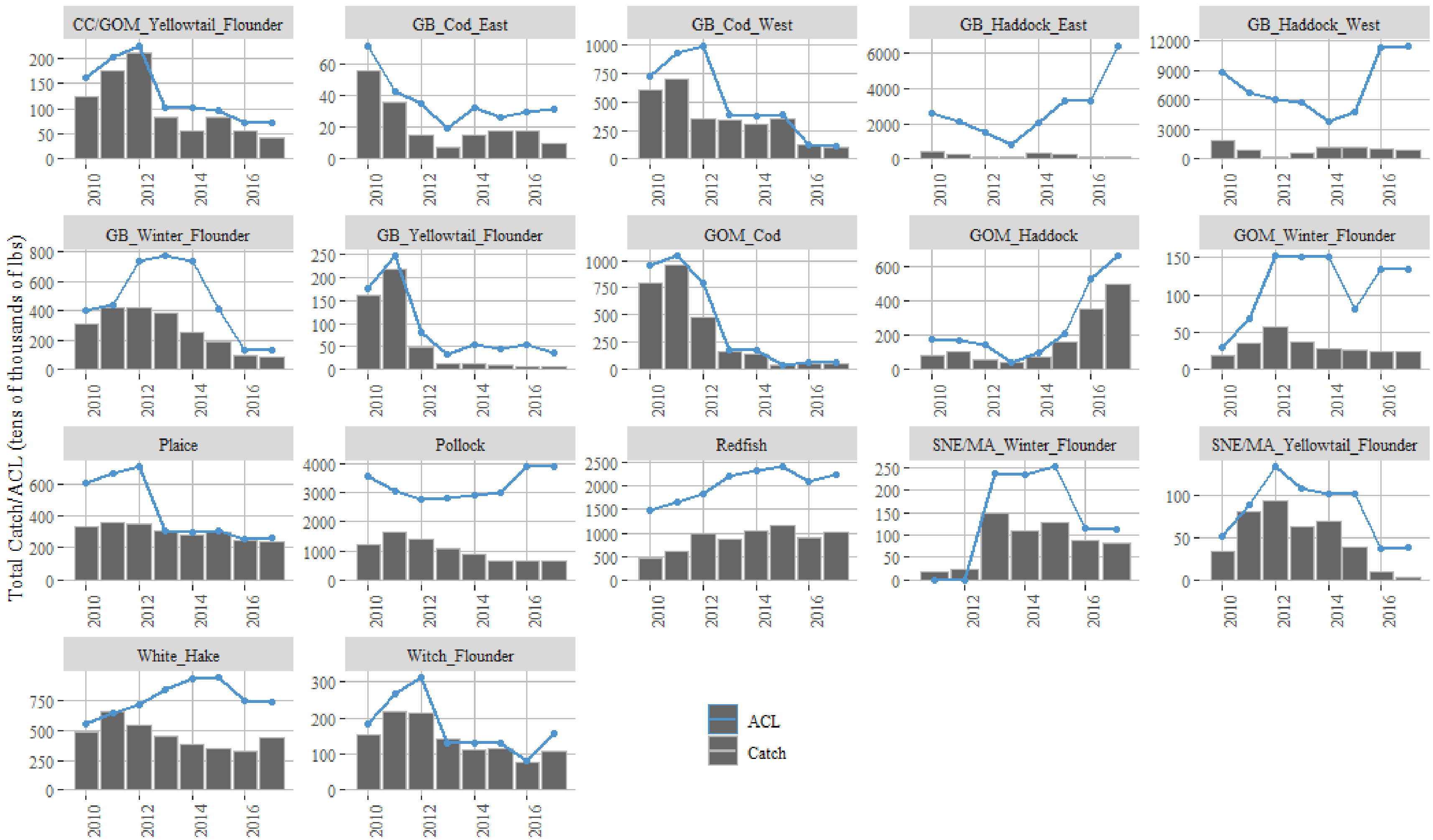

Figure 7: Utilization trends 2010-2017 showing the proportion of the commercial groundfish sub-ACL harvested by the sector program in each year. Note each panel has different y axis.

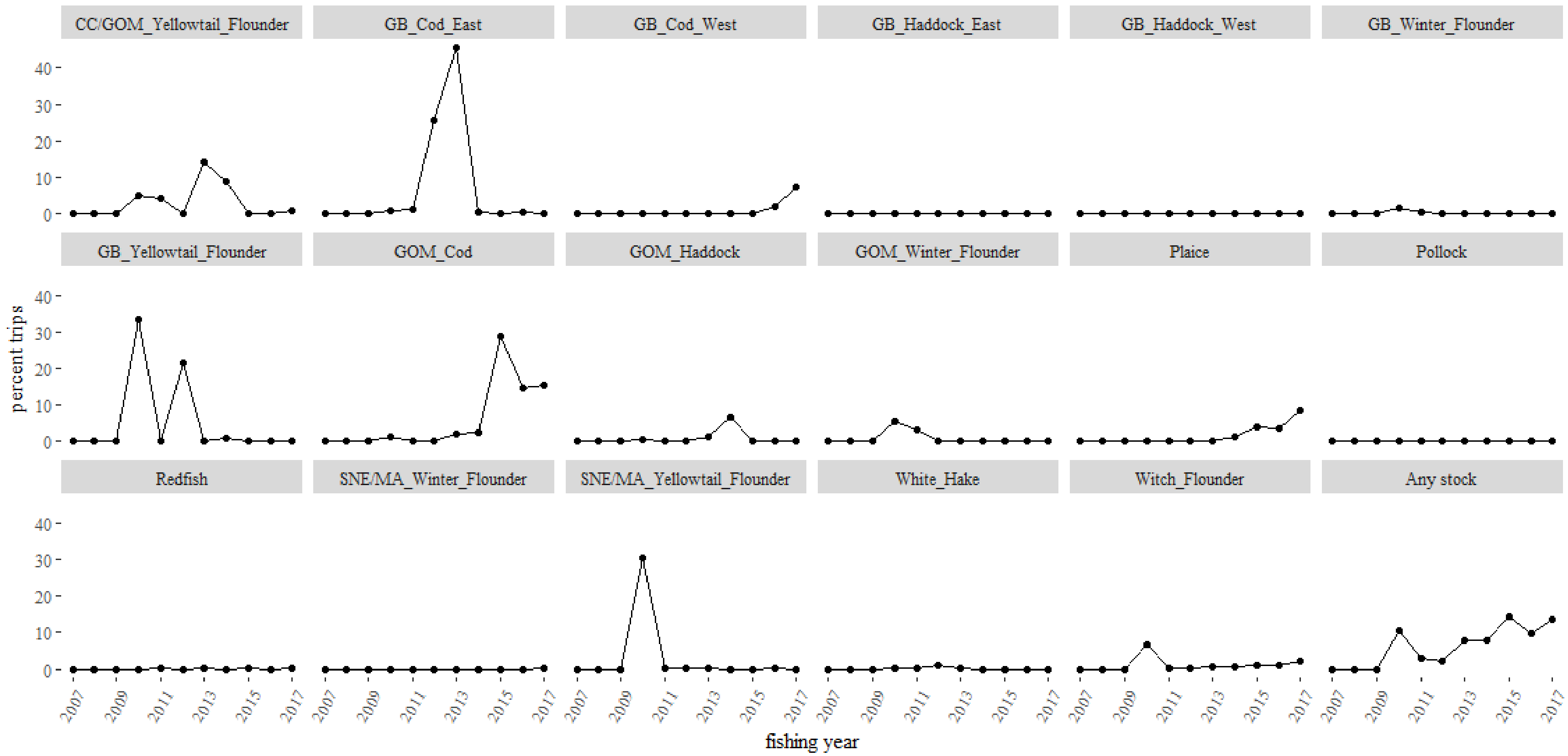

Figure 8. Percent of trips landing listed stock with positive discard incentive on that stock. All stocks plotted on 0-40 Y-axis.

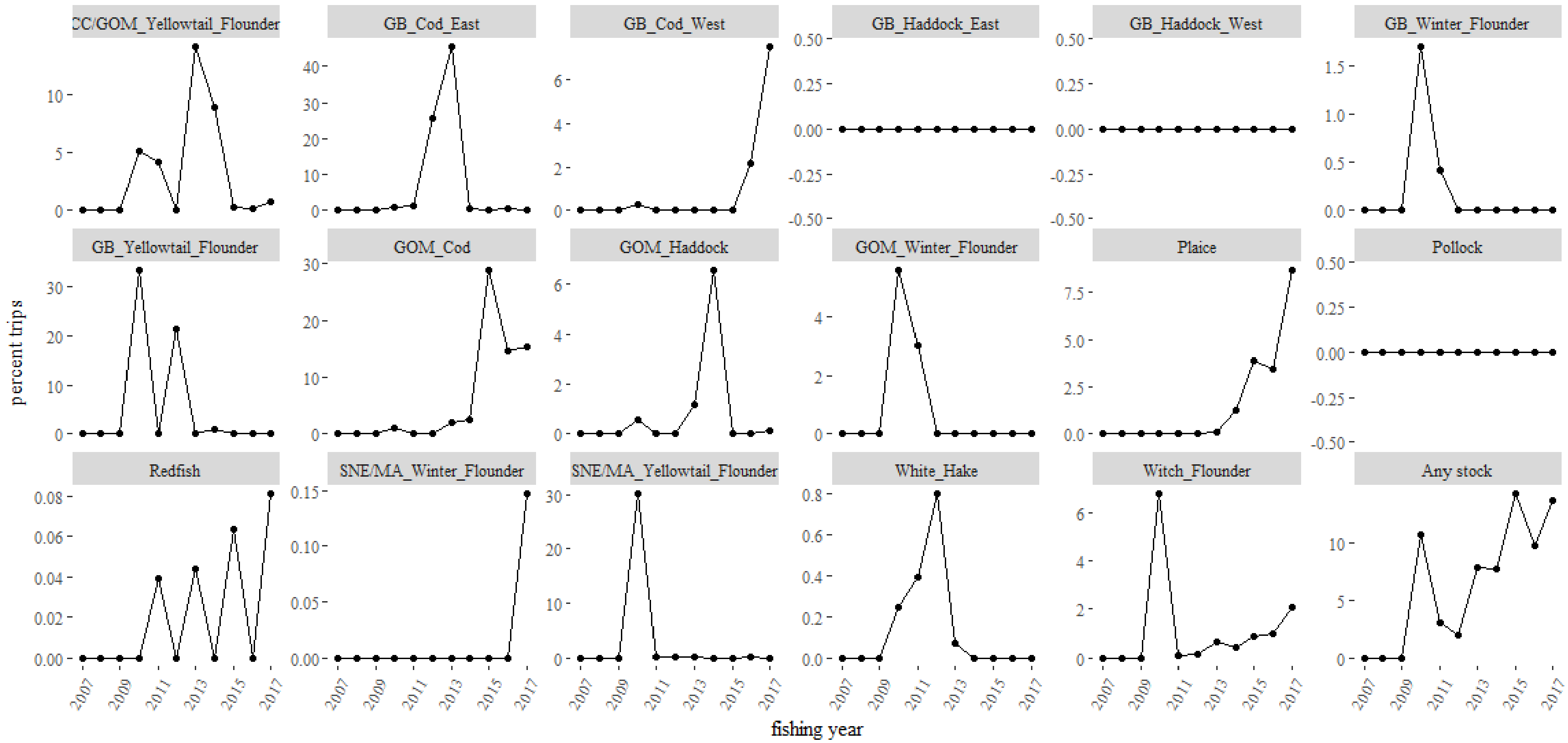

Figure 9. Percent of trips landing listed stock with positive discard incentive on that stock. All stocks plotted with differing Y-axis by stock.

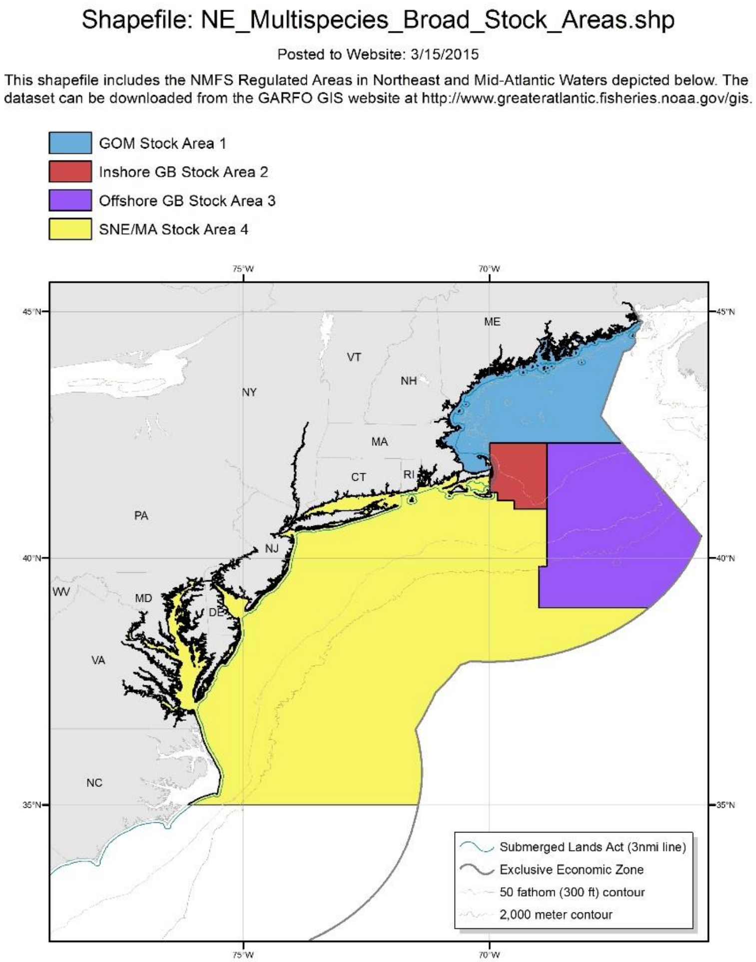

Figure 10. Broad stock areas (https://www.greateratlantic.fisheries.noaa.gov/educational_resources/gis/data/shapefiles/NE_Multispecies_Broad_Stock_Areas/NE_Multispecies_Broad_Stock_Areas_MAP.jpg)

Table 1: Adapted from GARFO ASM requirements summary FY 2019. *FY 2018 realized coverage not yet updated

Fishing year	NEFOP target coverage rate	ASM target coverage level	Total target coverage level	Realized coverage level
FY 2010	8%	30%	38%	32%
FY 2011	8%	30%	38%	27%
FY 2012	8%	17%	25%	22%
FY 2013	8%	14%	22%	20%
FY 2014	8%	18%	26%	25.7%
FY 2015	8%	20%	24%	19.8%
FY 2016	8%	10%	14%	14.8%
FY 2017	8%	8%	16%	14.1%
FY 2018	5%	10%	15%	n/a*

Table 2. Substitution method for applicable quarters with model estimated zero quota price

Quarter with estimated zero price	Substituted quarter price (non zero)
Q1	Q2
Q2	Average of Q1, Q3
Q3	Average of Q2, Q4
Q4	Q3

Table 3. Stock status

Stock	2017 Assessment	
	Overfishing?	Overfished?
GB Cod	Unknown	Yes
GOM Cod	Yes	Yes
GB Haddock	No	No
GOM Haddock	No	No
GB Yellowtail Flounder	Yes	Yes
SNE/MA Yellowtail Flounder	Yes	Yes
CC/GOM Yellowtail Flounder	Yes	Yes
American Plaice	No	No
Witch Flounder	Unknown	Yes
GB Winter Flounder	No	Approaching[2]
GOM Winter Flounder	No	Unknown
SNE/MA Winter Flounder	No	Yes
Acadian Redfish	No	No
White Hake	No	No
Pollock	No	No
Northern Windowpane Flounder	No	Yes
Southern Windowpane Flounder	No	No
Ocean Pout	No	Yes
Atlantic Halibut	No	Yes
Atlantic Wolffish	No	Yes

Table 3: Stock Status table from GARFO (2019)

Appendix:

Table A-1. Summary information for discard incentive model. Modelled quota costs, ex-vessel value, sublegal discard cost, as well as landing and discarding costs all represent trip-level means.

Fishing Year	Stock	Pounds landed	Quota costs (modelled $)		Ex vessel value($)		Quota cost of sublegal discards ($/trip)		Cost of landing ($/trip Cl)		Cost of discarding ($/trip Cd)		Discard Incentive (per trip)	
			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
2007	CC/GOM Yellowtail	140.95	NA	NA	262.17	460.66	NA	NA	8.46	13.72	266.21	462.68	-0.99	0.05
2008	CC/GOM Yellowtail	126.67	NA	NA	171.30	331.70	NA	NA	7.60	12.38	174.93	333.66	-0.98	0.06
2009	CC/GOM Yellowtail	130.62	NA	NA	196.70	290.22	NA	NA	7.84	11.39	200.47	292.35	-0.98	0.05
2010	CC/GOM Yellowtail	304.46	215.63	568.52	415.05	1105.15	9.17	33.62	252.99	660.03	419.69	1109.75	-0.38	0.22
2011	CC/GOM Yellowtail	266.04	99.03	275.54	331.57	995.57	5.47	19.80	129.19	360.01	335.87	1000.10	-0.53	0.26
2012	CC/GOM Yellowtail	356.98	171.54	432.20	509.20	1298.88	6.73	23.07	210.82	519.08	514.33	1303.69	-0.60	0.14
2013	CC/GOM Yellowtail	282.63	199.47	360.87	377.50	754.75	3.41	9.22	228.45	415.24	382.38	758.22	-0.33	0.33
2014	CC/GOM Yellowtail	213.78	83.46	183.60	253.02	705.67	2.37	7.16	105.46	229.91	257.01	708.92	-0.52	0.38
2015	CC/GOM Yellowtail	443.90	118.33	213.15	624.51	1116.80	7.72	15.61	166.86	284.35	630.67	1120.50	-0.73	0.16
2016	CC/GOM Yellowtail	383.98	145.54	266.92	681.56	1270.14	8.06	16.17	188.87	338.76	687.40	1273.87	-0.72	0.14
2017	CC/GOM Yellowtail	263.19	147.47	261.12	396.93	754.92	6.12	11.50	177.28	309.90	402.22	757.63	-0.54	0.25
2007	GB_Cod_East	2072.30	NA	NA	3240.59	2533.27	NA	NA	124.34	111.02	3255.91	2541.96	-0.97	0.01
2008	GB_Cod_East	1693.99	NA	NA	2955.40	2817.56	NA	NA	101.64	90.97	2968.82	2824.67	-0.97	0.02
2009	GB_Cod_East	1967.95	NA	NA	3025.11	2492.14	NA	NA	118.08	91.55	3039.94	2498.85	-0.97	0.02
2010	GB_Cod_East	1377.02	1348.77	1889.69	2668.41	3431.85	25.34	47.78	1497.42	2108.18	2680.29	3440.62	-0.46	0.16
2011	GB_Cod_East	579.09	466.42	671.53	1221.71	1989.55	9.70	27.34	526.50	757.87	1229.55	1994.34	-0.51	0.26
2012	GB_Cod_East	187.97	230.93	294.96	455.79	998.24	1.24	2.07	246.77	318.43	461.63	1000.38	-0.34	0.37

Fishing Year	Stock	Pounds landed	Quota costs (modelled $)		Ex vessel value($)		Quota cost of sublegal discards ($/trip)		Cost of landing ($/trip Cl)		Cost of discarding ($/trip Cd)		Discard Incentive (per trip)	
			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
2013	GB_Cod_East	196.95	115.15	152.78	429.31	929.87	0.51	0.87	128.81	151.88	435.04	931.86	-0.24	0.64
2014	GB_Cod_East	465.14	219.39	546.41	1013.42	2429.84	2.28	12.45	257.31	664.85	1020.54	2436.19	-0.71	0.16
2015	GB_Cod_East	757.05	150.53	347.73	1400.89	2914.41	2.67	6.21	204.26	426.96	1409.52	2922.09	-0.84	0.13
2016	GB_Cod_East	871.03	489.54	1138.93	2169.36	4123.63	4.00	6.83	557.74	1244.73	2178.60	4130.82	-0.72	0.28
2017	GB_Cod_East	752.29	430.41	810.70	2092.01	3973.23	2.77	4.64	485.37	903.26	2100.72	3980.18	-0.78	0.07
2007	GB_Cod_West	1795.79	NA	NA	3166.49	4147.33	NA	NA	107.75	145.46	3180.11	4159.13	-0.99	0.05
2008	GB_Cod_West	1470.52	NA	NA	2463.16	3454.65	NA	NA	88.23	125.51	2475.07	3464.76	-0.99	0.05
2009	GB_Cod_West	1548.46	NA	NA	2202.92	3025.46	NA	NA	92.91	127.23	2215.37	3035.16	-0.98	0.04
2010	GB_Cod_West	1515.17	1291.46	2150.03	3163.37	5187.51	17.65	37.69	1440.39	2391.26	3175.74	5199.68	-0.55	0.13
2011	GB_Cod_West	1972.02	1174.99	2281.91	4197.91	7492.87	12.15	35.37	1354.58	2602.06	4212.50	7511.34	-0.70	0.11
2012	GB_Cod_West	986.78	225.03	616.09	2525.92	5344.23	6.12	23.38	311.26	779.46	2535.57	5354.97	-0.92	0.07
2013	GB_Cod_West	1067.64	251.00	604.89	2218.23	3821.33	4.90	18.90	338.88	756.99	2228.21	3831.67	-0.88	0.07
2014	GB_Cod_West	982.52	484.13	861.23	2135.20	3448.49	4.14	10.79	566.02	1004.17	2144.64	3456.88	-0.77	0.10
2015	GB_Cod_West	1101.03	464.98	950.36	2250.04	3974.98	4.69	12.04	556.55	1114.88	2260.26	3985.69	-0.79	0.09
2016	GB_Cod_West	548.80	725.50	1236.12	1510.47	2155.73	4.45	10.07	774.43	1300.77	1517.87	2159.79	-0.55	0.24
2017	GB_Cod_West	584.73	1155.65	1798.43	1603.47	2266.36	4.18	14.01	1207.48	1875.71	1611.13	2270.87	-0.28	0.19
2007	GB_Haddock_East	3136.54	NA	NA	4838.95	8230.56	NA	NA	188.19	334.26	4859.60	8257.77	-0.98	0.03
2008	GB_Haddock_East	8970.81	NA	NA	9188.60	13042.11	NA	NA	538.25	806.46	9238.41	13105.87	-0.96	0.03
2009	GB_Haddock_East	14287.19	NA	NA	14890.52	17902.24	NA	NA	857.23	957.82	14966.84	17973.21	-0.95	0.03
2010	GB_Haddock_East	9714.63	0.00	0.00	11788.19	14170.84	86.40	92.74	825.44	880.14	11841.74	14223.81	-0.93	0.03
2011	GB_Haddock_East	5122.47	0.00	0.00	8571.47	13935.17	36.40	66.22	403.08	645.10	8602.08	13979.36	-0.96	0.03
2012	GB_Haddock_East	1833.36	25.68	58.33	4106.34	5967.01	16.49	38.98	174.02	257.90	4120.42	5980.63	-0.97	0.03
2013	GB_Haddock_East	4967.91	0.00	0.00	6587.74	8131.93	19.57	33.99	348.18	456.65	6617.48	8162.79	-0.95	0.04
2014	GB_Haddock_East	8913.79	0.00	0.00	10634.63	13917.27	29.33	40.63	688.74	937.17	10684.10	13972.92	-0.95	0.05
2015	GB_Haddock_East	8038.37	0.00	0.00	8988.77	11532.83	21.72	27.33	579.17	855.90	9033.91	11588.01	-0.95	0.04
2016	GB_Haddock_East	3992.91	0.00	0.00	5040.01	8964.16	16.30	29.40	278.04	456.63	5064.80	8999.00	-0.95	0.03
2017	GB_Haddock_East	4499.52	0.00	0.00	4278.57	9283.22	27.97	66.25	327.62	657.73	4305.71	9330.93	-0.93	0.06

Fishing Year	Stock	Pounds landed	Quota costs (modelled $)		Ex vessel value($)		Quota cost of sublegal discards ($/trip)		Cost of landing ($/trip Cl)		Cost of discarding ($/trip Cd)		Discard Incentive (per trip)	
			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
2007	GB_Haddock_West	3076.92	NA	NA	4826.96	9987.44	NA	NA	184.61	389.50	4846.67	10018.94	-0.99	0.05
2008	GB_Haddock_West	3841.95	NA	NA	4894.94	10698.35	NA	NA	230.52	492.67	4918.46	10737.31	-0.98	0.05
2009	GB_Haddock_West	4554.14	NA	NA	4878.71	9282.72	NA	NA	273.25	541.57	4905.82	9324.13	-0.98	0.05
2010	GB_Haddock_West	6118.16	0.00	0.00	7532.12	15568.08	54.87	125.43	545.12	1078.79	7567.38	15629.71	-0.96	0.06
2011	GB_Haddock_West	3089.06	0.00	0.00	4929.22	12019.77	12.67	49.04	262.90	666.49	4949.32	12060.00	-0.98	0.05
2012	GB_Haddock_West	833.62	26.95	145.58	1968.22	5135.25	3.76	13.31	96.01	311.70	1977.03	5147.02	-0.99	0.06
2013	GB_Haddock_West	2886.77	92.62	294.83	3977.76	8056.25	10.89	28.47	321.73	702.27	3996.91	8086.48	-0.95	0.06
2014	GB_Haddock_West	5306.92	0.00	0.00	6621.46	13203.37	15.31	34.67	403.50	778.76	6652.51	13255.67	-0.96	0.06
2015	GB_Haddock_West	4024.85	0.00	0.00	5009.12	11869.04	16.04	39.75	316.92	745.48	5033.65	11918.10	-0.96	0.06
2016	GB_Haddock_West	5649.64	0.00	0.00	7086.81	13938.56	36.37	92.17	443.13	889.03	7119.68	13997.77	-0.96	0.05
2017	GB_Haddock_West	6589.44	0.00	0.00	6596.36	11681.13	48.37	107.74	518.89	858.94	6633.98	11738.20	-0.93	0.06
2007	GB_Winter	1966.43	NA	NA	4430.15	4633.98	NA	NA	117.99	121.50	4444.78	4643.59	-0.99	0.04
2008	GB_Winter	2253.12	NA	NA	4482.23	4296.58	NA	NA	135.19	123.07	4498.26	4306.18	-0.99	0.04
2009	GB_Winter	3536.00	NA	NA	5861.61	6761.45	NA	NA	212.16	264.23	5884.09	6781.41	-0.98	0.04
2010	GB_Winter	3065.12	2786.52	3830.15	6048.49	8536.59	39.03	70.05	3101.52	4268.93	6068.59	8556.96	-0.48	0.17
2011	GB_Winter	4027.12	2176.52	3275.89	7073.64	9787.83	22.82	38.68	2550.75	3787.74	7098.56	9815.78	-0.66	0.16
2012	GB_Winter	6178.00	3350.29	4040.92	12447.66	13570.66	64.78	149.81	3958.44	4722.03	12483.39	13601.76	-0.73	0.15
2013	GB_Winter	6214.90	667.91	1035.20	9959.71	11251.57	36.62	61.66	1231.79	1603.32	9995.58	11283.74	-0.91	0.09
2014	GB_Winter	3802.68	537.50	1246.98	7541.70	9578.62	13.05	25.05	884.04	1600.41	7565.46	9601.53	-0.92	0.11
2015	GB_Winter	3702.39	158.10	257.33	7564.28	10950.29	14.46	23.84	487.94	769.69	7587.48	10973.62	-0.96	0.06
2016	GB_Winter	2384.96	1065.43	1222.87	8423.95	10286.78	16.40	24.92	1290.78	1487.19	8440.78	10300.61	-0.84	0.05
2017	GB_Winter	2761.07	1397.21	1883.20	9234.69	12481.29	11.67	16.67	1655.17	2232.58	9253.35	12499.29	-0.83	0.07
2007	GB_Yellowtail	2040.42	NA	NA	3469.27	4805.01	NA	NA	122.43	154.18	3484.17	4817.40	-0.98	0.04
2008	GB_Yellowtail	2439.25	NA	NA	3266.97	3039.41	NA	NA	146.36	127.11	3283.99	3048.67	-0.97	0.04
2009	GB_Yellowtail	2218.85	NA	NA	2598.95	2113.40	NA	NA	133.13	105.33	2614.78	2120.94	-0.96	0.05
2010	GB_Yellowtail	1867.60	1879.86	2666.41	2124.40	2660.78	24.51	50.95	2076.76	2960.49	2138.47	2672.85	-0.07	0.40
2011	GB_Yellowtail	2498.72	748.25	1395.25	2994.36	4822.47	12.42	24.40	986.50	1749.03	3011.58	4841.38	-0.72	0.15

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			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
2012	GB_Yellowtail	1148.81	885.95	1920.96	1669.02	3414.49	6.76	21.70	998.84	2135.60	1679.39	3426.83	-0.37	0.43
2013	GB_Yellowtail	532.67	7.72	18.40	1069.29	4591.71	1.51	4.62	57.13	217.98	1076.30	4602.99	-0.96	0.10
2014	GB_Yellowtail	477.40	184.31	685.26	690.77	1964.62	3.04	13.58	230.79	849.73	697.69	1972.64	-0.73	0.17
2015	GB_Yellowtail	353.64	51.08	300.36	607.42	1334.57	1.49	3.64	82.62	337.41	613.77	1338.32	-0.92	0.16
2016	GB_Yellowtail	449.60	0.00	0.00	994.33	2930.20	1.61	3.96	43.49	128.85	1000.95	2936.94	-1.00	0.05
2017	GB_Yellowtail	898.44	205.09	575.97	1571.93	4368.20	3.37	9.20	292.33	824.76	1580.47	4381.10	-0.87	0.09
2007	GOM_Cod	594.72	NA	NA	1143.67	906.66	NA	NA	35.68	26.75	1151.57	908.80	-0.98	0.03
2008	GOM_Cod	671.40	NA	NA	1133.51	942.86	NA	NA	40.28	30.85	1141.80	945.27	-0.98	0.03
2009	GOM_Cod	766.90	NA	NA	1137.70	988.57	NA	NA	46.01	33.96	1146.49	991.09	-0.97	0.02
2010	GOM_Cod	995.35	1082.01	1430.06	2258.39	3043.27	17.93	50.27	1188.67	1563.39	2268.27	3049.62	-0.46	0.18
2011	GOM_Cod	876.70	738.93	1144.86	2012.16	2963.79	13.82	29.28	830.96	1275.87	2021.49	2970.34	-0.60	0.10
2012	GOM_Cod	482.78	212.04	380.40	1225.72	2178.23	5.57	19.61	260.41	463.95	1233.03	2182.71	-0.80	0.10
2013	GOM_Cod	280.99	271.50	632.48	758.02	1507.99	2.91	9.36	298.37	676.17	764.18	1510.75	-0.58	0.44
2014	GOM_Cod	293.09	228.45	400.90	673.33	1121.03	2.20	6.57	255.71	452.40	679.60	1124.27	-0.61	0.28
2015	GOM_Cod	121.77	249.88	400.49	306.57	478.37	1.55	3.55	261.90	417.81	311.83	479.55	-0.08	0.46
2016	GOM_Cod	190.06	417.64	745.39	577.37	1037.63	2.85	9.64	437.01	777.34	583.16	1039.22	-0.29	0.27
2017	GOM_Cod	174.56	425.37	704.75	525.83	868.82	2.88	7.47	443.30	733.05	531.53	870.28	-0.16	0.24
2007	GOM_Haddock	121.38	NA	NA	240.73	899.42	NA	NA	7.28	30.50	244.59	902.33	-1.02	0.07
2008	GOM_Haddock	145.28	NA	NA	242.67	949.14	NA	NA	8.72	41.71	246.26	952.96	-1.01	0.07
2009	GOM_Haddock	182.44	NA	NA	288.51	1596.12	NA	NA	10.95	69.60	291.90	1601.60	-1.00	0.07
2010	GOM_Haddock	221.18	105.14	533.74	415.82	1937.80	4.92	34.05	128.62	649.29	420.03	1943.60	-0.71	0.16
2011	GOM_Haddock	200.63	55.76	535.18	451.44	2379.47	3.57	17.10	76.91	657.61	455.87	2385.74	-0.97	0.11
2012	GOM_Haddock	101.61	12.69	45.89	287.19	745.98	1.55	9.29	22.44	67.05	291.29	747.84	-0.99	0.09
2013	GOM_Haddock	119.22	86.79	229.27	254.24	676.88	1.31	7.76	97.13	259.88	258.12	679.12	-0.65	0.19
2014	GOM_Haddock	201.17	180.65	560.45	378.36	1271.97	1.71	6.64	196.79	608.71	382.66	1275.56	-0.45	0.28
2015	GOM_Haddock	521.09	195.13	793.99	756.06	2292.53	4.67	33.53	237.36	977.12	762.05	2302.14	-0.74	0.13
2016	GOM_Haddock	1172.75	98.77	259.70	1779.72	3977.37	12.01	30.40	197.48	477.79	1789.47	3990.84	-0.92	0.08

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			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
2017	GOM_Haddock	1509.36	286.36	638.49	1873.86	3864.05	15.69	39.42	419.21	922.72	1885.38	3880.27	-0.79	0.13
2007	GOM_Winter	59.77	NA	NA	121.05	318.07	NA	NA	3.59	10.20	124.06	319.70	-1.01	0.07
2008	GOM_Winter	58.28	NA	NA	101.08	338.79	NA	NA	3.50	11.56	103.52	340.52	-1.00	0.06
2009	GOM_Winter	54.77	NA	NA	90.50	337.70	NA	NA	3.29	12.53	92.58	339.50	-1.00	0.07
2010	GOM_Winter	52.01	53.17	133.30	94.83	233.55	1.58	6.03	59.61	149.05	97.34	235.22	-0.39	0.22
2011	GOM_Winter	67.69	40.80	118.12	122.72	327.68	1.70	6.40	48.84	136.35	125.76	329.36	-0.56	0.26
2012	GOM_Winter	105.57	13.74	45.72	211.84	564.98	2.29	8.86	25.85	73.72	215.53	566.95	-0.90	0.12
2013	GOM_Winter	128.20	0.00	0.00	227.64	541.60	2.09	8.86	14.03	34.55	231.25	543.89	-0.97	0.07
2014	GOM_Winter	115.35	0.00	0.00	204.16	851.11	1.34	6.08	12.25	59.76	207.41	854.42	-0.99	0.08
2015	GOM_Winter	144.31	0.60	2.60	296.02	598.15	2.69	7.37	16.93	34.36	299.97	600.38	-0.98	0.07
2016	GOM_Winter	162.09	1.14	8.04	460.17	954.26	3.84	8.86	20.28	41.34	464.74	956.30	-0.99	0.06
2017	GOM_Winter	161.23	0.00	0.00	451.48	1288.64	4.12	14.90	19.30	59.06	456.28	1291.31	-1.00	0.06
2007	Plaice	298.41	NA	NA	494.65	1387.79	NA	NA	17.90	52.64	498.90	1392.74	-1.00	0.06
2008	Plaice	361.21	NA	NA	468.91	1401.44	NA	NA	21.67	68.50	473.39	1407.53	-0.99	0.06
2009	Plaice	426.79	NA	NA	559.07	1645.68	NA	NA	25.61	75.92	563.79	1652.24	-0.98	0.06
2010	Plaice	603.97	116.65	300.40	881.79	2215.41	6.01	15.84	167.02	420.66	887.76	2223.75	-0.82	0.21
2011	Plaice	459.92	38.39	130.26	654.45	1931.54	2.64	7.38	74.99	217.28	659.46	1938.89	-0.87	0.12
2012	Plaice	444.60	10.71	58.66	737.65	2009.06	2.64	7.58	46.54	134.69	743.01	2015.77	-0.94	0.07
2013	Plaice	590.14	182.89	441.12	961.71	2225.85	3.78	9.36	229.66	532.22	967.78	2232.68	-0.76	0.13
2014	Plaice	645.11	363.21	809.23	1166.14	2336.86	4.50	10.49	416.02	899.53	1172.78	2343.58	-0.65	0.19
2015	Plaice	858.66	718.03	1268.40	1670.32	2902.99	7.17	17.38	789.51	1378.24	1678.56	2910.44	-0.50	0.24
2016	Plaice	847.23	1030.65	1766.55	2186.16	3724.51	10.52	21.12	1105.56	1879.42	2194.58	3731.61	-0.44	0.22
2017	Plaice	769.64	1076.26	1934.54	1927.93	3665.14	8.02	21.85	1144.73	2056.18	1936.04	3672.22	-0.30	0.32
2007	Pollock	1755.41	NA	NA	936.33	2853.56	NA	NA	105.32	312.99	948.86	2877.33	-0.92	0.08
2008	Pollock	1905.41	NA	NA	1093.42	2980.84	NA	NA	114.32	324.86	1106.87	3005.15	-0.93	0.07
2009	Pollock	1409.66	NA	NA	1091.96	3095.75	NA	NA	84.58	243.81	1102.88	3114.79	-0.95	0.06
2010	Pollock	1713.70	0.00	0.00	1602.16	3818.97	12.91	36.66	148.97	356.02	1614.78	3839.07	-0.93	0.08

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			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
2011	Pollock	1755.86	70.74	195.30	1571.04	3954.91	10.47	32.40	224.31	578.37	1583.97	3977.72	-0.87	0.07
2012	Pollock	1927.05	18.48	87.60	1995.13	4774.86	11.61	44.31	183.67	530.26	2008.96	4799.89	-0.94	0.07
2013	Pollock	2065.49	47.88	101.88	2384.32	4834.29	10.65	32.63	220.11	471.92	2399.07	4856.20	-0.93	0.06
2014	Pollock	1850.59	17.53	63.62	2498.70	4850.40	9.34	30.54	170.44	357.67	2512.50	4868.37	-0.96	0.06
2015	Pollock	1820.88	4.98	26.05	2252.31	4379.77	12.02	38.01	163.78	344.10	2265.83	4397.73	-0.96	0.06
2016	Pollock	2321.83	0.00	0.00	2543.88	4944.76	17.12	48.66	196.40	429.97	2559.79	4968.58	-0.96	0.07
2017	Pollock	2247.22	0.00	0.00	2191.42	4488.22	17.82	66.25	200.66	453.50	2206.81	4511.57	-0.94	0.08
2007	Redfish	552.48	NA	NA	304.05	1021.91	NA	NA	33.15	123.29	309.37	1032.36	-0.95	0.07
2008	Redfish	638.53	NA	NA	337.69	1304.68	NA	NA	38.31	174.00	343.32	1319.56	-0.95	0.07
2009	Redfish	696.12	NA	NA	336.56	1283.39	NA	NA	41.77	186.19	342.27	1299.15	-0.94	0.07
2010	Redfish	1432.36	0.00	0.00	820.28	2892.84	9.79	40.59	117.91	453.91	830.07	2922.34	-0.90	0.08
2011	Redfish	1394.36	18.23	141.31	920.16	4083.95	5.90	26.12	125.91	503.38	929.53	4115.14	-0.88	0.10
2012	Redfish	2137.75	37.46	155.51	1281.73	5133.88	11.77	92.34	210.93	864.62	1294.92	5176.61	-0.89	0.08
2013	Redfish	2240.06	11.16	55.00	1180.57	3861.41	10.67	44.05	193.84	692.46	1194.54	3899.91	-0.90	0.09
2014	Redfish	3176.08	7.51	52.98	1777.57	5640.82	15.69	56.23	263.63	827.52	1796.40	5690.80	-0.90	0.07
2015	Redfish	4919.05	57.66	192.21	2832.19	8439.65	20.99	67.97	457.37	1273.17	2860.24	8510.88	-0.88	0.09
2016	Redfish	4915.88	49.99	171.44	2940.39	8829.78	26.30	98.28	468.67	1374.88	2968.65	8904.09	-0.89	0.08
2017	Redfish	5506.34	56.02	155.01	2981.12	8486.35	27.29	70.99	539.82	1434.37	3012.26	8561.32	-0.87	0.11
2007	SNE/MA_Winter	658.31	NA	NA	1366.02	3250.22	NA	NA	39.50	98.43	1373.82	3258.28	-1.00	0.05
2008	SNE/MA_Winter	547.79	NA	NA	877.62	2633.26	NA	NA	32.87	115.00	884.63	2642.38	-1.00	0.05
2009	SNE/MA_Winter	449.62	NA	NA	753.60	2265.55	NA	NA	26.98	89.10	759.24	2272.87	-1.01	0.06
2010	SNE/MA_Winter	83.72	0.00	0.00	126.43	513.08	0.21	0.51	7.93	39.22	128.85	515.84	-0.99	0.08
2011	SNE/MA_Winter	44.89	0.00	0.00	69.84	124.67	0.29	0.63	4.49	8.32	73.37	125.94	-1.00	0.08
2012	SNE/MA_Winter	30.36	0.00	0.00	61.05	130.48	0.20	0.48	2.97	5.64	63.32	131.99	-0.98	0.07
2013	SNE/MA_Winter	841.86	383.87	1313.67	1452.60	4341.69	4.16	24.22	457.67	1519.37	1461.25	4354.44	-0.74	0.13
2014	SNE/MA_Winter	653.33	102.45	347.97	1245.46	4149.07	1.50	5.53	158.63	508.51	1252.96	4160.89	-0.91	0.12
2015	SNE/MA_Winter	700.40	14.51	67.55	1587.43	5392.54	2.22	12.15	75.55	210.68	1595.47	5403.46	-0.97	0.05

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			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
2016	SNE/MA_Winter	719.59	364.99	987.06	2203.60	6443.31	6.27	28.27	429.21	1159.73	2211.78	6453.05	-0.78	0.08
2017	SNE/MA_Winter	710.58	439.33	1296.99	2146.25	6513.79	4.79	21.14	499.83	1458.13	2154.27	6523.86	-0.76	0.10
2007	SNE/MA_Yellowtail	285.81	NA	NA	599.78	667.88	NA	NA	17.15	22.12	605.85	669.92	-0.99	0.04
2008	SNE/MA_Yellowtail	301.70	NA	NA	504.95	501.71	NA	NA	18.10	19.20	510.99	503.59	-0.98	0.04
2009	SNE/MA_Yellowtail	268.06	NA	NA	478.04	451.71	NA	NA	16.08	18.13	484.14	453.32	-0.99	0.02
2010	SNE/MA_Yellowtail	727.93	850.84	1185.25	973.52	1169.87	9.86	21.38	927.93	1289.13	982.01	1174.59	-0.09	0.27
2011	SNE/MA_Yellowtail	1123.82	465.49	518.48	1657.96	1829.74	6.37	13.94	575.17	629.79	1668.31	1835.58	-0.64	0.13
2012	SNE/MA_Yellowtail	951.14	491.82	454.65	1603.80	1558.65	11.84	20.74	592.31	545.44	1613.39	1562.78	-0.61	0.13
2013	SNE/MA_Yellowtail	693.44	294.24	434.64	1230.63	1581.30	3.46	15.25	361.69	531.20	1238.72	1586.13	-0.72	0.11
2014	SNE/MA_Yellowtail	903.30	304.13	526.86	1480.15	2336.56	2.66	6.65	391.75	687.99	1489.27	2344.73	-0.77	0.08
2015	SNE/MA_Yellowtail	528.37	109.91	172.70	1016.65	1570.00	0.81	2.65	160.27	250.06	1023.80	1574.63	-0.86	0.07
2016	SNE/MA_Yellowtail	178.33	105.44	167.61	471.67	746.43	1.34	4.60	122.47	193.01	476.56	748.44	-0.75	0.11
2017	SNE/MA_Yellowtail	54.93	26.13	57.09	147.18	330.64	0.35	1.43	31.37	67.89	150.83	331.92	-0.80	0.11
2007	White_Hake	409.37	NA	NA	578.15	1432.52	NA	NA	24.56	59.35	583.47	1437.62	-0.99	0.07
2008	White_Hake	388.37	NA	NA	514.98	1370.73	NA	NA	23.30	60.13	520.34	1375.82	-0.99	0.07
2009	White_Hake	464.79	NA	NA	561.02	1496.68	NA	NA	27.89	71.95	566.73	1502.92	-0.98	0.07
2010	White_Hake	796.79	299.71	736.52	1059.67	2604.55	6.10	17.11	361.78	874.93	1067.34	2614.31	-0.66	0.17
2011	White_Hake	801.36	329.36	842.77	1026.44	2558.43	4.01	9.76	392.67	975.44	1034.40	2567.90	-0.64	0.16
2012	White_Hake	726.57	443.60	899.18	1270.77	2623.79	4.03	9.64	502.86	1005.64	1278.62	2631.28	-0.56	0.20
2013	White_Hake	890.68	103.73	357.82	1567.88	3019.42	4.63	12.45	173.18	452.99	1576.70	3027.94	-0.90	0.12
2014	White_Hake	792.12	52.14	138.68	1571.72	3360.62	4.26	13.87	112.64	268.24	1579.87	3369.69	-0.95	0.07
2015	White_Hake	970.09	38.07	116.74	1876.73	3815.01	6.36	24.63	112.33	256.06	1885.75	3825.34	-0.96	0.06
2016	White_Hake	1053.07	25.32	65.24	2030.67	3351.17	9.14	19.81	110.06	200.20	2040.19	3360.67	-0.96	0.06
2017	White_Hake	1485.73	17.27	33.48	2020.09	3672.25	12.70	29.23	141.21	261.26	2031.55	3686.12	-0.94	0.06
2007	Witch_Flounder	302.77	NA	NA	690.68	1721.14	NA	NA	18.17	47.93	695.44	1725.62	-1.00	0.05
2008	Witch_Flounder	292.95	NA	NA	614.52	1433.77	NA	NA	17.58	43.64	619.14	1437.96	-1.00	0.05
2009	Witch_Flounder	305.05	NA	NA	592.81	1302.22	NA	NA	18.30	41.24	597.42	1306.23	-0.99	0.05

Fishing Year	Stock	Pounds landed	Quota costs (modelled $)		Ex vessel value($)		Quota cost of sublegal discards ($/trip)		Cost of landing ($/trip Cl)		Cost of discarding ($/trip Cd)		Discard Incentive (per trip)	
			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
2010	Witch_Flounder	296.67	441.61	913.92	727.89	1439.37	3.84	9.42	468.91	967.57	732.66	1443.14	-0.37	0.28
2011	Witch_Flounder	298.45	172.55	423.61	597.11	1355.27	2.49	7.40	199.22	484.74	601.60	1359.64	-0.70	0.13
2012	Witch_Flounder	289.98	140.92	337.03	581.40	1273.01	2.41	5.57	166.74	394.57	586.19	1276.98	-0.74	0.14
2013	Witch_Flounder	292.68	238.27	447.56	719.95	1311.18	2.11	4.91	263.48	491.46	724.89	1314.69	-0.64	0.16
2014	Witch_Flounder	269.73	236.61	480.89	725.69	1266.29	2.13	5.24	260.06	518.40	730.45	1269.56	-0.66	0.20
2015	Witch_Flounder	326.27	280.30	466.71	837.57	1248.49	3.19	7.54	309.42	509.32	843.04	1251.70	-0.66	0.20
2016	Witch_Flounder	257.20	319.54	539.21	826.50	1295.02	3.51	7.38	343.81	574.60	831.64	1297.67	-0.61	0.20
2017	Witch_Flounder	384.17	391.06	641.86	854.80	1240.87	4.62	11.59	426.92	698.41	860.79	1244.40	-0.51	0.23

** all values have not been adjusted for inflation

Table A-2: Annualized marginal discarding incentive and marginal parameter values by stock. Ex-vessel price and quota price represent weighted means. Prices have not been adjusted for inflation.

Fishing year	stock	Ex-vessel price ($/lb, pf)	Quota price ($/lb, pq)	Quota cost of sublegal discards ($/lb)	Cost of Landing ($/lb)	Cost of Discarding ($/lb)	Discard Incentive ($/lb)
2007	CC/GOM Yellowtail	1.86	NA	NA	0.06	1.89	-1.83
2008	CC/GOM Yellowtail	1.35	NA	NA	0.06	1.38	-1.32
2009	CC/GOM Yellowtail	1.51	NA	NA	0.06	1.53	-1.47
2010	CC/GOM Yellowtail	1.36	0.71	0.03	0.83	1.38	-0.55
2011	CC/GOM Yellowtail	1.25	0.37	0.02	0.49	1.26	-0.78
2012	CC/GOM Yellowtail	1.43	0.48	0.02	0.59	1.44	-0.85

Fishing year	stock	Ex-vessel price ($/lb, pf)	Quota price ($/lb, pq)	Quota cost of sublegal discards ($/lb)	Cost of Landing ($/lb)	Cost of Discarding ($/lb)	Discard Incentive ($/lb)
2013	CC/GOM Yellowtail	1.34	0.71	0.01	0.81	1.35	-0.54
2014	CC/GOM Yellowtail	1.18	0.39	0.01	0.49	1.20	-0.71
2015	CC/GOM Yellowtail	1.41	0.27	0.02	0.38	1.42	-1.04
2016	CC/GOM Yellowtail	1.77	0.38	0.02	0.49	1.79	-1.30
2017	CC/GOM Yellowtail	1.51	0.56	0.02	0.67	1.53	-0.85
2007	GB Cod East	1.56	NA	NA	0.06	1.57	-1.51
2008	GB Cod East	1.74	NA	NA	0.06	1.75	-1.69
2009	GB Cod East	1.54	NA	NA	0.06	1.54	-1.48
2010	GB Cod East	1.94	0.98	0.02	1.09	1.95	-0.86
2011	GB Cod East	2.11	0.81	0.02	0.91	2.12	-1.21
2012	GB Cod East	2.42	1.23	0.01	1.31	2.46	-1.14
2013	GB Cod East	2.18	0.58	0.00	0.65	2.21	-1.55
2014	GB Cod East	2.18	0.47	0.00	0.55	2.19	-1.64
2015	GB Cod East	1.85	0.20	0.00	0.27	1.86	-1.59
2016	GB Cod East	2.49	0.56	0.00	0.64	2.50	-1.86
2017	GB Cod East	2.78	0.57	0.00	0.65	2.79	-2.15
2007	GB Cod West	1.76	NA	NA	0.06	1.77	-1.71
2008	GB Cod West	1.68	NA	NA	0.06	1.68	-1.62
2009	GB Cod West	1.42	NA	NA	0.06	1.43	-1.37
2010	GB Cod West	2.09	0.85	0.01	0.95	2.10	-1.15
2011	GB Cod West	2.13	0.60	0.01	0.69	2.14	-1.45
2012	GB Cod West	2.56	0.23	0.01	0.32	2.57	-2.25
2013	GB Cod West	2.08	0.24	0.00	0.32	2.09	-1.77
2014	GB Cod West	2.17	0.49	0.00	0.58	2.18	-1.61
2015	GB Cod West	2.04	0.42	0.00	0.51	2.05	-1.55
2016	GB Cod West	2.75	1.32	0.01	1.41	2.77	-1.35

Fishing year	stock	Ex-vessel price ($/lb, pf)	Quota price ($/lb, pq)	Quota cost of sublegal discards ($/lb)	Cost of Landing ($/lb)	Cost of Discarding ($/lb)	Discard Incentive ($/lb)
2017	GB Cod West	2.74	1.98	0.01	2.07	2.76	-0.69
2007	GB Haddock East	1.54	NA	NA	0.06	1.55	-1.49
2008	GB Haddock East	1.02	NA	NA	0.06	1.03	-0.97
2009	GB Haddock East	1.04	NA	NA	0.06	1.05	-0.99
2010	GB Haddock East	1.21	0.00	0.01	0.08	1.22	-1.13
2011	GB Haddock East	1.67	0.00	0.01	0.08	1.68	-1.60
2012	GB Haddock East	2.24	0.01	0.01	0.09	2.25	-2.15
2013	GB Haddock East	1.33	0.00	0.00	0.07	1.33	-1.26
2014	GB Haddock East	1.19	0.00	0.00	0.08	1.20	-1.12
2015	GB Haddock East	1.12	0.00	0.00	0.07	1.12	-1.05
2016	GB Haddock East	1.26	0.00	0.00	0.07	1.27	-1.20
2017	GB Haddock East	0.95	0.00	0.01	0.07	0.96	-0.88
2007	GB Haddock West	1.57	NA	NA	0.06	1.58	-1.52
2008	GB Haddock West	1.27	NA	NA	0.06	1.28	-1.22
2009	GB Haddock West	1.07	NA	NA	0.06	1.08	-1.02
2010	GB Haddock West	1.23	0.00	0.01	0.09	1.24	-1.15
2011	GB Haddock West	1.60	0.00	0.00	0.09	1.60	-1.52
2012	GB Haddock West	2.36	0.03	0.00	0.12	2.37	-2.26
2013	GB Haddock West	1.38	0.03	0.00	0.11	1.38	-1.27

Fishing year	stock	Ex-vessel price ($/lb, pf)	Quota price ($/lb, pq)	Quota cost of sublegal discards ($/lb)	Cost of Landing ($/lb)	Cost of Discarding ($/lb)	Discard Incentive ($/lb)
2014	GB Haddock West	1.25	0.00	0.00	0.08	1.25	-1.18
2015	GB Haddock West	1.24	0.00	0.00	0.08	1.25	-1.17
2016	GB Haddock West	1.25	0.00	0.01	0.08	1.26	-1.18
2017	GB Haddock West	1.00	0.00	0.01	0.08	1.01	-0.93
2007	GB Winter	2.25	NA	NA	0.06	2.26	-2.20
2008	GB Winter	1.99	NA	NA	0.06	2.00	-1.94
2009	GB Winter	1.66	NA	NA	0.06	1.66	-1.60
2010	GB Winter	1.97	0.91	0.01	1.01	1.98	-0.97
2011	GB Winter	1.76	0.54	0.01	0.63	1.76	-1.13
2012	GB Winter	2.01	0.54	0.01	0.64	2.02	-1.38
2013	GB Winter	1.60	0.11	0.01	0.20	1.61	-1.41
2014	GB Winter	1.98	0.14	0.00	0.23	1.99	-1.76
2015	GB Winter	2.04	0.04	0.00	0.13	2.05	-1.92
2016	GB Winter	3.53	0.45	0.01	0.54	3.54	-3.00
2017	GB Winter	3.34	0.51	0.00	0.60	3.35	-2.75
2007	GB Yellowtail	1.70	NA	NA	0.06	1.71	-1.65
2008	GB Yellowtail	1.34	NA	NA	0.06	1.35	-1.29
2009	GB Yellowtail	1.17	NA	NA	0.06	1.18	-1.12
2010	GB Yellowtail	1.14	1.01	0.01	1.11	1.15	-0.03
2011	GB Yellowtail	1.20	0.30	0.00	0.39	1.21	-0.81
2012	GB Yellowtail	1.45	0.77	0.01	0.87	1.46	-0.59
2013	GB Yellowtail	2.01	0.01	0.00	0.11	2.02	-1.91
2014	GB Yellowtail	1.45	0.39	0.01	0.48	1.46	-0.98
2015	GB Yellowtail	1.72	0.14	0.00	0.23	1.74	-1.50
2016	GB Yellowtail	2.21	0.00	0.00	0.10	2.23	-2.13
2017	GB Yellowtail	1.75	0.23	0.00	0.33	1.76	-1.43

Fishing year	stock	Ex-vessel price ($/lb, pf)	Quota price ($/lb, pq)	Quota cost of sublegal discards ($/lb)	Cost of Landing ($/lb)	Cost of Discarding ($/lb)	Discard Incentive ($/lb)
2007	GOM Cod	1.92	NA	NA	0.06	1.94	-1.88
2008	GOM Cod	1.69	NA	NA	0.06	1.70	-1.64
2009	GOM Cod	1.48	NA	NA	0.06	1.49	-1.43
2010	GOM Cod	2.27	1.09	0.02	1.19	2.28	-1.08
2011	GOM Cod	2.30	0.84	0.02	0.95	2.31	-1.36
2012	GOM Cod	2.54	0.44	0.01	0.54	2.55	-2.01
2013	GOM Cod	2.70	0.97	0.01	1.06	2.72	-1.66
2014	GOM Cod	2.30	0.78	0.01	0.87	2.32	-1.45
2015	GOM Cod	2.52	2.05	0.01	2.15	2.56	-0.41
2016	GOM Cod	3.04	2.20	0.02	2.30	3.07	-0.77
2017	GOM Cod	3.01	2.44	0.02	2.54	3.04	-0.51
2007	GOM Haddock	1.98	NA	NA	0.06	2.02	-1.96
2008	GOM Haddock	1.67	NA	NA	0.06	1.70	-1.64
2009	GOM Haddock	1.58	NA	NA	0.06	1.60	-1.54
2010	GOM Haddock	1.88	0.48	0.02	0.58	1.90	-1.32
2011	GOM Haddock	2.25	0.28	0.02	0.38	2.27	-1.89
2012	GOM Haddock	2.83	0.12	0.02	0.22	2.87	-2.65
2013	GOM Haddock	2.13	0.73	0.01	0.81	2.17	-1.35
2014	GOM Haddock	1.88	0.90	0.01	0.98	1.90	-0.92
2015	GOM Haddock	1.45	0.37	0.01	0.46	1.46	-1.01
2016	GOM Haddock	1.52	0.08	0.01	0.17	1.53	-1.36
2017	GOM Haddock	1.24	0.19	0.01	0.28	1.25	-0.97
2007	GOM Winter	2.03	NA	NA	0.06	2.08	-2.02
2008	GOM Winter	1.73	NA	NA	0.06	1.78	-1.72
2009	GOM Winter	1.65	NA	NA	0.06	1.69	-1.63
2010	GOM Winter	1.82	1.02	0.03	1.15	1.87	-0.73
2011	GOM Winter	1.81	0.60	0.03	0.72	1.86	-1.14
2012	GOM Winter	2.01	0.13	0.02	0.24	2.04	-1.80

Fishing year	stock	Ex-vessel price ($/lb, pf)	Quota price ($/lb, pq)	Quota cost of sublegal discards ($/lb)	Cost of Landing ($/lb)	Cost of Discarding ($/lb)	Discard Incentive ($/lb)
2013	GOM Winter	1.78	0.00	0.02	0.11	1.80	-1.69
2014	GOM Winter	1.77	0.00	0.01	0.11	1.80	-1.69
2015	GOM Winter	2.05	0.00	0.02	0.12	2.08	-1.96
2016	GOM Winter	2.84	0.01	0.02	0.13	2.87	-2.74
2017	GOM Winter	2.80	0.00	0.03	0.12	2.83	-2.71
2007	Plaice	1.66	NA	NA	0.06	1.67	-1.61
2008	Plaice	1.30	NA	NA	0.06	1.31	-1.25
2009	Plaice	1.31	NA	NA	0.06	1.32	-1.26
2010	Plaice	1.46	0.19	0.01	0.28	1.47	-1.19
2011	Plaice	1.42	0.08	0.01	0.16	1.43	-1.27
2012	Plaice	1.66	0.02	0.01	0.10	1.67	-1.57
2013	Plaice	1.63	0.31	0.01	0.39	1.64	-1.25
2014	Plaice	1.81	0.56	0.01	0.64	1.82	-1.17
2015	Plaice	1.95	0.84	0.01	0.92	1.95	-1.04
2016	Plaice	2.58	1.22	0.01	1.30	2.59	-1.29
2017	Plaice	2.50	1.40	0.01	1.49	2.52	-1.03
2007	Pollock	0.53	NA	NA	0.06	0.54	-0.48
2008	Pollock	0.57	NA	NA	0.06	0.58	-0.52
2009	Pollock	0.77	NA	NA	0.06	0.78	-0.72
2010	Pollock	0.93	0.00	0.01	0.09	0.94	-0.86
2011	Pollock	0.89	0.04	0.01	0.13	0.90	-0.77
2012	Pollock	1.04	0.01	0.01	0.10	1.04	-0.95
2013	Pollock	1.15	0.02	0.01	0.11	1.16	-1.05
2014	Pollock	1.35	0.01	0.01	0.09	1.36	-1.27
2015	Pollock	1.24	0.00	0.01	0.09	1.24	-1.15
2016	Pollock	1.10	0.00	0.01	0.08	1.10	-1.02
2017	Pollock	0.98	0.00	0.01	0.09	0.98	-0.89
2007	Redfish	0.55	NA	NA	0.06	0.56	-0.50

Fishing year	stock	Ex-vessel price ($/lb, pf)	Quota price ($/lb, pq)	Quota cost of sublegal discards ($/lb)	Cost of Landing ($/lb)	Cost of Discarding ($/lb)	Discard Incentive ($/lb)
2008	Redfish	0.53	NA	NA	0.06	0.54	-0.48
2009	Redfish	0.48	NA	NA	0.06	0.49	-0.43
2010	Redfish	0.57	0.00	0.01	0.08	0.58	-0.50
2011	Redfish	0.66	0.01	0.00	0.09	0.67	-0.58
2012	Redfish	0.60	0.02	0.01	0.10	0.61	-0.51
2013	Redfish	0.53	0.00	0.00	0.09	0.53	-0.45
2014	Redfish	0.56	0.00	0.00	0.08	0.57	-0.48
2015	Redfish	0.58	0.01	0.00	0.09	0.58	-0.49
2016	Redfish	0.60	0.01	0.01	0.10	0.60	-0.51
2017	Redfish	0.54	0.01	0.00	0.10	0.55	-0.45
2007	SNE/MA Winter	2.08	NA	NA	0.06	2.09	-2.03
2008	SNE/MA Winter	1.60	NA	NA	0.06	1.61	-1.55
2009	SNE/MA Winter	1.68	NA	NA	0.06	1.69	-1.63
2010	SNE/MA Winter	1.51	0.00	0.00	0.09	1.54	-1.44
2011	SNE/MA Winter	1.56	0.00	0.01	0.10	1.63	-1.53
2012	SNE/MA Winter	2.01	0.00	0.01	0.10	2.09	-1.99
2013	SNE/MA Winter	1.73	0.46	0.00	0.54	1.74	-1.19
2014	SNE/MA Winter	1.91	0.16	0.00	0.24	1.92	-1.67
2015	SNE/MA Winter	2.27	0.02	0.00	0.11	2.28	-2.17
2016	SNE/MA Winter	3.06	0.51	0.01	0.60	3.07	-2.48
2017	SNE/MA Winter	3.02	0.62	0.01	0.70	3.03	-2.33
2007	SNE/MA Yellowtail	2.10	NA	NA	0.06	2.12	-2.06

Fishing year	stock	Ex-vessel price ($/lb, pf)	Quota price ($/lb, pq)	Quota cost of sublegal discards ($/lb)	Cost of Landing ($/lb)	Cost of Discarding ($/lb)	Discard Incentive ($/lb)
2008	SNE/MA Yellowtail	1.67	NA	NA	0.06	1.69	-1.63
2009	SNE/MA Yellowtail	1.78	NA	NA	0.06	1.81	-1.75
2010	SNE/MA Yellowtail	1.34	1.17	0.01	1.27	1.35	-0.07
2011	SNE/MA Yellowtail	1.48	0.41	0.01	0.51	1.48	-0.97
2012	SNE/MA Yellowtail	1.69	0.52	0.01	0.62	1.70	-1.07
2013	SNE/MA Yellowtail	1.77	0.42	0.00	0.52	1.79	-1.26
2014	SNE/MA Yellowtail	1.64	0.34	0.00	0.43	1.65	-1.22
2015	SNE/MA Yellowtail	1.92	0.21	0.00	0.30	1.94	-1.63
2016	SNE/MA Yellowtail	2.64	0.59	0.01	0.69	2.67	-1.99
2017	SNE/MA Yellowtail	2.68	0.48	0.01	0.57	2.75	-2.17
2007	White Hake	1.41	NA	NA	0.06	1.43	-1.37
2008	White Hake	1.33	NA	NA	0.06	1.34	-1.28
2009	White Hake	1.21	NA	NA	0.06	1.22	-1.16
2010	White Hake	1.33	0.38	0.01	0.45	1.34	-0.89
2011	White Hake	1.28	0.41	0.01	0.49	1.29	-0.80
2012	White Hake	1.75	0.61	0.01	0.69	1.76	-1.07
2013	White Hake	1.76	0.12	0.01	0.19	1.77	-1.58
2014	White Hake	1.98	0.07	0.01	0.14	1.99	-1.85
2015	White Hake	1.93	0.04	0.01	0.12	1.94	-1.83
2016	White Hake	1.93	0.02	0.01	0.10	1.94	-1.83
2017	White Hake	1.36	0.01	0.01	0.10	1.37	-1.27
2007	Witch	2.28	NA	NA	0.06	2.30	-2.24
2008	Witch	2.10	NA	NA	0.06	2.11	-2.05

Fishing year	stock	Ex-vessel price ($/lb, pf)	Quota price ($/lb, pq)	Quota cost of sublegal discards ($/lb)	Cost of Landing ($/lb)	Cost of Discarding ($/lb)	Discard Incentive ($/lb)
2009	Witch	1.94	NA	NA	0.06	1.96	-1.90
2010	Witch	2.45	1.49	0.01	1.58	2.47	-0.89
2011	Witch	2.00	0.58	0.01	0.67	2.02	-1.35
2012	Witch	2.00	0.49	0.01	0.57	2.02	-1.45
2013	Witch	2.46	0.81	0.01	0.90	2.48	-1.58
2014	Witch	2.69	0.88	0.01	0.96	2.71	-1.74
2015	Witch	2.57	0.86	0.01	0.95	2.58	-1.64
2016	Witch	3.21	1.24	0.01	1.34	3.23	-1.90
2017	Witch	2.23	1.02	0.01	1.11	2.24	-1.13

Unlawful discarding of Regulated Northeast Multispecies

Enforcing unlawful discarding of regulated Northeast multispecies is extremely challenging. Most investigations are reactive in nature, responding to complaints from the fishing industry or the observer program. Proactive enforcement focused on discarding can only be done at sea which adds to the complexity and presents other limitations.

The act of discarding fish can happen relatively quickly. It is easy for violators to actively look for enforcement while discarding fish at sea. NOAA's Office of Law Enforcement (OLE) receives and handles a number of discarding investigations, however, OLE is often unable to conclude investigations due to a lack of evidence. Even in instances where enforcement is on scene to witness a discarding violation, it can still be difficult to make a case. For example, the fish being discarded could be unmarketable or undersized which would otherwise be legal to discard. Enforcement cannot always make this determination on scene as fish are being actively discarded. To support an unlawful discard case, it would almost be necessary to either measure the fish before they are discarded or recover the fish being discarded to determine their size or disposition. Recovering discarded fish at sea would be difficult and could pose safety issues. Consequently, even if an unlawful discarding event is witnessed by enforcement, it can be difficult to make a case for these reasons.

In cases where we have been able to take some investigatory steps, there typically has to be some supporting information, such as information from crew, observer, or member of the industry. It is rare that we can initiate an investigation based on witnessing this behavior, even when conducting a patrol focused on targeting discarding violations. Most discarding incidents reported to OLE are generated from observer referrals. Most of these lack sufficient evidence for many of the reasons listed above and the data collection process utilized by the observer program.

The sector quota and leasing system does not provide enforcement with the ability to track quotas in real time. This limits enforcement's ability to use quotas as a reliable indicator of potential discarding violations. The annual quota calculations used in the sector system enables unscrupulous operators to strategically plan to discard when they believe a low probability of detection exists. This contrasts with other fisheries such as the common pool system where an overage landed on a single trip, cannot be offset by leasing additional quota.

Unlawful Discarding Incident Dispositions (Fishing years 2017 and 2018)

Total incidents –	12
Closed due to lack of evidence –	8
Ongoing investigations –	2
Written warnings –	1
Closed due to lack of resources -	1

Unlawful Discarding Incidents Reporting Source (Fishing years 2017 and 2018)

Observer generated – 8
Industry complaint - 3
Enforcement generated – 1

Unlawful Discarding Violations Penalties

Unlawful discarding investigations that result in enforcement action can be handled with either Compliance Assistance, a Written Warning, or a Notice of Violation and Assessment (NOVA). Summary settlements are another method of addressing a violation, but unlawful discarding is not included in the summary settlement schedule and therefore cannot not be applied for this offense. However, offenses associated with a discarding violations may be included in the summary settlement schedule. For example, a $500 summary settlement could be issued for a failure to maintain, keep, or submit accurate reports.

A NOVA may be issued for an unlawful discard violation in accordance with General Counsel's Penalty Policy Schedule, which utilizes a complex matrix to determine NOVA penalty amounts. Unlawful discarding is generally considered a Level II offense, with penalties ranging from $2,000 to $20,000. Factors considered in assessing a civil penalty may include the nature, circumstances, extent, and gravity of the alleged violation; the respondent's degree of culpability, any history of prior violations, and ability to pay; and such other matters as justice may require.

#1b (version 2)

Evaluating the Observer Effect for the Northeast U.S. Groundfish Fishery

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updated April 18, 2019

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– DRAFT –

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Introduction

The commercial component of the Northeast U.S. Multispecies fishery comprises 20 individual fish stocks and 2 management units[1]. Of these, commercial fisherman are allocated quota for 15 stocks, leaving 5 for which retention is prohibited. Fishing quota is allocated to approximately 1,000 permits and actively fished by around 200 participating commercial vessels (NEFMC 2017). The majority of the commercial fishery for groundfish (~98% of landings) is managed under the sector system whereby individual vessel owners pool stock-level quota into any one of 21 sectors, each operating as a collective, pooling the quota and allocating it to individual member fisherman. Quota for allocated stocks may be traded between sectors. Trades are remunerated in three ways: single stock trades for a given amount of money (fish-for-cash), pounds of multiple stocks traded for a single value (basket trades), and pounds of quota for one stock traded for pounds of quota of another stock with no money exchanged (swaps). All regulated groundfish species have a prescribed minimum fish size and regulations prohibit retaining fish below that size, and discarding fish above it.

Observers are deployed on participating vessels to estimate discarded catch for each of the 20 fish stocks on each trip. Observer coverage levels vary but in general observers have been onboard trips accounting for between 10-35% of all trips taken in any given fishing year. Discards on observed trips are calculated by dividing the sum of observed stock-level discards on observed tows by the total amount of retained catch on these tows. For trips with no observer coverage, discards are estimated by applying the annualized observed discard rate (stock-level discards divided by the sum of kept catch), stratified by broad stock area, sector and fishing gear. Discards count against a sector's quota after adjusting for gear and stock-based discard mortality rates. Vessels are assessed estimated discards on unobserved trips based on their strata, regardless of whether or not an individual species was reported on that trip. Sectors must have adequate quota reserves for all species in a given stock area prior to any member vessels fishing in that area. Observers have also been the primary source of enforcement for mandatory retention regulations.

As observer coverage only represents a fraction of the total fishing activity in the sector component of the commercial groundfish fishery, obvious questions arise: Does data generated on observed fishing trips reflect the activities of the whole fleet? Are estimates generated from these data unbiased? Bias may be induced by either a deployment effect, where the assignment of observers to vessels is non-random, or an observer effect, where the fishing activities on observed trips vary in detectable ways from those on unobserved trips (Benoit and Allard 2009). These two effects, deployment and observer, may act separately or in combination

[1] George's Bank is divided into a "west" component for which haddock and cod stocks are assessed exclusively by NOAA fisheries, and an "east" component for which these stocks together with yellowtail flounder are jointly assessed with the Canadian Department of Fisheries and Oceans under a trans-boundary management agreement.

to render data collected by on board observers biased. This paper focuses specifically on one component of the the latter effect: do individual vessels alter their behavior in response to the presence of an observer?

Fisherman may alter their fishing behavior when carrying an observer for any one of at least five reasons: (1) people may act differently as a response to simply being watched, an established phenomena referred to as the Hawthorne Effect (McCambridge et al. 2018); (2) fisherman may not want to impart their individual discarding preferences on the other members of their sector, an effect driven primarily by within-strata fishing practice heterogeneity; (3) observers incur costs associated with slower fish processing and handling times, carrying extra food, and general inconvenience, all of which may incentivize fisherman to make shorter trips when observers are on board; (4) catch of undersized fish varies across space and fishing in areas and at times where undersized fish are relatively less abundant may minimize discard rates, though at the cost of reduced revenues; and (5) binding quota constraints impart strong economic incentives to discard legal-sized fish when an observer is not on board and to avoid these stocks in the presence of an observer, again presumably at a cost in terms of reduced trip revenues.

Methods

This paper uses an exact matching method to determine if vessel performance along several metrics vary in a detectable way when an observer is on board, and when one is not. Following a procedure laid out by Benoit and Allard (2009), same-vessel trip sequences are analyzed to test for differences among various metrics. These trip sequences take the form of either: (1) three unobserved trips in a row (UUU), or (2) one observed trip between unobserved trips (UOU). To attenuate the possibility of interpreting seasonal effects as behavioral effects, only trips occurring within 45 days of each other are included. Trips are not repeated in multiple sequences. Vessels with less than two sequences are excluded from the analysis.

Triplet sequences are winnowed to pairs by taking the difference of either the leading or lagging trip with respect to the middle trip. The variable U in equation (1) and U^1 in equation (2), below, are selected randomly as either the leading or trailing trip in the triplet sequence, while the middle trip in the sequence is always the reference trip (O or U^1, below). To mitigate against regulatory changes affecting fishing behavior within sequences while maximizing the number of OU pairs, sequences overlapping the start of a new fishing year (May 1 of each year) select only the lead or lag pair that occurs in the same FY as the reference trip.

Differences are calculated as

$$\Delta O_{yfv} = (O - U/\acute{U})_{yfv} * 100$$

(Equation 1)

$$\Delta U_{yfv} = \left(U^1 - U^2/\acute{U}\right)_{yfv} * 100$$

(Equation 2)

where y is a fishing year, f is fishing vessel and v is any one of the metrics evaluated. $\acute{U}$ is the mean unobserved value for each year, vessel and metric combination.

Metrics evaluated, v, are:

1. Trip duration
2. Kept catch
3. Total revenue
4. Kept groundfish
5. Kept non-groundfish
6. Groundfish average price
7. Opportunity cost of quota

8. Number of groundfish market categories included in kept catch

The difference between the median values for ΔU's and O's is calculated as

$$(M_{\Delta U-\Delta O})_{yfv} = median(\Delta U)_{yfv} - median(\Delta O)_{yfv}$$

.

(Equation 3)

Differences between observed and unobserved trips are tested in three ways: (1) location differences are observed in $M_{\Delta U-\Delta O}$, with 95% confidence intervals estimated using bootstrap sampling (1,000 replicates) from the U_{yfv} and O_{yfv} values, where a lack of overlap with zero implies a 95% probability that the true median values for each population are significantly different[2]; (2) the Kolmogorov-Smirnov statistic is used to test for general differences in shape of the U_{yfv} and O_{yfv} distributions; and (3) the Kuiper statistic is used to test for differences in the extremities of the distributions (Conover 1980).

Multiple hypothesis tests are performed with the Kolmogorov-Smirnov (KSA) and Kuiper (KA) statistics. For these, a p-value of 0.005 is considered to be significant. As always, statistical significance should be considered in light of the data and research question. All p-values are reported.

Data

Vessel Trip Report (VTR) and Commercial Fishery Dealer (CFDBS) data are combined to construct trip-level data using the Data Matching and Imputation System (DMIS) database [cite needed]. Trips with an Allocation Management System (AMS) declaration code of "NMS" are included in the initial dataset[3]. Only vessels fishing with trawl or gillnet gears are retained. Observer trips are matched by a step-wise algorithm, focusing on permit number, VTR serial number, days-at-sea (DAS) identification number, date and time sailed. For the sector years, both Northeast Fishery Observer Program (NEFOP) and at-sea monitoring (ASM) data are matched.

U and O values are extracted from these data, and annual fishing year (May 1 – April 30) data sets are built with same-vessel two-trip sequences.

Trips in the United States-Canada Resource Sharing Agreement Area (USCA area) are removed from the pre-sector (FY 2007-2009) dataset, as these trips were subject to observer coverage at higher rates than trips outside the area. All trips fishing with extra large mesh (ELM) and targeting non-groundfish are excluded for all years, as are all trips by vessels enrolled in the Common Pool from 2010-2017[4]. All excluded trips and their corresponding triplets are retained and, to better understand the potential drivers of observer effects, are be analyzed separately in the future.

Results

Results are reported at two levels of aggregation:

- regulatory regime, as
  - pre-sector years (FY's 2007-2009),

[2] "Location" refers to the central tendency of the data, in this case the median values, and has no geographic connotation here.

[3] "NMS" is the code denoting trips made under the Northeast Multispecies Fishery Management Plan.

[4] In 2015 the New England Fishery Management Council exempt gillnet vessels fishing with mesh larger than 10 inches in certain areas near the coast from ASM coverage, as these trips had a documented history of catch very little groundfish. These trips are subject to NEFOP coverage, however.

  - initial sector years (FY's 2010-2012),
  - intermediate sector years (FY's 2013-2015),
  - contemporary sector years (FY's 2016-2018)[5]; and
- gear type, distinguishing between trawl and gillnet gears[6].

Results at the fishing year (FY) level, further disaggregated by gillnet and trawl, are estimated for context. Separate analyses have also been completed for single-day and multi-day trips, as well as a stock-level analysis of kept catch for 15 individual groundfish stocks.

Tests for differences in central tendency

Equations (1) and (2) are scaled by each vessel's mean annual values and median value differences are represented as percentages. For example, a median value of -0.04 for the kept catch variable implies that vessels catch roughly 4% less fish on an observed trip, relative to a neighboring unobserved trip by that same vessel, as measured across all vessels in the dataset. If the bootstrapped 95% confidence intervals fail to overlap with zero, the value is interpreted as significant using the confidence interval test. With eight metrics evaluated over four time stanzas, there are 32 units evaluated for observer effects. However, in the first stanza, before the sector system, there were no tradeable quota allocations.

Trawl vessels

For trawl vessels, 18 bootstrapped 95% confidence intervals failed to overlap zero. In the pre-sector years, three of seven metrics are significant under this test. In the three sector stanzas, 15 metrics are significant and nine are not.

Trawl vessels catch less fish when an observer is onboard. In the stanzas after 2009, they fish for less time and land less groundfish. Statistical significance is obtained for kept catch in all four stanzas, and for trip duration, groundfish kept catch and total revenues in the three post-2009 stanzas. Groundfish average prices are statically higher for three of the four stanzas, the exception being the period from 2010-2012. Composition of groundfish catch on observed and unobserved trips appears to be different. In the second and third time stanzas, groundfish vessels landed less high quota value stocks on observed trips, while in the final stanza the median differential is zero. Based on the reductions in catch and fishing time on observed trips after 2009, the changes in response to observer presense appear to be related to incentives embedded in catch accountability and quota constraints.

[5] FY 2018 data are complete through February 28 and inclusive of the first 10 full months of the fishing year.
[6] Trawl gears include the Vessel Trip Report (VTR) codes 'OHS','OTB','OTC','OTF','OTM','OTO','OTR','OTS', and 'OTT'. Gillnet gears include the codes 'GNR','GNS', and 'GNT'.

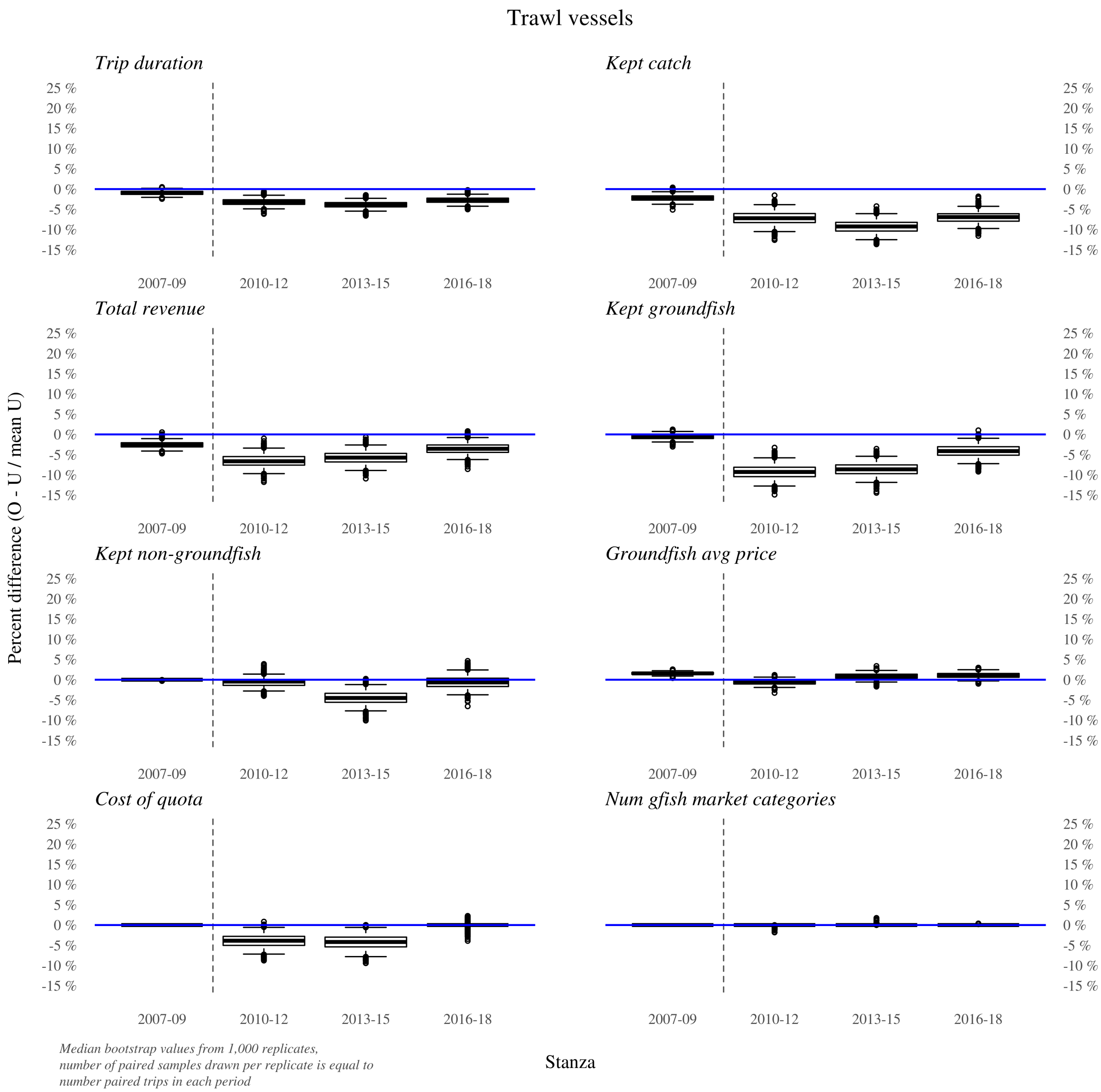


Figure 1: Results of bootstrap analysis, observed and unobserved same-vessel paired trips by stanza

Table 1: Stanza 1, 2007-2009

Gear	Variable	CIs <> 0	95% CI, lower	Median	95% CI, upper	n Unobserved	n Observed
Trawl	Kept groundfish		-1.9 %	-0.6 %	0.5 %	10,844	726
Trawl	Number groundfish market categories		0 %	0 %	0 %	10,844	726
Trawl	Groundfish avg price	*	0.9 %	1.6 %	2.3 %	10,845	726
Trawl	Kept catch	*	-3.7 %	-2.2 %	-0.7 %	10,845	726
Trawl	Kept non-groundfish		0 %	0 %	0 %	10,845	726
Trawl	Opportunity cost of quota		0 %	0 %	0 %	10,845	726
Trawl	Total revenue	*	-4.1 %	-2.6 %	-1.1 %	10,845	726
Trawl	Trip duration		-2 %	-0.9 %	0 %	10,845	726

Table 2: Stanza 2, 2010-2012

Gear	Variable	CIs <> 0	95% CI, lower	Median	95% CI, upper	n Unobserved	n Observed
Trawl	Kept groundfish	*	-12.6 %	-9.3 %	-5.9 %	2,787	1,413
Trawl	Number groundfish market categories		-0.4 %	0 %	0 %	2,787	1,413
Trawl	Groundfish avg price		-1.9 %	-0.6 %	0.6 %	2,787	1,413
Trawl	Kept catch	*	-10.2 %	-7.2 %	-4.1 %	2,787	1,413
Trawl	Kept non-groundfish		-3.3 %	-0.4 %	1.7 %	2,787	1,413
Trawl	Opportunity cost of quota	*	-7.3 %	-3.9 %	-0.8 %	2,787	1,411
Trawl	Total revenue	*	-9.4 %	-6.6 %	-3.4 %	2,787	1,413
Trawl	Trip duration	*	-4.9 %	-3.2 %	-1.6 %	2,787	1,413

Table 3: Stanza 3, 2013-2015

Gear	Variable	CIs <> 0	95% CI, lower	Median	95% CI, upper	n Unobserved	n Observed
Trawl	Kept groundfish	*	-12 %	-8.6 %	-5.4 %	2,920	954
Trawl	Number groundfish market categories		0 %	0 %	0.1 %	2,920	954
Trawl	Groundfish avg price		-0.5 %	0.8 %	2.3 %	2,920	954
Trawl	Kept catch	*	-12.3 %	-9.2 %	-6.1 %	2,920	954
Trawl	Kept non-groundfish	*	-7.9 %	-4.5 %	-1.4 %	2,920	954
Trawl	Opportunity cost of quota	*	-8 %	-4.2 %	-0.6 %	2,920	954
Trawl	Total revenue	*	-8.8 %	-5.7 %	-2.8 %	2,920	954
Trawl	Trip duration	*	-5.5 %	-3.8 %	-2.3 %	2,920	954

Table 4: Stanza 4, 2016-2018

Gear	Variable	CIs <> 0	95% CI, lower	Median	95% CI, upper	n Unobserved	n Observed
Trawl	Kept groundfish	*	-7 %	-4.1 %	-1.2 %	2,805	799
Trawl	Number groundfish market categories		0 %	0 %	0 %	2,805	799
Trawl	Groundfish avg price		-0.2 %	1.1 %	2.4 %	2,805	799
Trawl	Kept catch	*	-9.9 %	-6.9 %	-4.3 %	2,805	799
Trawl	Kept non-groundfish		-3.5 %	-0.7 %	2.5 %	2,805	799
Trawl	Opportunity cost of quota		-1.7 %	0 %	1 %	2,805	799
Trawl	Total revenue	*	-6.3 %	-3.5 %	-0.7 %	2,805	799
Trawl	Trip duration	*	-4.2 %	-2.7 %	-1.3 %	2,805	799

Gillnet vessels

For gillnet vessels the picture is less clear-cut. 13 units in total have 95% confidence intervals that fail to overlap with zero. Pre-sector, from 2007-2009, four metrics were significant and three were not. Under sector management, the three stanzas from 2010-2018, nine are signficant and thirteen are not. However, in the most recent stanza (FY 2016-2018), six of the eight metrics yeild significant differences in bootstrapped confidence intervals, and a seventh (number of groundfish market categories), while statistically insignificant, shows a trend toward more market categories landed on observed trips.

Gillnet vessels consistently make shorter trips, generate less revenue and appear to retain slightly less catch overall in the presence of an observer. There is a trend in later stanzas toward more groundfish and less non-groundfish on observed trips for these vessels, indicating that observers affect the mix of species landed. More groundfish market categories in the last stanza may indicate differential groundfish targeting, or perhaps high-grading of specific species. The most striking result is that, in the last stanza, with an observer on board the same gillnet vessels have a 17% higher opportunity cost of quota than when they do not. Statistically different behavior in response to an observer is nearly equally prevalent for gillnet and trawl vessels, though the nature of the response does differ between the two. This may be an artifact of smaller sample sizes (fewer number of paired trips, particularly in the later stanzas) which attenuate the model's power to discern effects. The distinction in response before and after the implementation of sectors is less clear cut for gillnetters than for trawlers, noting that gillnet vessels demonstrated a stronger behavioral response than trawlers before sectors. Finally, during the contemporary sector years (fourth stanza) a trend of less non-groundfish landed, more groundfish and, in particular, more high quota value species landed is noteworthy.

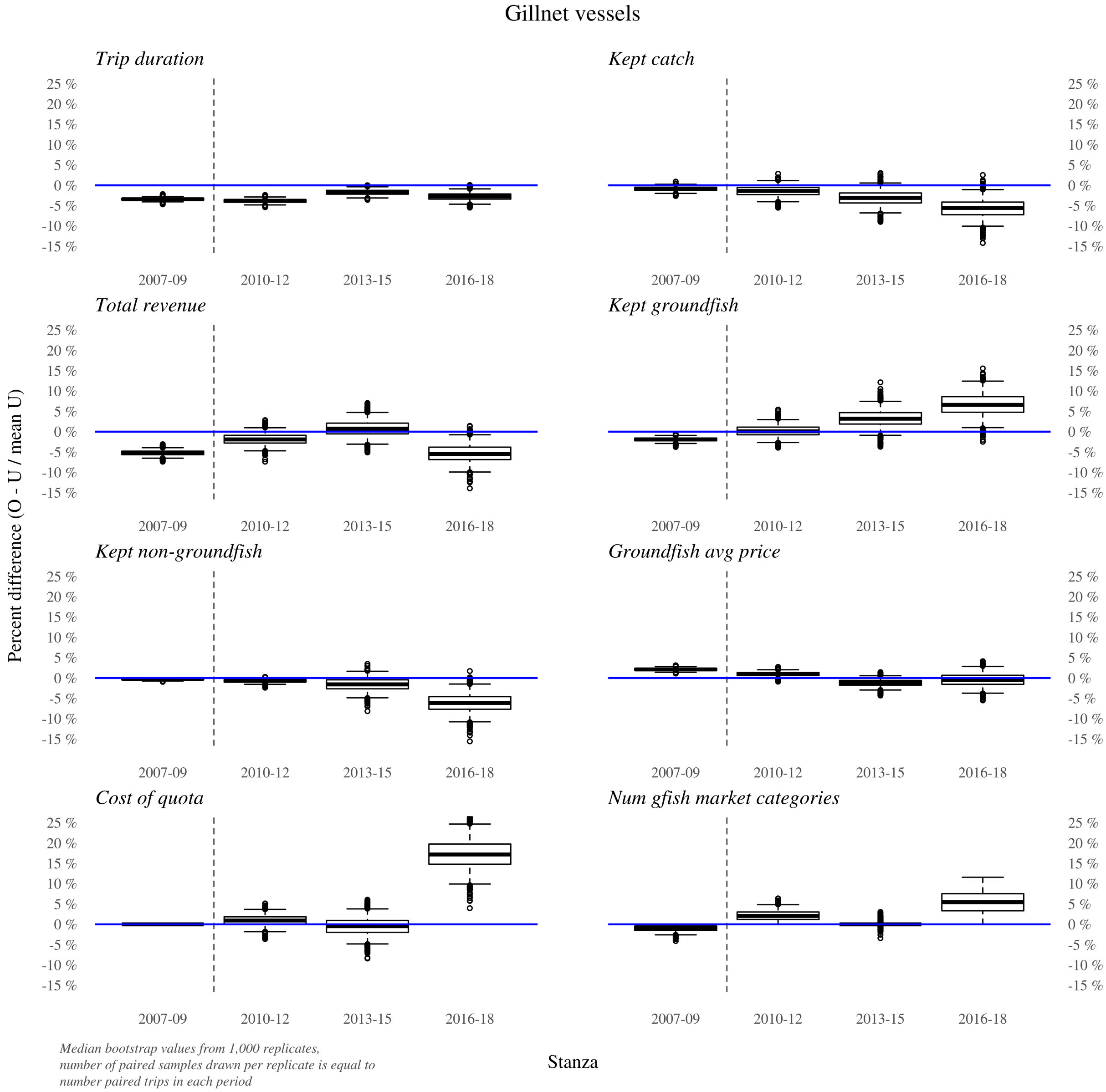


Figure 2: Results of bootstrap analysis, observed and unobserved same-vessel paired trips by stanza

Table 5: Stanza 1, 2007-2009

Gear	Variable	CIs <> 0	95% CI, lower	Median	95% CI, upper	n Unobserved	n Observed
Gillnet	Kept groundfish	*	-2.9 %	-1.9 %	-1 %	10,782	531
Gillnet	Number groundfish market categories		-2.8 %	-1 %	0 %	10,782	531
Gillnet	Groundfish avg price	*	1.5 %	2.1 %	2.8 %	10,782	531
Gillnet	Kept catch		-1.9 %	-0.8 %	0.1 %	10,782	531
Gillnet	Kept non-groundfish		-0.6 %	-0.3 %	0 %	10,782	531
Gillnet	Opportunity cost of quota		0 %	0 %	0 %	10,782	531
Gillnet	Total revenue	*	-6.5 %	-5.2 %	-4 %	10,782	531
Gillnet	Trip duration	*	-4.2 %	-3.4 %	-2.7 %	10,782	531

Table 6: Stanza 2, 2010-2012

Gear	Variable	CIs <> 0	95% CI, lower	Median	95% CI, upper	n Unobserved	n Observed
Gillnet	Kept groundfish		-2.4 %	0.1 %	3.2 %	2,609	1,330
Gillnet	Number groundfish market categories		0 %	2.1 %	4.9 %	2,609	1,330
Gillnet	Groundfish avg price		-0.2 %	1 %	2 %	2,609	1,330
Gillnet	Kept catch		-4.1 %	-1.4 %	1 %	2,609	1,330
Gillnet	Kept non-groundfish		-1.6 %	-0.7 %	0 %	2,609	1,330
Gillnet	Opportunity cost of quota		-1.8 %	0.9 %	3.8 %	2,609	1,330
Gillnet	Total revenue		-4.7 %	-1.9 %	1.1 %	2,609	1,330
Gillnet	Trip duration	*	-4.8 %	-3.8 %	-2.8 %	2,609	1,330

Table 7: Stanza 3, 2013-2015

Gear	Variable	CIs <> 0	95% CI, lower	Median	95% CI, upper	n Unobserved	n Observed
Gillnet	Kept groundfish		-0.9 %	3.2 %	7.6 %	1,622	434
Gillnet	Number groundfish market categories		-0.9 %	0 %	1.4 %	1,622	434
Gillnet	Groundfish avg price		-2.9 %	-1.2 %	0.4 %	1,622	434
Gillnet	Kept catch		-6.5 %	-3.1 %	0.4 %	1,622	434
Gillnet	Kept non-groundfish		-5.1 %	-1.6 %	1.2 %	1,622	434
Gillnet	Opportunity cost of quota		-5 %	-0.5 %	4.2 %	1,622	434
Gillnet	Total revenue		-3 %	0.7 %	4.9 %	1,622	434
Gillnet	Trip duration	*	-3 %	-1.7 %	-0.4 %	1,622	434

Table 8: Stanza 4, 2016-2018

Gear	Variable	CIs <> 0	95% CI, lower	Median	95% CI, upper	n Unobserved	n Observed
Gillnet	Kept groundfish	*	1.1 %	6.6 %	12.2 %	833	277
Gillnet	Number groundfish market categories		0 %	5.5 %	10.3 %	833	277
Gillnet	Groundfish avg price		-3.4 %	-0.5 %	2.7 %	833	277
Gillnet	Kept catch	*	-10.6 %	-5.6 %	-1 %	833	277
Gillnet	Kept non-groundfish	*	-10.8 %	-6.1 %	-1.5 %	833	277
Gillnet	Opportunity cost of quota	*	10.2 %	17.2 %	24.7 %	833	277
Gillnet	Total revenue	*	-9.6 %	-5.5 %	-1.1 %	833	277
Gillnet	Trip duration	*	-4.5 %	-2.7 %	-1 %	833	277

Tests for differences in distribution shape

The Kolmogorov-Smirnov (K-S) test, a nonparametric test evaluating the difference between cumulative distribution functions of two independent samples, U and O, is sensitive to differences in location and shape. Generally, at a 0.005 signficance level this test finds fewer significant differences in distribution shapes than the bootstrap confidence interval method for changes in location.

The Kuiper (K) test, another nonparametric test, is similar to the K-S but evaluates in an additive way both positive and negative differences in the cumulative distribution functions of the U and O values. It is more senstive, therefore, to changes in the tails of the distributions in question.

Trawl vessels

Of the 31 evaluated units, 12 are significant under the Kolmogorov-Smirnov test and 22 under the Kuiper test. In the pre-sector stanza, three of seven units have statistically significant differences in distribution shape (K-S) and, for all seven units, the tails of the U and O distributions are significantly different under the Kuiper test. In the three sector stanzas, nine units exhibit significantly different distributions under the K-S test, with 16 significanly different distributions under the Kuiper test.

The K-S test highlights similar units to the bootstrapped confidence intervals, namely kept catch, trip duration and kept groundfish. The Kuiper test, however, reveals differences in U and O distribution shapes for opportunity cost of quota (three sector stanzas) and number of groundfish market categories (all four stanzas).

Table 9: Stanza 1, 2007-2009

Gear	Variable	KS <= 0.005	p(KS)	K <= 0.005	p(K)	n Unobserved	n Observed
Trawl	Kept groundfish		0.179	*	0.002	10,844	726
Trawl	Number groundfish market categories	*	0.001	*	0.000	10,844	726
Trawl	Groundfish avg price	*	0.002	*	0.000	10,845	726
Trawl	Kept catch	*	0.002	*	0.000	10,845	726
Trawl	Kept non-groundfish		0.102	*	0.000	10,845	726
Trawl	Total revenue		0.169		0.031	10,845	726
Trawl	Trip duration		0.066	*	0.005	10,845	726

Table 10: Stanza 2, 2010-2012

Gear	Variable	KS <= 0.005	p(KS)	K <= 0.005	p(K)	n Unobserved	n Observed
Trawl	Kept groundfish	*	0.000	*	0.000	2,787	1,413
Trawl	Number groundfish market categories		0.149	*	0.000	2,787	1,413
Trawl	Groundfish avg price		0.272		0.029	2,787	1,413
Trawl	Kept catch	*	0.000	*	0.004	2,787	1,413
Trawl	Kept non-groundfish		0.625	*	0.002	2,787	1,413
Trawl	Opportunity cost of quota		0.101	*	0.000	2,787	1,411
Trawl	Total revenue	*	0.003		0.021	2,787	1,413
Trawl	Trip duration		0.007	*	0.001	2,787	1,413

Table 11: Stanza 3, 2013-2015

Gear	Variable	KS <= 0.005	p(KS)	K <= 0.005	p(K)	n Unobserved	n Observed
Trawl	Kept groundfish	*	0.000	*	0.002	2,920	954
Trawl	Number groundfish market categories		0.426	*	0.000	2,920	954
Trawl	Groundfish avg price		0.251		0.059	2,920	954
Trawl	Kept catch	*	0.001	*	0.004	2,920	954
Trawl	Kept non-groundfish		0.128		0.448	2,920	954
Trawl	Opportunity cost of quota		0.013	*	0.000	2,920	954
Trawl	Total revenue		0.016		0.077	2,920	954
Trawl	Trip duration	*	0.000	*	0.000	2,920	954

Table 12: Stanza 4, 2016-2018

Gear	Variable	KS <= 0.005	p(KS)	K <= 0.005	p(K)	n Unobserved	n Observed
Trawl	Kept groundfish	*	0.002	*	0.002	2,805	799
Trawl	Number groundfish market categories		0.127	*	0.000	2,805	799
Trawl	Groundfish avg price		0.180		0.346	2,805	799
Trawl	Kept catch	*	0.000	*	0.001	2,805	799
Trawl	Kept non-groundfish		0.649		0.443	2,805	799
Trawl	Opportunity cost of quota		0.178	*	0.000	2,805	799
Trawl	Total revenue		0.032		0.073	2,805	799
Trawl	Trip duration	*	0.000	*	0.000	2,805	799

Gillnet vessels

Only six of 31 units are significant under the Kolmogorov-Smirnov test and 9 under the Kuiper test for gillnet vessels. In the pre-sector stanza, three of seven units have statistically significant differences in distribution shape for both the K-S and Kuiper tests. In the three sector stanzas, three of 24 possible units exhibit significantly different U and O distributions under the K-S test, and 6 under the Kuiper test.

As with trawl vessels, the K-S test here highlights, when significant, difference similar o the bootstrapped confidence intervals. And also like with trawl vessels, the Kuiper test reveals differences in U and O distribution shapes for the number of groundfish market categories in all four stanzas.

Table 13: Stanza 1, 2007-2009

Gear	Variable	KS <= 0.005	p(KS)	K <= 0.005	p(K)	n Unobserved	n Observed
Gillnet	Kept groundfish		0.104		0.179	10,782	531
Gillnet	Number groundfish market categories		0.111	*	0.000	10,782	531
Gillnet	Groundfish avg price		0.012		0.027	10,782	531
Gillnet	Kept catch		0.722		0.456	10,782	531
Gillnet	Kept non-groundfish	*	0.001	*	0.000	10,782	531
Gillnet	Total revenue	*	0.002		0.007	10,782	531
Gillnet	Trip duration	*	0.002	*	0.001	10,782	531

Table 14: Stanza 2, 2010-2012

Gear	Variable	KS <= 0.005	p(KS)	K <= 0.005	p(K)	n Unobserved	n Observed
Gillnet	Kept groundfish		0.594		0.070	2,609	1,330
Gillnet	Number groundfish market categories	*	0.001	*	0.000	2,609	1,330
Gillnet	Groundfish avg price		0.161		0.645	2,609	1,330
Gillnet	Kept catch		0.182		0.108	2,609	1,330
Gillnet	Kept non-groundfish		0.006	*	0.000	2,609	1,330
Gillnet	Opportunity cost of quota		0.239		0.025	2,609	1,330
Gillnet	Total revenue		0.612		0.917	2,609	1,330
Gillnet	Trip duration	*	0.000	*	0.000	2,609	1,330

Table 15: Stanza 3, 2013-2015

Gear	Variable	KS <= 0.005	p(KS)	K <= 0.005	p(K)	n Unobserved	n Observed
Gillnet	Kept groundfish		0.137		0.018	1,622	434
Gillnet	Number groundfish market categories		0.942	*	0.000	1,622	434
Gillnet	Groundfish avg price		0.314		0.210	1,622	434
Gillnet	Kept catch		0.228		0.222	1,622	434
Gillnet	Kept non-groundfish		0.223		0.043	1,622	434
Gillnet	Opportunity cost of quota		0.167		0.028	1,622	434
Gillnet	Total revenue		0.110		0.010	1,622	434
Gillnet	Trip duration		0.034	*	0.004	1,622	434

Table 16: Stanza 4, 2016-2018

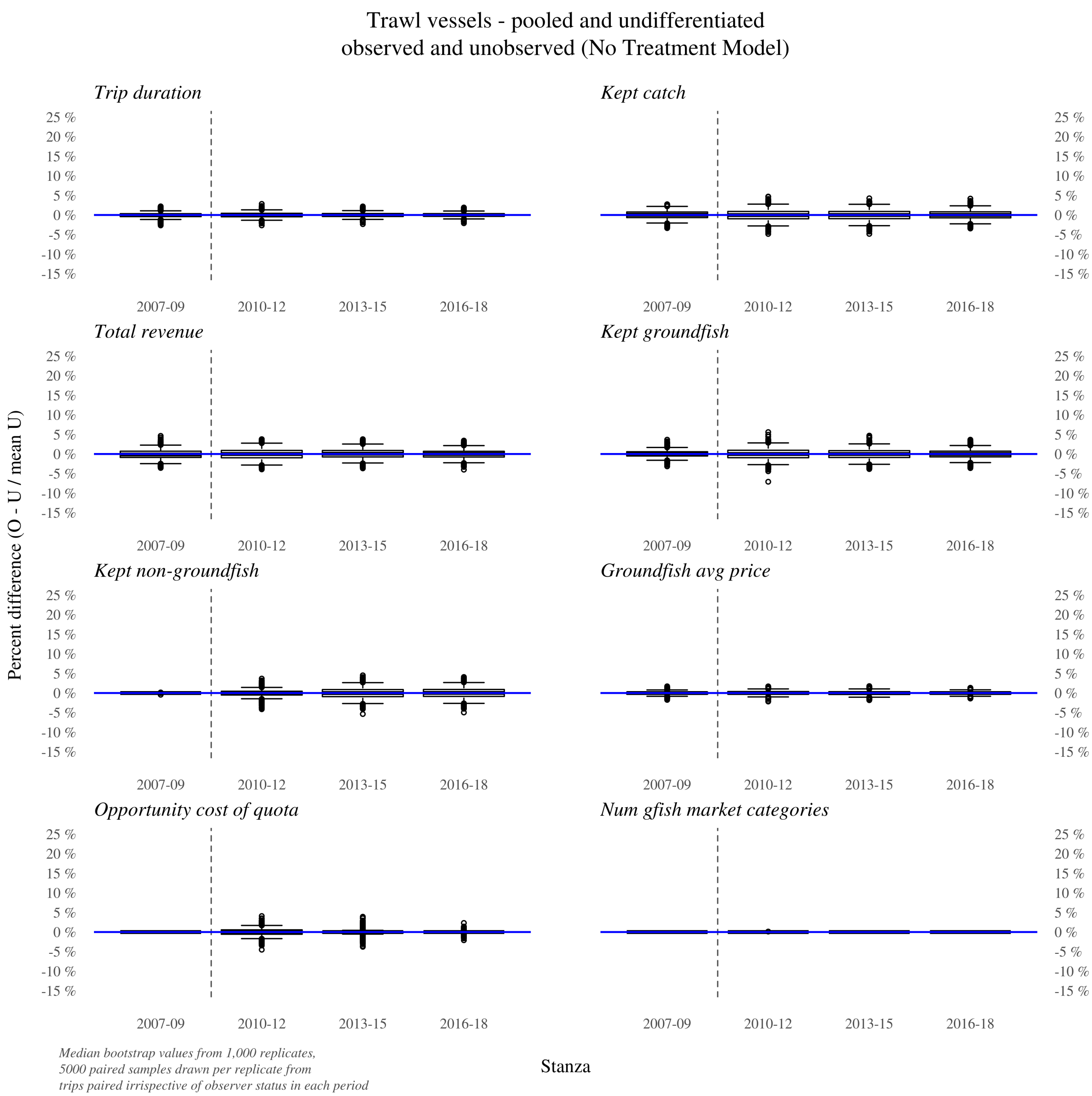
Gear	Variable	KS <= 0.005	p(KS)	K <= 0.005	p(K)	n Unobserved	n Observed
Gillnet	Kept groundfish		0.144		0.101	833	277
Gillnet	Number groundfish market categories		0.077	*	0.000	833	277
Gillnet	Groundfish avg price		0.702		0.486	833	277
Gillnet	Kept catch		0.040		0.033	833	277
Gillnet	Kept non-groundfish		0.041		0.100	833	277
Gillnet	Opportunity cost of quota	*	0.004		0.013	833	277
Gillnet	Total revenue		0.032		0.053	833	277
Gillnet	Trip duration		0.092		0.019	833	277

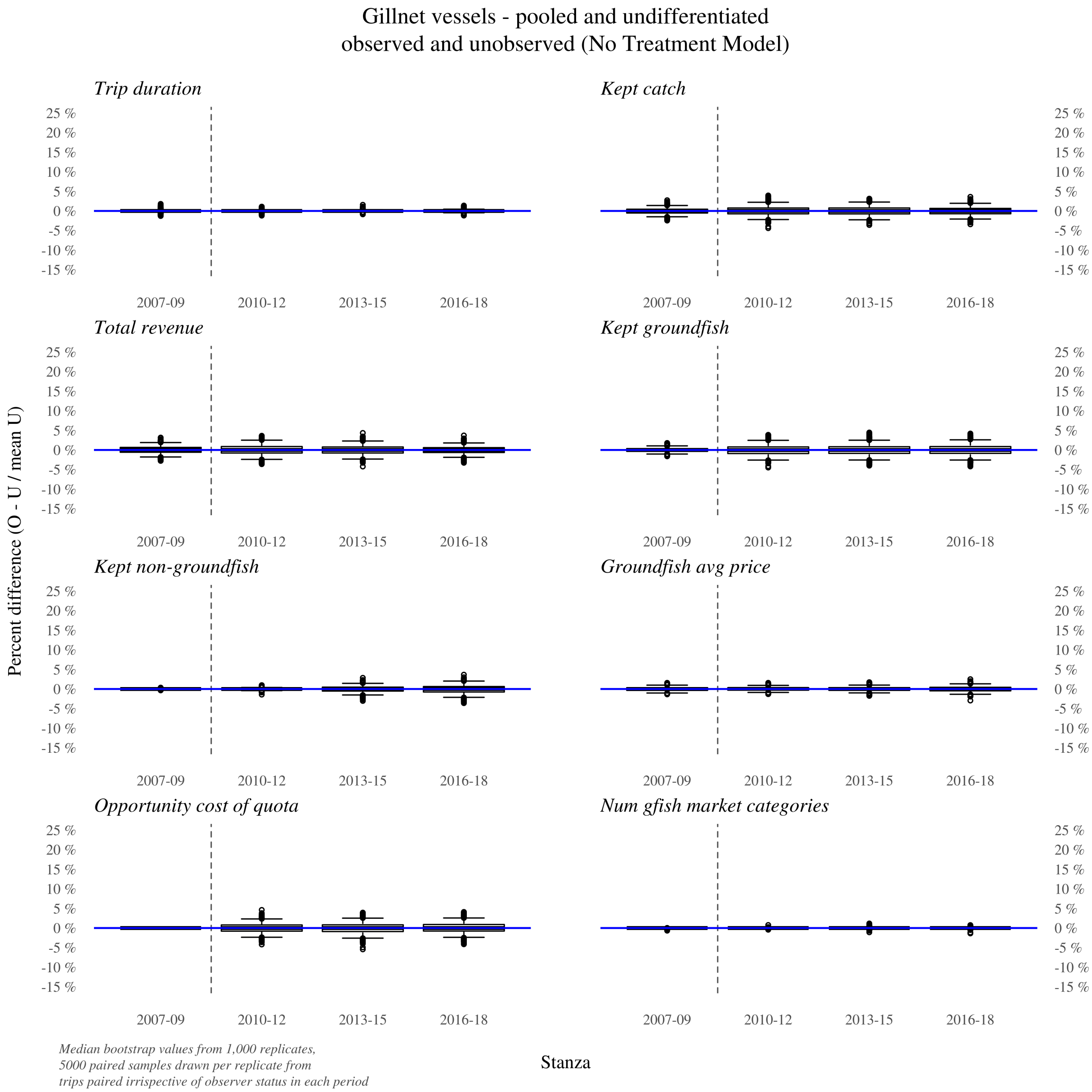
Discussion

It is clear that fishing vessels engaged in the groundfish fishery alter their behavior in response to observers. Estimated confidence intervals for U and O values overlap with zero for only a handful of the metrics evaluated across stanzas or fishing years. Generally, the most pronounced effects are seen across trip duration, kept catch, kept groundfish, trip revenue and opportunity cost of quota. Observer presence has the smallest affect on the number of groundfish market categories and non-groundfish average prices, but, particulary in the former, even here we see differences in the tails of the distributions.

No treatment model

In an effort to demonstrate that the effects estimated here are, in fact, the result of observer presence and not driven by underlying variability in trip-level data driven by unobserved factors, the model was run as previously described, but with assignment to triplets (U and O) made irrespective of actual observer status. As one would expect, the No Treatment estimates across all metrics and stanzas are median-centered on zero with little variance in the two distributions. This demonstrates that the observed variation between U and O triplets in the primary (treatment) model is almost certainly a function of observer presence. See Appenix (forthcoming) for details.


Trawl vessels - pooled and undifferentiated
observed and unobserved (No Treatment Model)
Trip duration
Kept catch
Total revenue
Kept groundfish
Kept non-groundfish
Groundfish avg price
Opportunity cost of quota
Num gfish market categories
25 %
20 %
15 %
10 %
5 %
0 %
-5 %
-10 %
-15 %
2007-09
2010-12
2013-15
2016-18
Percent difference (O - U / mean U)
Stanza
Median bootstrap values from 1,000 replicates,
5000 paired samples drawn per replicate from
trips paired irrispective of observer status in each period



Differences across time

Incentives to alter fishing behavior have varied across time. Prior to sector implementation discards had no direct cost to fisherman and trip limits required discarding certain species. These factors may have reduced the incentive to alter fishing practices in response to an observer, noting that gillnet vessels did demonstrate a significant behavioral response prior to sectors. Gillnet vessels, however, are also more likely to have encounters with marine mammals and have other gear-specific requirements (i.e. pingers) that may further affect responses to observers independent of quota-based management and associated regulatiosn.

After full sector implementation, the accountability of discards and the application of sector/gear specific discard rates to unobserved trips, together with the potential catch of constraining stocks and the high opportunity cost of quota associated with landing such stocks, increased the incentive to change behavior. We see this most dramatically in the contemporary sector stanza for gillnet vessels, but the trend from lower quota costs on observed trip toward zero difference on trawl vessels may reflect a similar response.

The two-sided problem

Incentives to alter behavior in response to an observer may induce less effort, catch, etc...or more, as some vessels fish longer (or shorter) trips or otherwise alter their fishing practices due to quota allocations, fishing preferences, or other factors. One vessel may attempt to minimize observed discarding of flatfish at the expense of cod, while another vessel may take the exact opposite approach. Such offsetting behavior could change the central tendency of the $M_{\Delta U - \Delta O}$ distribution very little, but affect it's shape, particularly at the tails. Number of market categories for groundfish and opportunity cost of quota differ at the tails for both gillnet and trawl vessels. These distribution differences may point toward highgrading and/or circumventing mandatory fish retention regulations.

More broadly, the two-sided nature of the problem is important to understand because directionally opposite responses to observer presence attenuates the central tendency test and some may view location differences on the order of 5-10% as trivial when, taken in context, they represent large and statistically significant differences between observed and unobserved populations.

To better understand the influence of positive and negative observer responses, we estimated median annual (FY) values across each of the eight metrics for all vessels represented in the matched pair data, subtracting each vessel's annual median U value from it's median O to get a median difference in observed behavior. An example of the distribution of vessel-level observer effects by FY, in this case for opportunity cost of quota, can be seen below.

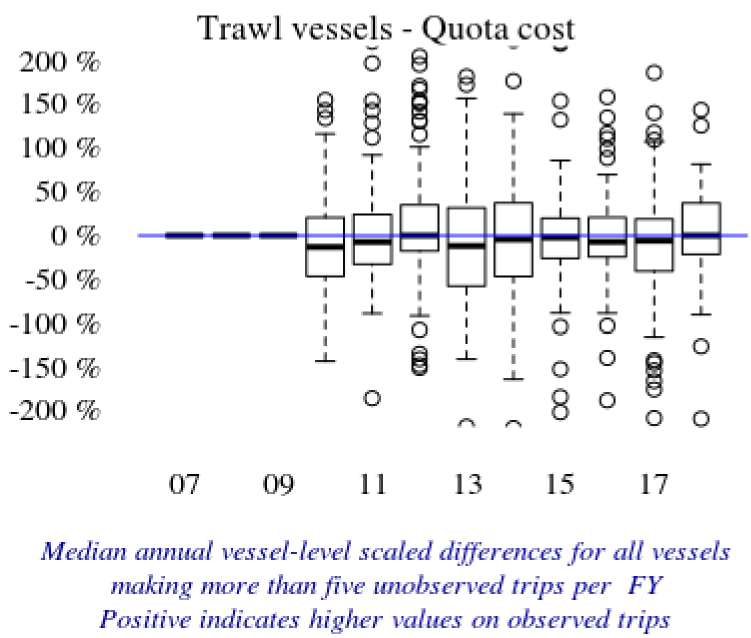


Figure 3: Distribution of vessel-level median annual observer effects, trawl)

These plots make clear the point that over the course of a year, some vessels persistently shift their behavoir in response to observer in a positive direction, others the opposite.

The effect of these off-setting behaviors may be that a large amount of catch can be taken by vessels that persistently alter behavior in one direction or the other. To test this, and to better understand how much fishing activity may be affected, we take two sub-sets of vessels–those that exhibit a +/- 15% median annual

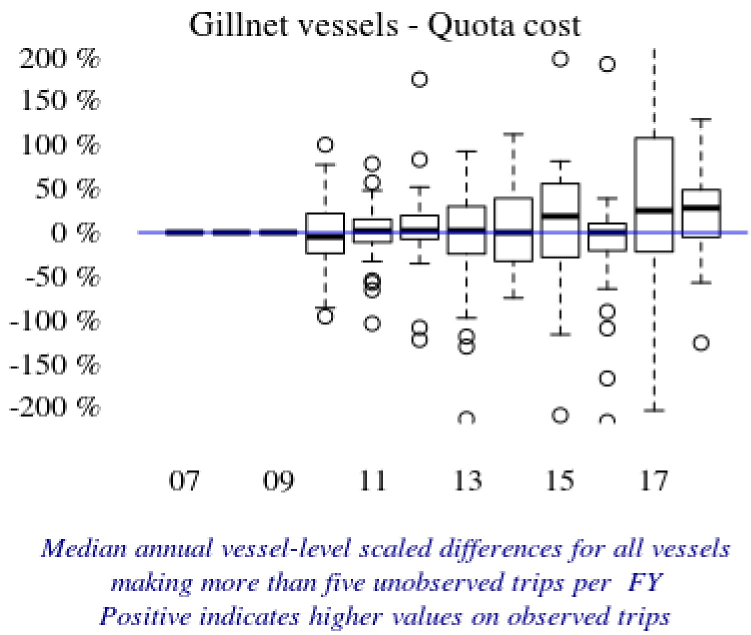


Figure 4: Distribution of vessel-level median annual observer effects, gillnet)

difference in behavior (oserver effect) for each metric, and those with a +/- 30% difference–and estimate the proportion of vessels and groundfish catch accounted for annually by these sets. We find that across a range of metrics, vessels with an annual observer effect response of +/- 15% or more account for roughly 20-30% of the groundfish vessels, and roughly 50-60% of the groundfish catch. Vessels with a +/- 30% response account for 10-20% of the vessels and 30-40% of the catch. Vessels exhibiting these levels of observer effect for the opportunity cost of quota metric, in particular, represent the largest share of groundfish catch, from 40-80% depending on threshold and year. It is important to note that, even in the case of no observer effect, the nature of fishing and it's underlying variability would likely result in some vessels fitting into one or both of these threshold categories. Further analysis of, for example, the extra-large mesh fishery, which has no quota-based incentives that may benefit from observer effects, may shed more light on the question of underlying variability versus strategic behavioral responses.

Last word

These analyses point toward a consistent pattern of different fishing behaviors when an observer is on board. The Benoit and Allard method isolates vessel effects by focusing on the differences in behavior in response to an observer *for the same vessel*. The data show a clear trend for three key metrics–in almost all circumstances vessels appear to retain less fish, fish for less time and obtain lower revenues when an observer is on board. Gillnet vessels retain substantially more groundfish, at a higher opportuntiy cost of quota, in the most recent time stanza. The distributions of U and O pairs is substantially different at the tails for the number of groundfish market categories landed, pointing toward highgrading by a subset of the fleet. Persistent differences such as higher average groundfish prices with an observer on board (trawl vessels) and emerging differences like a greater number of market categories retained with an observer (gillnet vessels) indicate that the composition of catch on observed trips is different. This suggests that data collected by observers are not merely a compressed representation of unobserved fishing practices but, rather, they are non-representative along critical dimensions such as proportions and quantities of discarded fish, legally and perhaps illegally, and fish retained.

\begin{table}[t]

\caption{Vessel median observer effects > +/- 15% and 30%, proportion of total and proportion of groundfish landed}

FY	Variable	N vsls	Vsls, > +/-15%	% gfish caught +/-15	Vsls, > +/-30%	% gfish caught +/-30
2007	gfish_lbs	564	125	0.35	90	0.27
2007	gfish_mcat	564	91	0.22	53	0.11
2007	gfish_price	564	77	0.29	32	0.13
2007	k_all	564	114	0.38	86	0.28
2007	non_gfish_lbs	564	92	0.26	75	0.23
2007	total_value	564	124	0.39	91	0.28
2007	trip_dur	564	89	0.30	57	0.17
2008	gfish_lbs	527	129	0.31	91	0.23
2008	gfish_mcat	527	117	0.27	61	0.12
2008	gfish_price	527	81	0.25	54	0.17
2008	k_all	527	137	0.35	95	0.26
2008	non_gfish_lbs	527	113	0.38	80	0.28
2008	total_value	527	134	0.38	90	0.25
2008	trip_dur	527	101	0.30	59	0.15
2009	gfish_lbs	476	114	0.51	79	0.35
2009	gfish_mcat	476	107	0.33	60	0.18
2009	gfish_price	476	88	0.36	48	0.24
2009	k_all	476	120	0.51	86	0.33
2009	non_gfish_lbs	476	118	0.48	93	0.33
2009	total_value	476	124	0.46	86	0.30
2009	trip_dur	476	102	0.40	63	0.25
2010	gfish_lbs	377	96	0.55	56	0.26
2010	gfish_mcat	377	72	0.27	33	0.14
2010	gfish_price	377	56	0.36	22	0.18
2010	k_all	377	95	0.48	66	0.33
2010	non_gfish_lbs	377	82	0.49	64	0.37
2010	quota_cost	377	103	0.53	76	0.43
2010	total_value	377	99	0.49	63	0.32
2010	trip_dur	377	64	0.43	31	0.22
2011	gfish_lbs	362	113	0.54	80	0.43
2011	gfish_mcat	362	61	0.23	22	0.09
2011	gfish_price	362	49	0.29	18	0.08
2011	k_all	362	98	0.41	58	0.30
2011	non_gfish_lbs	362	79	0.41	55	0.29
2011	quota_cost	362	99	0.45	61	0.30
2011	total_value	362	108	0.48	68	0.28
2011	trip_dur	362	64	0.35	32	0.22

\end{table}

\begin{table}[t]

\caption{Vessel median observer effects > +/- 15% and 30%, proportion of total and proportion of groundfish landed}

FY	Variable	N vsls	Vsls, > +/-15%	% gfish caught +/-15	Vsls, > +/-30%	% gfish caught +/-30
2012	gfish_lbs	352	131	0.67	87	0.44
2012	gfish_mcat	352	75	0.27	29	0.09
2012	gfish_price	352	77	0.44	41	0.20
2012	k_all	352	122	0.62	75	0.45
2012	non_gfish_lbs	352	115	0.59	91	0.48
2012	quota_cost	352	113	0.61	79	0.43
2012	total_value	352	125	0.65	72	0.37
2012	trip_dur	352	90	0.53	52	0.34
2013	gfish_lbs	305	102	0.62	67	0.43
2013	gfish_mcat	305	62	0.26	31	0.10
2013	gfish_price	305	65	0.49	27	0.25
2013	k_all	305	100	0.63	72	0.49
2013	non_gfish_lbs	305	95	0.66	62	0.36
2013	quota_cost	305	105	0.73	84	0.60
2013	total_value	305	92	0.61	52	0.35
2013	trip_dur	305	64	0.55	36	0.31
2014	gfish_lbs	280	85	0.70	60	0.45
2014	gfish_mcat	280	52	0.32	26	0.14
2014	gfish_price	280	57	0.51	32	0.24
2014	k_all	280	80	0.64	48	0.39
2014	non_gfish_lbs	280	71	0.53	55	0.41
2014	quota_cost	280	95	0.71	72	0.49
2014	total_value	280	90	0.67	56	0.39
2014	trip_dur	280	66	0.54	31	0.21
2015	gfish_lbs	250	75	0.55	56	0.37
2015	gfish_mcat	250	50	0.18	27	0.11
2015	gfish_price	250	46	0.42	24	0.19
2015	k_all	250	76	0.52	63	0.41
2015	non_gfish_lbs	250	82	0.63	63	0.45
2015	quota_cost	250	80	0.46	59	0.36
2015	total_value	250	76	0.47	51	0.28
2015	trip_dur	250	63	0.52	41	0.35
2016	gfish_lbs	230	67	0.56	46	0.29
2016	gfish_mcat	230	39	0.14	19	0.05
2016	gfish_price	230	46	0.42	20	0.16
2016	k_all	230	82	0.70	51	0.40
2016	non_gfish_lbs	230	69	0.56	53	0.32
2016	quota_cost	230	78	0.74	44	0.41
2016	total_value	230	73	0.54	41	0.35
2016	trip_dur	230	50	0.66	20	0.12

\end{table}

\begin{table}[t]

\caption{Vessel median observer effects > +/- 15% and 30%, proportion of total and proportion of groundfish landed}

FY	Variable	N vsls	Vsls, > +/-15%	% gfish caught +/-15	Vsls, > +/-30%	% gfish caught +/-30
2017	gfish_lbs	213	73	0.63	50	0.35
2017	gfish_mcat	213	42	0.17	14	0.06
2017	gfish_price	213	48	0.43	24	0.12
2017	k_all	213	67	0.59	43	0.28
2017	non_gfish_lbs	213	73	0.63	48	0.44
2017	quota_cost	213	76	0.60	54	0.43
2017	total_value	213	72	0.61	49	0.44
2017	trip_dur	213	52	0.66	25	0.46
2018	gfish_lbs	198	50	0.31	39	0.25
2018	gfish_mcat	198	45	0.20	13	0.05
2018	gfish_price	198	37	0.25	15	0.09
2018	k_all	198	58	0.51	28	0.34
2018	non_gfish_lbs	198	51	0.64	27	0.39
2018	quota_cost	198	58	0.69	39	0.44
2018	total_value	198	51	0.46	33	0.20
2018	trip_dur	198	36	0.42	18	0.22

\end{table}

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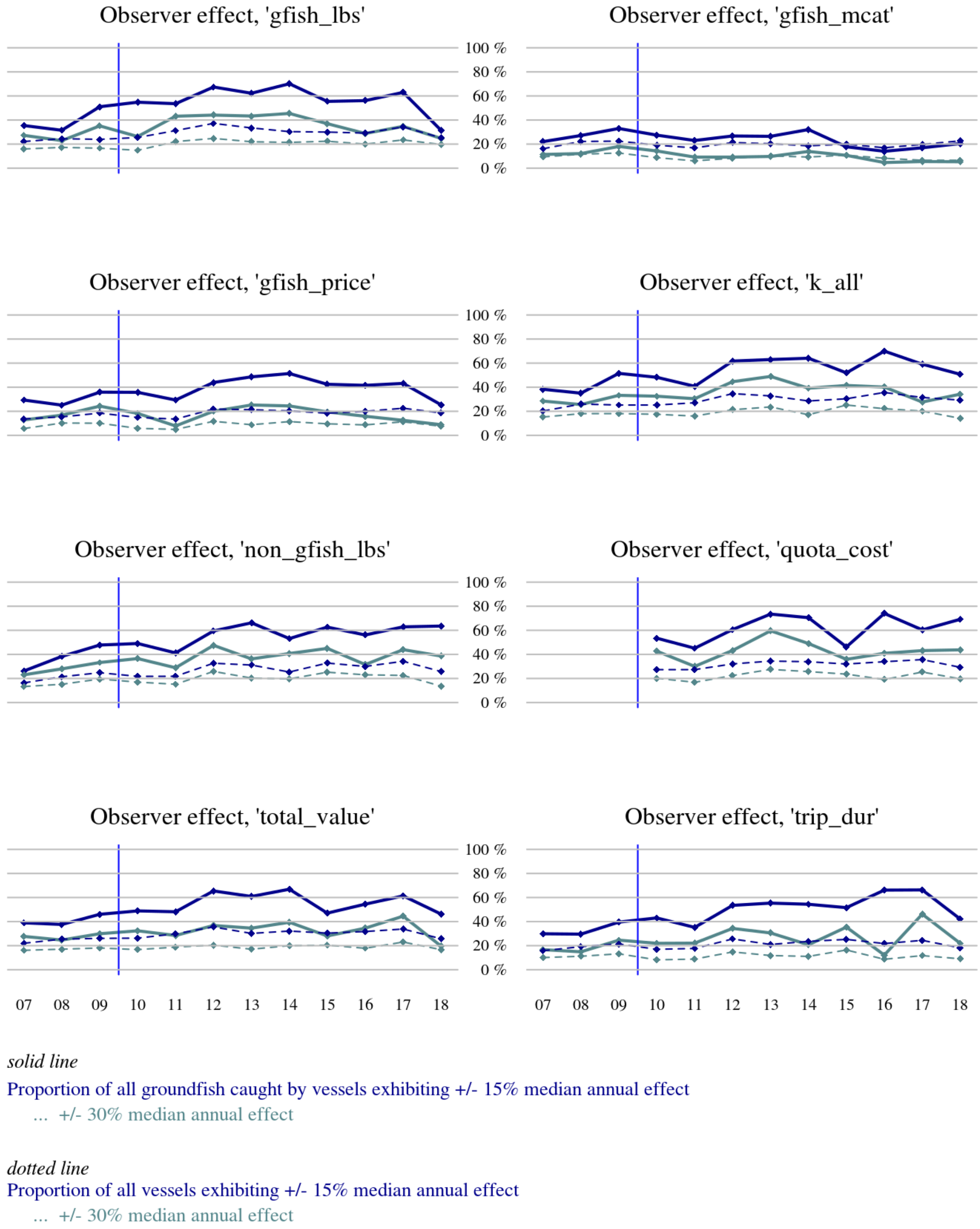

Figure 5: Proportion of vessels and catch accounted for by vessels with median annual observer effect greater than +/- 15 and 30%

#1c

Predicting Gulf of Maine (GOM) cod catch on Northeast Multispecies (groundfish) sector trips: implications for observer bias and fishery catch accounting

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15 April 2019

–DRAFT–

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The National Marine Fisheries Service (NMFS) estimates total groundfish catch across 20 stocks for the Northeast multispecies (groundfish) sector fleet by integrating several sources of information on landings and discards. Landings are reported by dealers for all trips, while discards are known only for ~15–30% of trips in a given year that are selected to carry a fisheries observer from the Northeast Fisheries Observer Program (NEFOP) or the At-Sea Monitoring Program (ASM). Under the assumption that trips can be randomly selected for observation and that the observed fishing activity and harvest outcomes are representative of behavior across the fleet (within defined strata), rates of discarding are calculated and applied to unobserved trips to obtain estimates of the unobserved discards in the fishery. Total catch for a given stock is then the summation of reported landings, observed discards, and the estimated discards on unobserved trips.

Evidence that observed trips are *not* representative of the effort across the fleet has been presented by the Groundfish Plan Development Team (PDT), calling into question the accuracy of the catch estimation methods used by NMFS to monitor the fishery. An increase in the amount of landed groundfish catch on unobserved trips, for example, suggests differences in catch rates that cannot be easily assessed given that total catches (landings + discards) are not known with certainty for unobserved trips (discards are estimated). Other Groundfish PDT work has quantified the incentives to modify fishing behavior in the presence of constraining stocks (e.g., Atlantic cod), which could result in spatial/temporal avoidance on observed trips and illegal discarding of legal-sized fish on unobserved trips. While both empirical and anecdotal evidence suggests that observed trips are not representative, the resulting implications of observer bias on total catch estimation have not been quantified.

Here, we used observed trips in the Gulf of Maine (GOM) stock area to model cod catch while accounting for typical effort attributes (e.g., total kept catch, vessel size, trip length) in addition to spatial and temporal covariance in catch. Using this predictive model, we then predicted total catch (kept + discarded) on unobserved trips and compared the summed predictions across a fishing season to the catch estimates for sectors reported by NMFS. Discrepancies suggest the potential for unreported catch.

Methods

Data

The catch data came from the Greater Atlantic Regional Fisheries Office (GARFO) database known as the Data Matching & Identification System (DMIS) which integrates multiple sources of information including dealer records, Vessel Trip Reports (VTRs), and NEFOP/ASM observer records for all commercial fisheries trips. The data were limited to groundfish trips (or subtrips) taken by sector vessels in fishing years (FY)

2011, 2013, 2015, and 2017 using otter trawls (OTF) or gillnets (GNS) in the GOM stock area (as defined by the VTR). These years were chosen as a reasonable representation of the sector management program (implemented in 2010). Subtrips are defined as fishing effort in a single NMFS statistical area (and gear), allowing for a focus exclusively on GOM effort, and landings from OTF and GNS vessels comprise >95% of cod catch for sector vessels. Records were also limited to those trips with a VTR-recorded latitude and longitude location, which included >99% of available trips. Finally, we further limited the data to those trips with reported landings of >0 lbs for cod. This last choice reflected a desire to simplify the modeling by removing the encounter process (i.e., whether a trip encountered cod), recognizing that any trips with unreported cod would be missed.

For each fishing year and gear type, the data were split between observed and unobserved trips. Total cod catch on an observed trip included the landings (i.e., kept catch) reported by the dealer and the discards recorded by the observer. Unobserved trips had discards assigned by DMIS according to a rate as calculated by observed trips within the same stratum (i.e., gear, stock area), consistent with the Standardized Bycatch Reporting Methodology (Wigley et al. 2007).

Model fitting: observed trips

The predictive model of cod catch was built using the observed trips for each gear and fishing year combination. The model included fixed effects representing attributes of fishing effort and random effects for variation according to vessel permit, space, and time. The spatial and temporal effects were modeled with predictive processes (PPs) to estimate covariances in space and time and partition variation that could be attributed to either dimension (Viana et al. (2013); Finley et al. (2009)).

Total cod catch (discards + landings), y_i, for each trip i was modeled as a Poisson random variable such that:

$$y_i \sim Poisson(\mu_i)$$
$$log(\mu_i) = \mathbf{X}\boldsymbol{\beta} + \nu_j + \omega_1(s_i) + \omega_2(t_i) + \epsilon_i$$

where $\mathbf{X}$ is a vector of predictors for trip i taken by vessel j, and $\boldsymbol{\beta}$ is the vector of fixed effects on the log scale. The model also included a random effect for vessel, v_j; the spatial PP for residual variation due to space, $\omega_1(s_i)$; and the temporal PP for residual variation due to the date of the trip, $\omega_2(t_i)$. Random error not attributed to vessel, space, or time was estimated by ϵ_i, which was modeled by a mean-zero normal distribution with variance σ^2_ϵ. We used a Poisson distribution for expected catch, $E[y_i]$, to accommodate increased variance at larger quantities.

The fixed effects in $\mathbf{X}$ included: 1) intercept; 2) total kept catch; 3) pollock, 4) haddock, 5) winter flounder, and 6) yellowtail flounder landings; 7) trip length and 8) squared trip length; 9) vessel tonnage and 10) squared vessel tonnage. Both trip length and vessel tonnage included squared terms to accommodate non-linear relationships. These covariates were chosen to represent attributes of fishing effort that might correlate with cod catch. The covariates representing catch/landings were log10-transformed (after adding 1). All covariates for the fixed effects were standardized to have mean of 0 and unit variance.

The random effects for space and time relied on spatial and temporal PPs, respectively, that were estimated at a reduced resolution in comparison to the observed data (Viana et al. 2013). The spatial PP was defined at 224 knots spaced on a 15-km grid restricted to where active fishing was recorded (e.g., Fig. 1). The temporal PP was defined at 25 knots spaced every 2 weeks throughout the fishing year. We specified Gaussian processes on the spatial and temporal knots with covariances that were a function of distance (in space or time). Following Viana et al. (2013), one can define a generic covariance function between 2 locations:

$$C(x_a, x_b|\phi) = \sigma^2 \rho(x_a, x_b|\phi)$$

where $\rho(x_a, x_b|\phi) = exp[-|d_{ab}|/\phi]$ is the correlation between locations x_a and x_b, and d_{ab} is the distance between the locations; σ^2 is the random effect variance; and ϕ is a scale parameter controlling the rate of decay in correlation between points as distance increases. By using coarse-scale spatial/temporal knots on which to define the Gaussian processes, the computational burden of the modeling procedure is greatly reduced. The Gaussian processes were therefore defined as:

$$\omega_1(s^*) \sim GP(0, \sigma_s^2 \rho(s_a, s_b|\phi_s))$$
$$\omega_2(t^*) \sim GP(0, \sigma_t^2 \rho(t_a, t_b|\phi_t))$$

Further details for how the Gaussian processes estimated on the knots relate to the random effects $\omega_1(s)$ and $\omega_2(t)$ estimated for the observed data can be found in Viana et al. (2013) and Finley et al. (2009).

We fit the models using a Bayesian approach and estimated the posterior distributions of parameters via Markov chain Monte Carlo (MCMC) methods with JAGS (Plummer 2003) and R (R Core Team 2018). We used standard vague priors for most parameters, with slightly-informative priors for the scale parameters, $\phi_s \sim Ga(3, 0.066)$, and $\phi_t \sim Ga(3, 0.033)$; and for the spatial and temporal random variances, $\sigma_s \equiv \sigma_t \propto T(\mu = 0, \tau = 1, \nu = 5)[\sigma > 0]$. The latter specification indicates a scaled Half Student-T distribution, which can be useful for constraining variance parameters (Rankin et al. 2016). We also used a highly informative prior for the residual variance (i.e., standard deviation for ϵ_i) such that $\sigma_\epsilon \sim N(0.7, \sigma^2 = 0.0225)$; this prior was chosen after some initial model fitting to stabilize the residual variance estimate. The models were run for 6,000 iterations over 3 chains after an adaption phase of 6,000, resulting in posterior distributions of 18,000 values. Convergence was achieved by examining trace plots and ensuring that the potential scale reduction factor was <1.1 for all parameters (Gelman and Rubin 1992).

Model predictions: unobserved trips

We used the parameter estimates from each model to predict the cod catch on unobserved trips. The linear functions of expected catch were straightforward for the 10 $\hat{\beta}$ estimates (9 covariates with intercept) and vessel-specific random effects, $\hat{\nu}_j$. For vessels with no observed trips (and, hence, no estimated random effect), the vessel-specific random effect was set to 0. For the spatial and temporal random effects, distance matrices were calculated between all unobserved trips and the spatial and temporal knot locations so that expected values of $\hat{\omega}_1(s_i)$ and $\hat{\omega}_2(t_i)$ for each trip i could be calculated. Random error as estimated by $\hat{\sigma}_\epsilon$ was also added to the predictions to capture the full uncertainty in the model. The predictions for all individual trips were summed to estimate a total predicted cod catch for each gear and year, across the full posterior distribution of parameter estimates.

We also made predictions for the observed trips to illustrate how well the models could predict total cod catch without the observation-specific deviations, $\hat{\epsilon}_i$. All other fixed- and random-effect parameter estimates across the full posterior distributions were used as with the unobserved trips. Random error was re-inserted according to estimates of $\hat{\sigma}_\epsilon$ to account for over-dispersion.

Finally, the entire model fitting and prediction process was replicated for pollock to help contextualize the patterns observed for cod. Pollock is an abundant species that is not overfished and has not had a constraining quota during the period of analysis. The only differences in model structure were the species landings included as predictors (haddock, white hake, winter flounder, redfish). The full modeling results for pollock are not presented here, aside from the final predictions of total catch for observed and unobserved trips.

Results

Decreases in the observed catch (discards + landings) of cod between 2011 and 2017 are apparent for vessels using otter trawls and gillnets (Figs. S1–S8 in Supplement 1). The number of observed and unobserved trips also decreased over time (Table 1). Sample sizes for the predictive models ranged from a high of 1,489 trawl trips in 2011 to a low of 183 gillnet trips in 2017.

Table 1: Number of observed and unobserved sector trips taken in the Gulf of Maine with cod landings >0 lbs.

Gear	FY	Observed	Unobserved
OTF	2011	1193	2735
	2013	561	1768
	2015	437	1311
	2017	384	1353
GNS	2011	1489	3416
	2013	555	2059
	2015	295	839
	2017	183	763

Full model results are presented in Supplement 2. The fixed effects estimates varied by gear type and year (Figs. 2–3). Some species had a strong positive relationship with expected cod catch each year (e.g., pollock (β_3) for gillnets), while others had variable relationships (e.g., yellowtail (β_6) in 2017 was negative for gillnets and positive for otter trawls). Kept all (β_2) was a relatively strong predictor of cod catch for otter trawls across all years but decreased gradually for gillnets from 2011 to 2017. Trip length and vessel tonnage were not strongly associated with cod catch, likely due to the effect of kept all.

The amount of random variation explained by spatial location (σ_s) decreased over time for both otter trawl and gillnet vessels (Figs. 4–5). Vessel-specific variation (σ_ν) was as large as temporal variation (σ_t) for most years across both gear types. The patterns in residual spatial variation in observed cod catch (conditional on total kept catch, trip length, etc.) were stronger in the earlier years for both gear types (Figs. 6–7). The spatial patterns also changed between the gear types in later years. For example, in 2017 there appeared to be greater relative catch for inshore otter trawl trips while for gillnet trips, higher relative catches occurred farther offshore. Temporal variation exhibited different patterns between the gear types, and often across years within a gear type (Fig. 8.

The predictions of total cod catch for observed trips were fairly accurate even after removing the trip-specific random effects (ϵ_i) and re-inserting random error (Table 2, Fig. 9). The percentage differences between the reported catch and the posterior mode of predictions was <5% for 6 of the 8 models. The highest difference was in 2013 for otter trawls, where the model under-predicted total catch by 13%.

Table 2: Reported vs. model-predicted cod catch (mt) for **observed** trips, with percentage of reported by which posterior mode differs.

			Posterior distribution				
Gear	FY	Reported catch	Mode	2.5%	50%	97.5%	% Diff.
OTF	2011	819.70	852.25	743.23	849.64	967.96	4
	2013	102.64	89.57	75.59	92.57	114.11	-13
	2015	23.26	21.61	17.73	21.77	26.31	-7
	2017	34.95	36.53	28.93	37.51	48.29	5
GNS	2011	391.03	378.55	339.36	378.47	422.27	-3
	2013	54.72	52.78	45.78	53.87	62.96	-4
	2015	18.16	17.53	14.61	18.16	22.14	-3
	2017	18.79	18.36	13.91	18.76	25.67	-2

The predictions of total cod catch for unobserved trips exhibited a trend across time for gillnets with no apparent pattern for otter trawls (Table 3, Fig. 10). The discrepancy for gillnets increased over the years, with model predictions suggesting greater estimates of cod catch than that which was reported. In 2017, the posterior mode of total catch was 68% larger than the reported catch. For otter trawls, the differences between modes and reported catches were never >15% and varied in direction across the years.

Table 3: Reported vs. model-predicted cod catch (mt) for **unobserved** trips, with percentage of reported by which posterior mode differs.

			Posterior distribution				
Gear	FY	Reported catch	Mode	2.5%	50%	97.5%	% Diff.
OTF	2011	1786.65	2063.37	1829.05	2076.19	2322.05	15
	2013	365.44	333.12	276.58	339.97	416.49	-9
	2015	81.01	78.74	65.61	80.63	97.20	-3
	2017	123.72	140.08	114.71	144.61	177.96	13
GNS	2011	989.78	985.43	888.04	990.10	1110.04	0
	2013	189.80	207.54	174.06	211.30	259.75	9
	2015	50.81	71.45	57.63	74.80	97.14	41
	2017	54.39	91.11	66.66	96.77	143.19	68

The predictions for pollock suggested that our regression models were not as accurate at predicting catch for this species Supplement 3. For observed trips, model predictions were typically higher than reported catch (*always* for gillnets), suggesting a positive bias that was unaccounted for by the fixed effects and structured random effects. As a result, the predictions for unobserved trips are difficult to assess. It should be noted that the relative relationships between the reported catch and the predicted catch were similar between observed and unobserved trips.

Discussion

The predictive models leveraged information from observer data to estimate relationships between cod catch (landings + discards) and measures of effort, other species landings, and random variation attributed to space, time, and vessel. The models fit the observed data well, suggesting that predictions of total cod catch (across a fleet) using structured information might be useful for understanding discrepancies in expected and reported catch.

It appears that discrepancies for gillnet vessels could be indicative of unreported catch, which has increased over time. This assumes that observed trips can adequately represent unobserved trips with regards to "pre-catch" behavior – the manner in which gear is fished and effort expended. We modeled pre-catch behavior using several attributes of effort (e.g., kept all, location) that were expected and shown to influence catch outcomes. If other important attributes of effort were not modeled explicitly, then catch per unit effort (CPUE) of cod estimated by the observed trips may not accurately predict expected catch on unobserved trips. Under the assumption that estimated CPUE is representative, the predicted discrepancies indicate the potential unreported catch that may be attributed to differences in "post-catch" behavior (e.g., non-compliance with discarding regulations mandating retainment of legal-sized fish).

For otter trawls, the erratic pattern of predicted vs. reported cod catch is difficult to explain. It is possible that important pre-catch behavior specific to mobile gear was missing from the model structure (e.g., tow speed, tow length), which would invalidate the transfer of inferences on CPUE from observed trips to unobserved trips. This uncertainty illustrates the general difficulty of measuring fishing effort using limited information at coarse scales, compared to detailed haul-level reporting.

Additional caveats of the modeling process necessitate tempered conclusions. Other statistical distributions for expected catch on a trip (e.g., quasi-Poisson, negative binomial) may provide a better fit to the catch data, though the random error should have been useful at capturing over-dispersion and helping adjust predictions. The scales of the spatial and temporal knots were not explored and other choices may have been better able to estimate the covariances in each dimension. In particular, the majority of fishing effort is expended in a small proportion of the GOM relatively close to shore (e.g., Fig. S1), suggesting that a finer spatial resolution might pick up more nuanced variation in space. This caveat also highlights the limitations of using a single, self-reported latitude and longitude for each subtrip of effort, which likely prevents fine-scale spatial inferences and induces additional uncertainties.

The reduction in effort and observer coverage across time also increases uncertainty for models from later years. For example, the sample size of observed trips for gillnets was almost an order of magnitude smaller in 2017 (n=183) compared to 2011 (n=1,489) (Table 1). A larger model that combines multiple years of data and leverages parameter pooling across years might yield more accurate parameter estimation. Nevertheless, the added complexity of statistical modeling would not overcome any deficiencies in the sampling design or violations regarding the validity of inferences from observed trips to unobserved trips.

The predicted cod catch was 40% and 68% greater than the reported catch in 2015 and 2017, respectively, for unobserved gillnet trips. The time period coincides with highly constraining quotas for the species. These numbers overwhelm the potential error attributed to sub-legal discard estimation that otherwise serves as the target for observer coverage in the fishery. While the modeling effort presented here cannot prove the existence of unreported catch on unobserved trips, it provides an approximation to the scale of the problem.

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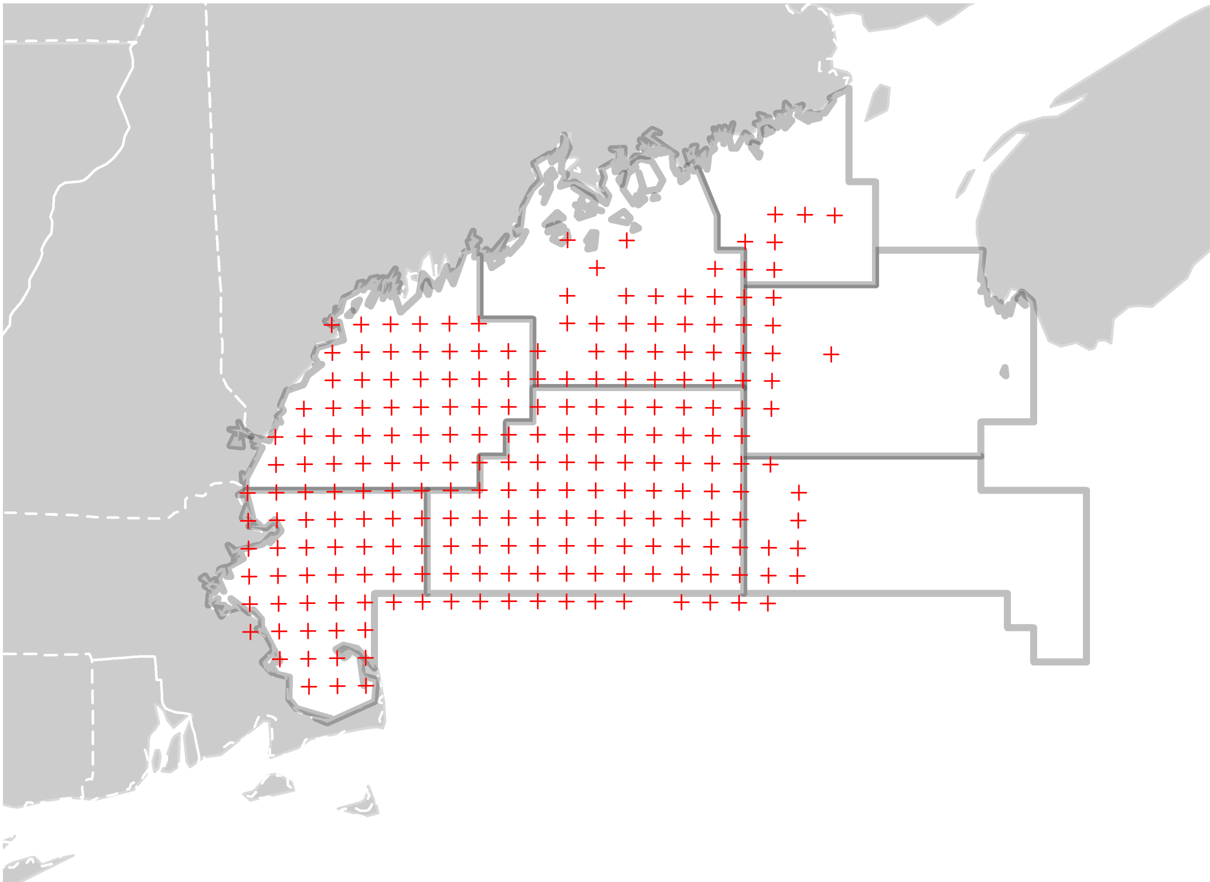

Figure 1: Gulf of Maine broad stock area with NMFS statistical areas for reference and location of the n=224 spatial knots spaced at 15 km used for modeling spatial covariance.

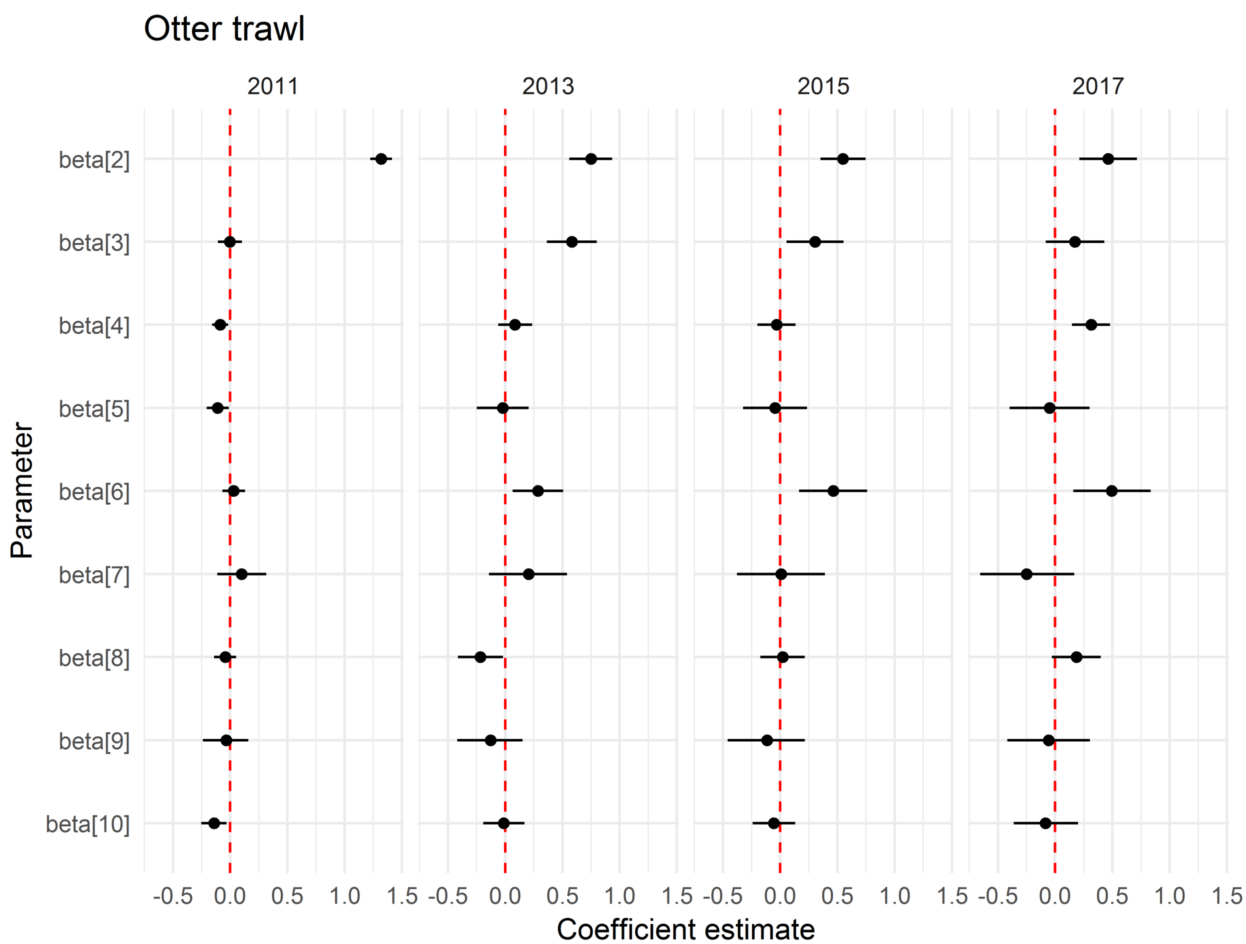

Figure 2: Parameter estimates for log-scale models of GOM cod catch on otter trawl vessels. The fixed effects (β) correspond to the following (absent the intercept): 2) kept all; 3) pollock; 4) haddock; 5) winter flounder; 6) yellowtail flounder; 7) trip length; 8) squared trip length; 9) vessel tonnage; 10) squared vessel tonnage.

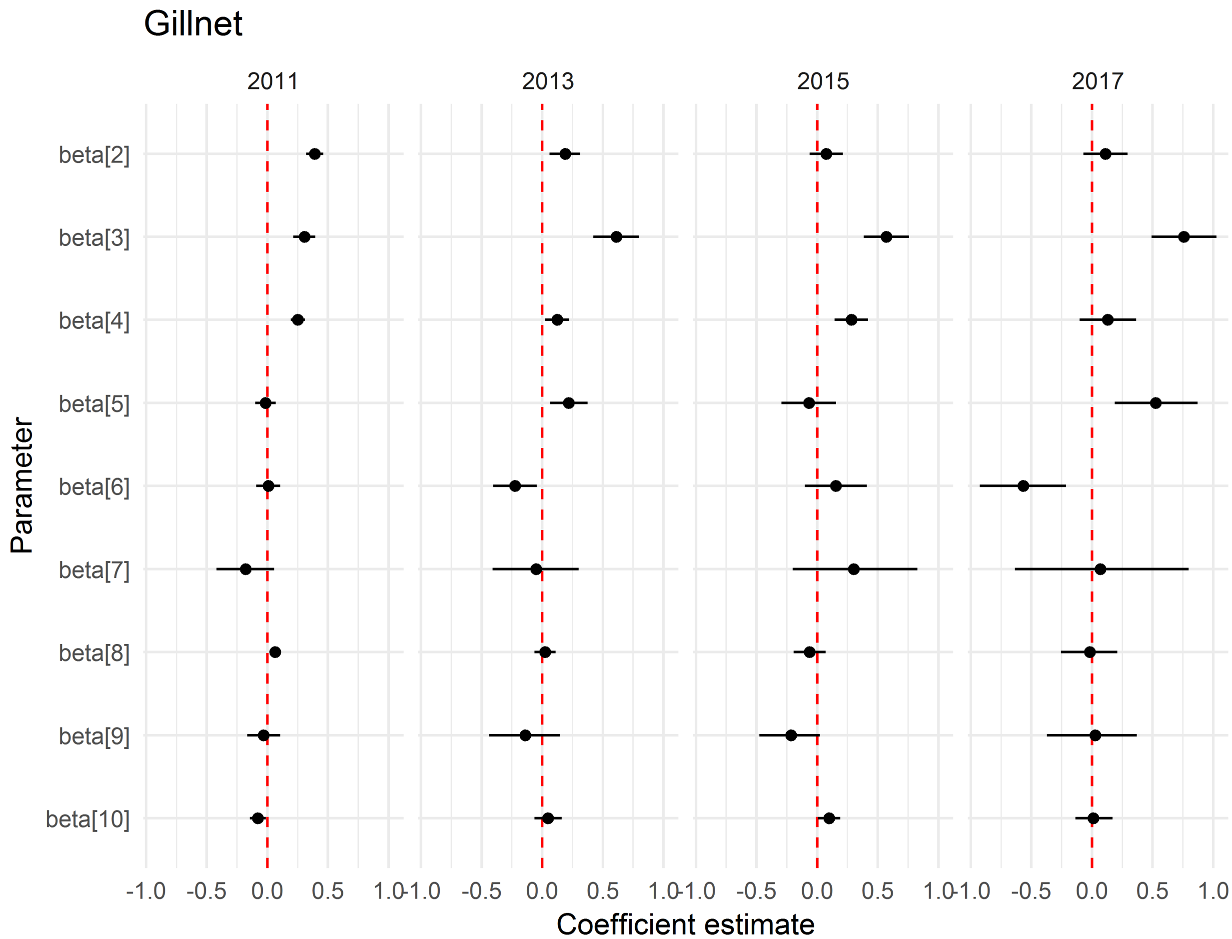

Figure 3: Parameter estimates for log-scale models of GOM cod catch on gillnet vessels. The fixed effects (β) correspond to the following (absent the intercept): 2) kept all; 3) pollock; 4) haddock; 5) winter flounder; 6) yellowtail flounder; 7) trip length; 8) squared trip length; 9) vessel tonnage; 10) squared vessel tonnage.

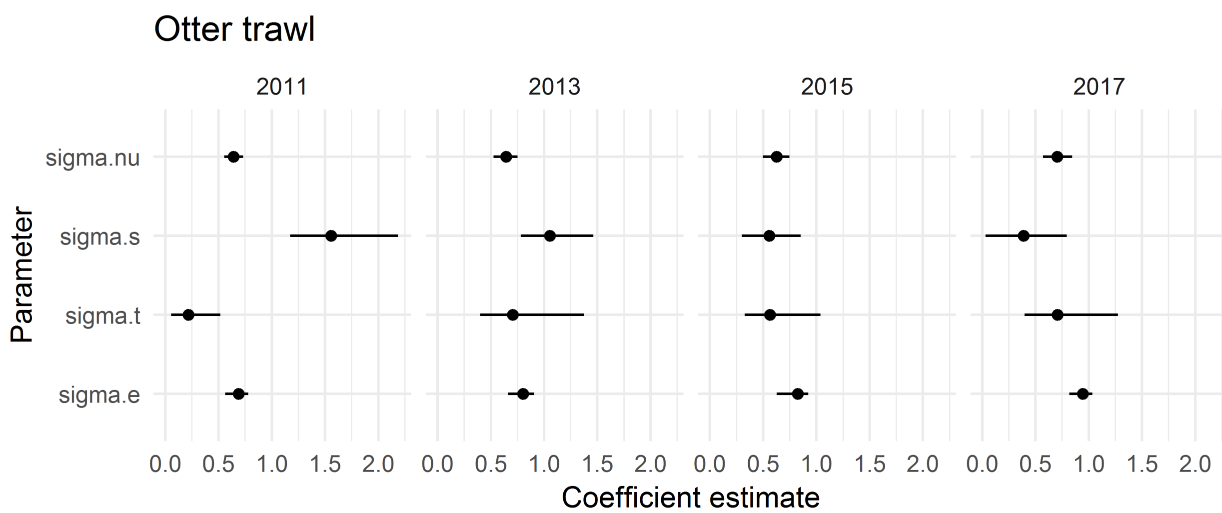

Figure 4: Parameter estimates for log-scale models of GOM cod catch on otter trawl vessels. The variance (standard deviation) estimates correspond to random effects for vessel (σ_ν), space (σ_s), time (σ_t), and residual (σ_ϵ).

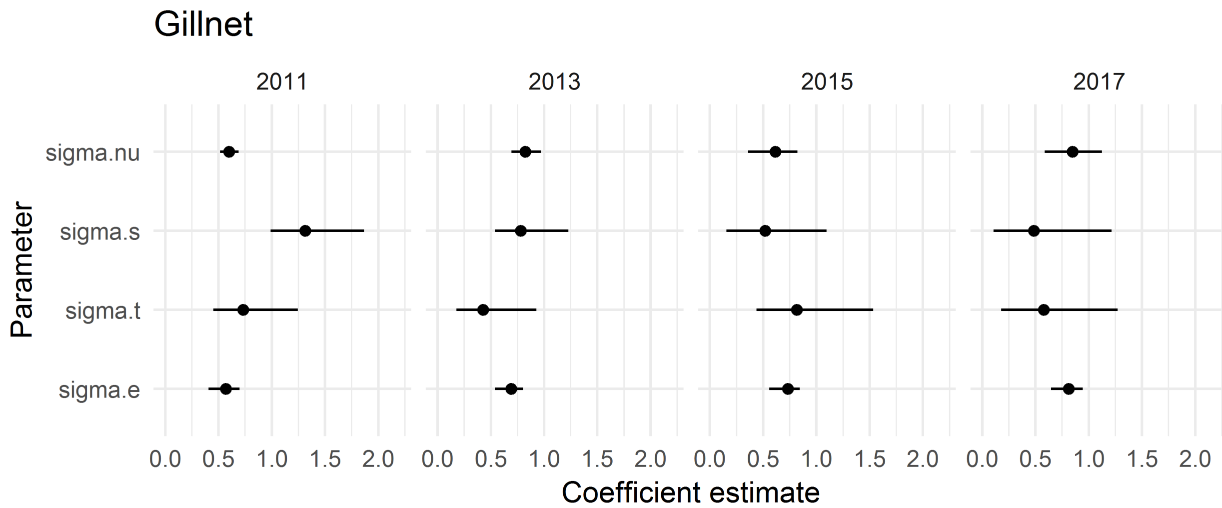

Figure 5: Parameter estimates for log-scale models of GOM cod catch on gillnet vessels. The variance (standard deviation) estimates correspond to random effects for vessel (σ_ν), space (σ_s), time (σ_t), and residual (σ_ϵ).

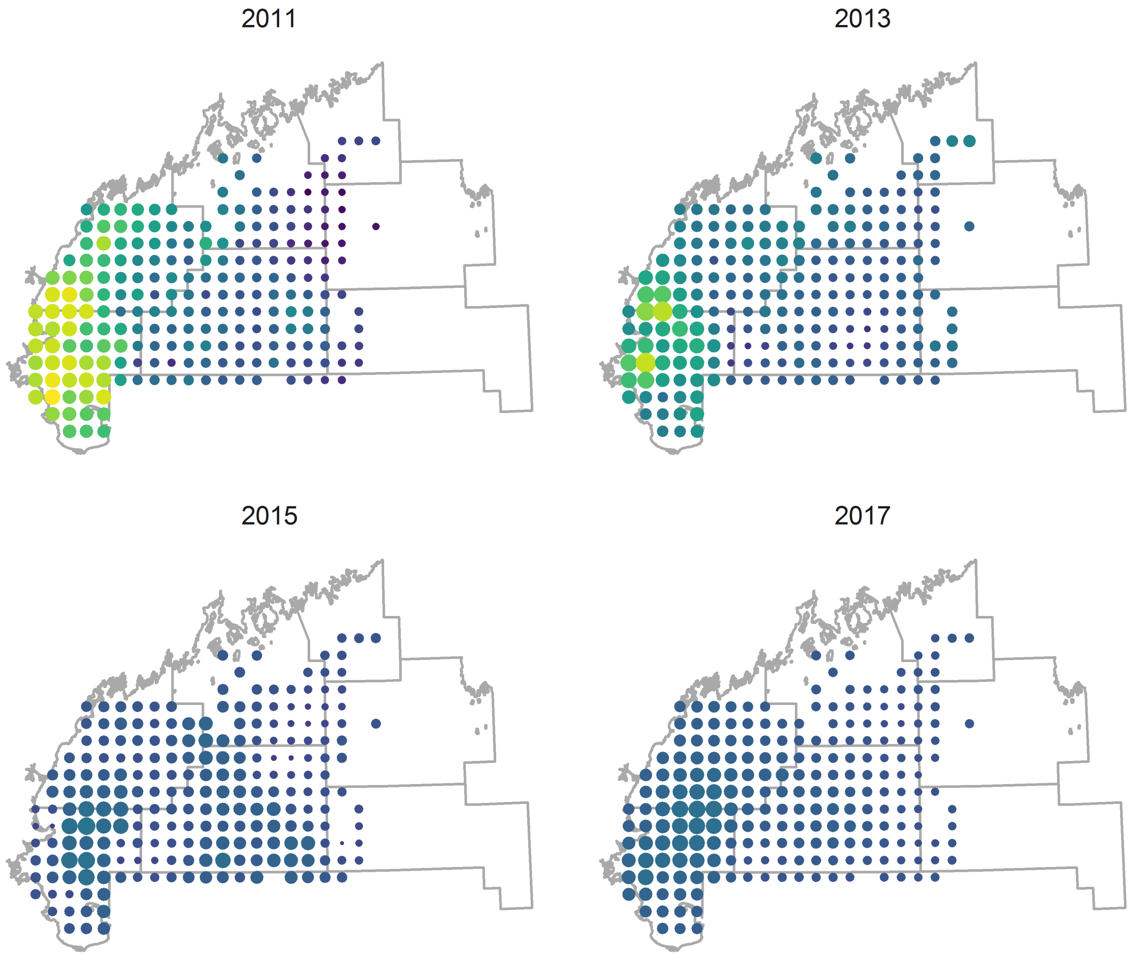

Figure 6: Relative spatial variation in cod catch unexplained by predictors of effort on observed trips taken by sector vessels using otter trawls in the Gulf of Maine during fishing years 2011, 2013, 2015, and 2017. Circle color represents relative variation across years (lighter = higher catch) while circle size represents variation within a year (larger = higher catch).

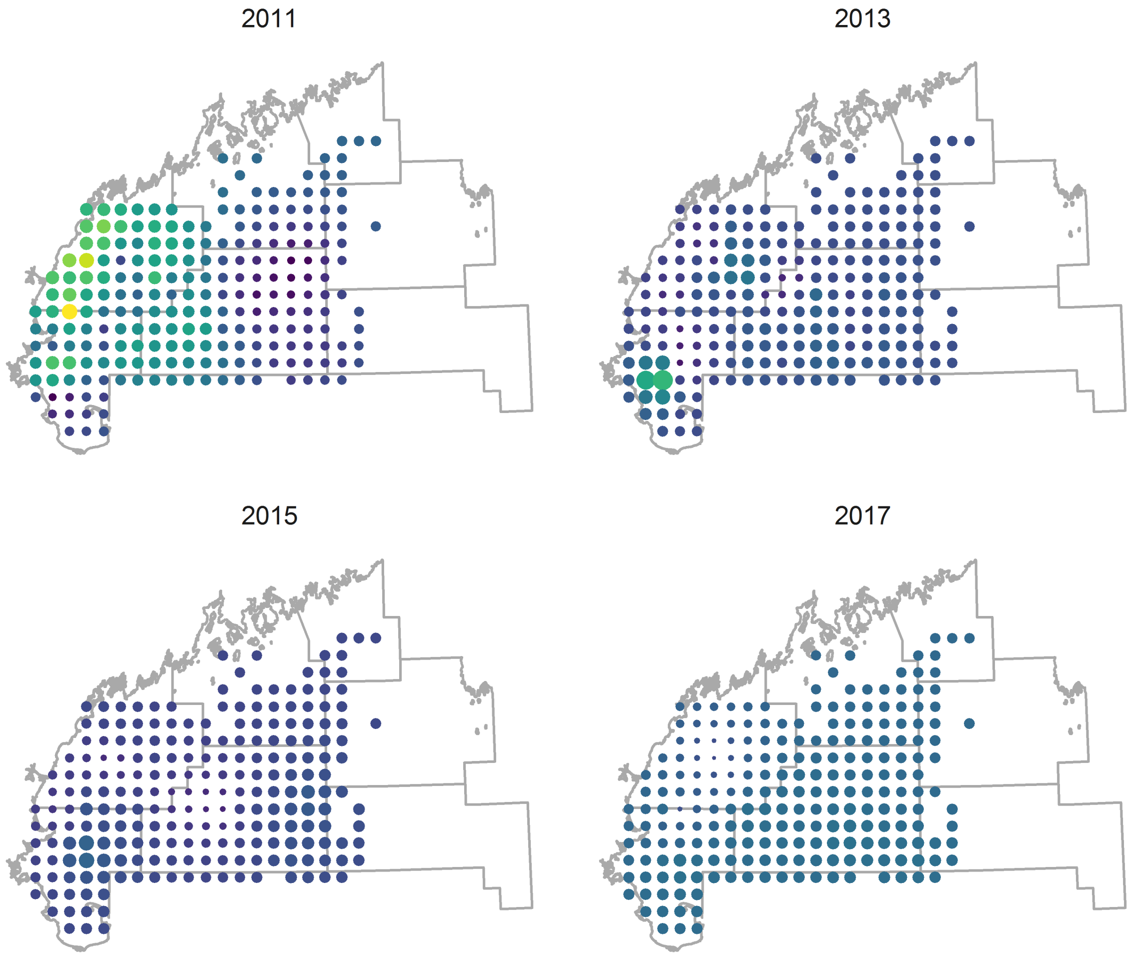

Figure 7: Relative spatial variation in cod catch unexplained by predictors of effort on observed trips taken by sector vessels using gillnets in the Gulf of Maine during fishing years 2011, 2013, 2015, and 2017. Circle color represents relative variation across years (lighter = higher catch) while circle size represents variation within a year (larger = higher catch).

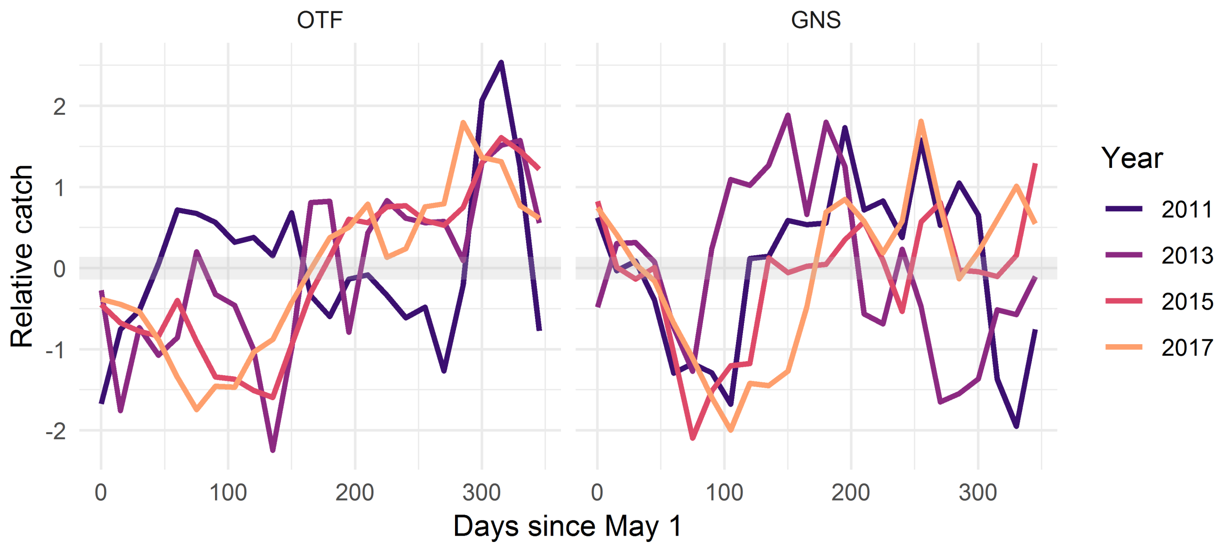

Figure 8: Relative temporal variation in cod catch unexplained by predictors of effort on observed trips taken by sector vessels using otter trawls and gillnets in the Gulf of Maine during fishing years 2011, 2013, 2015, and 2017.

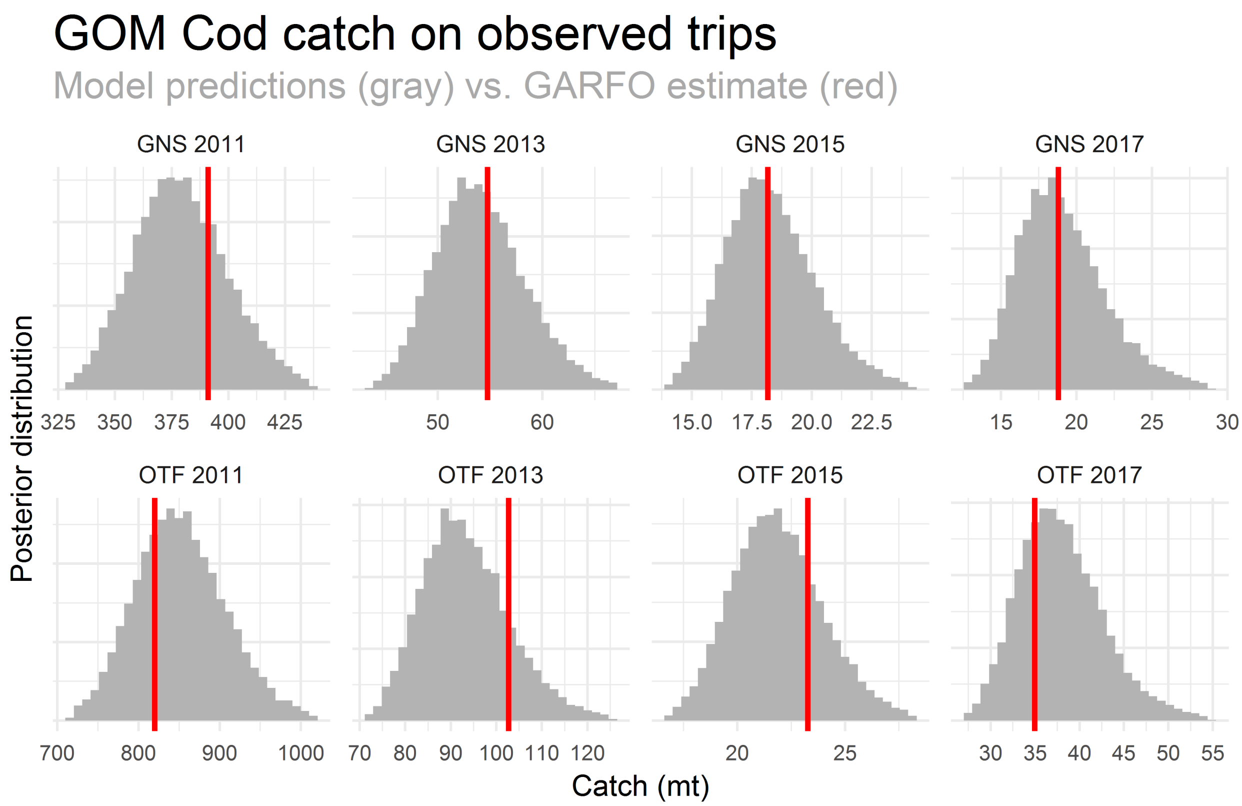

Figure 9: Model predictions of total cod catch (landed + discarded) compared to reported catch (red) on **observed** trips. While observed trips were used to fit the models, estimates of ϵ_i (residual variation) were not used to make predictions. Gear types included otter trawls (OTF) and gillnets (GNS).

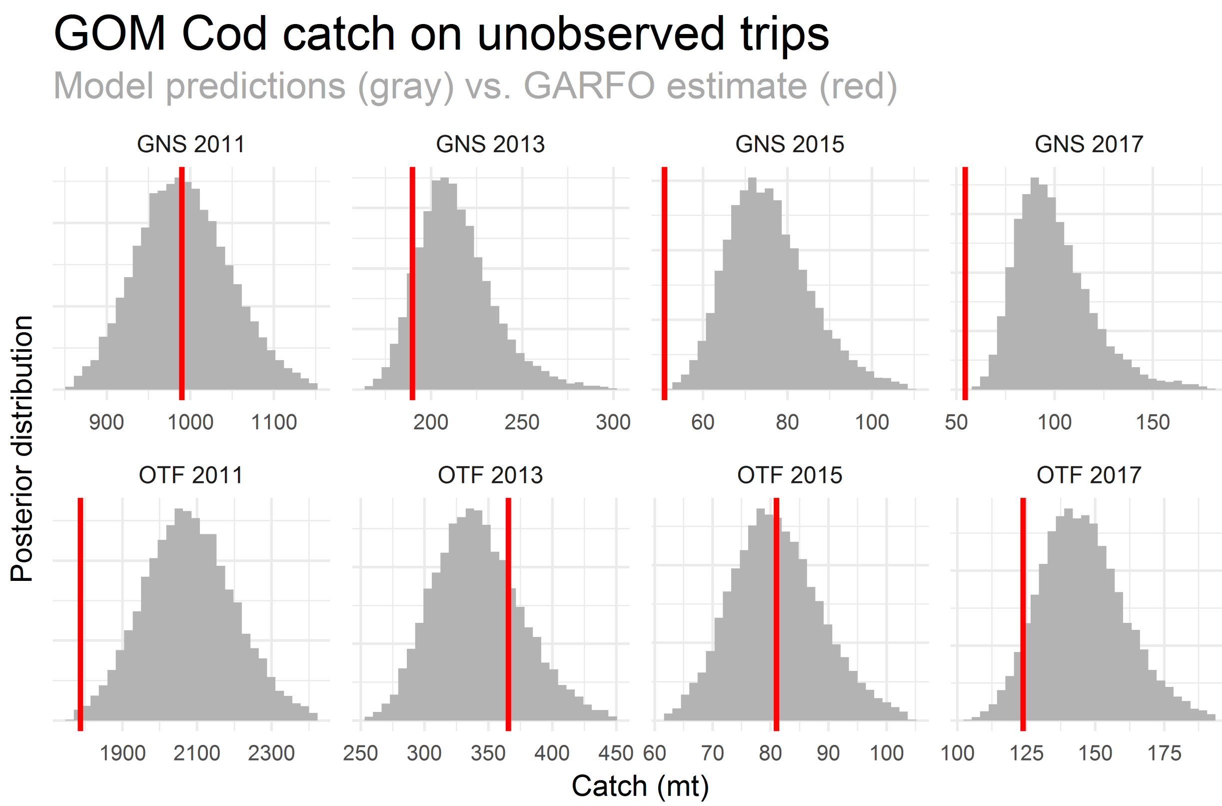

Figure 10: Model predictions of total cod catch (landed + discarded) compared to reported catch (red) on **unobserved** trips. Parameter estimates of fixed and structured random effects from the models for observed trips were used to make predictions. Gear types included otter trawls (OTF) and gillnets (GNS).

Supplement 1 - Observed cod catch

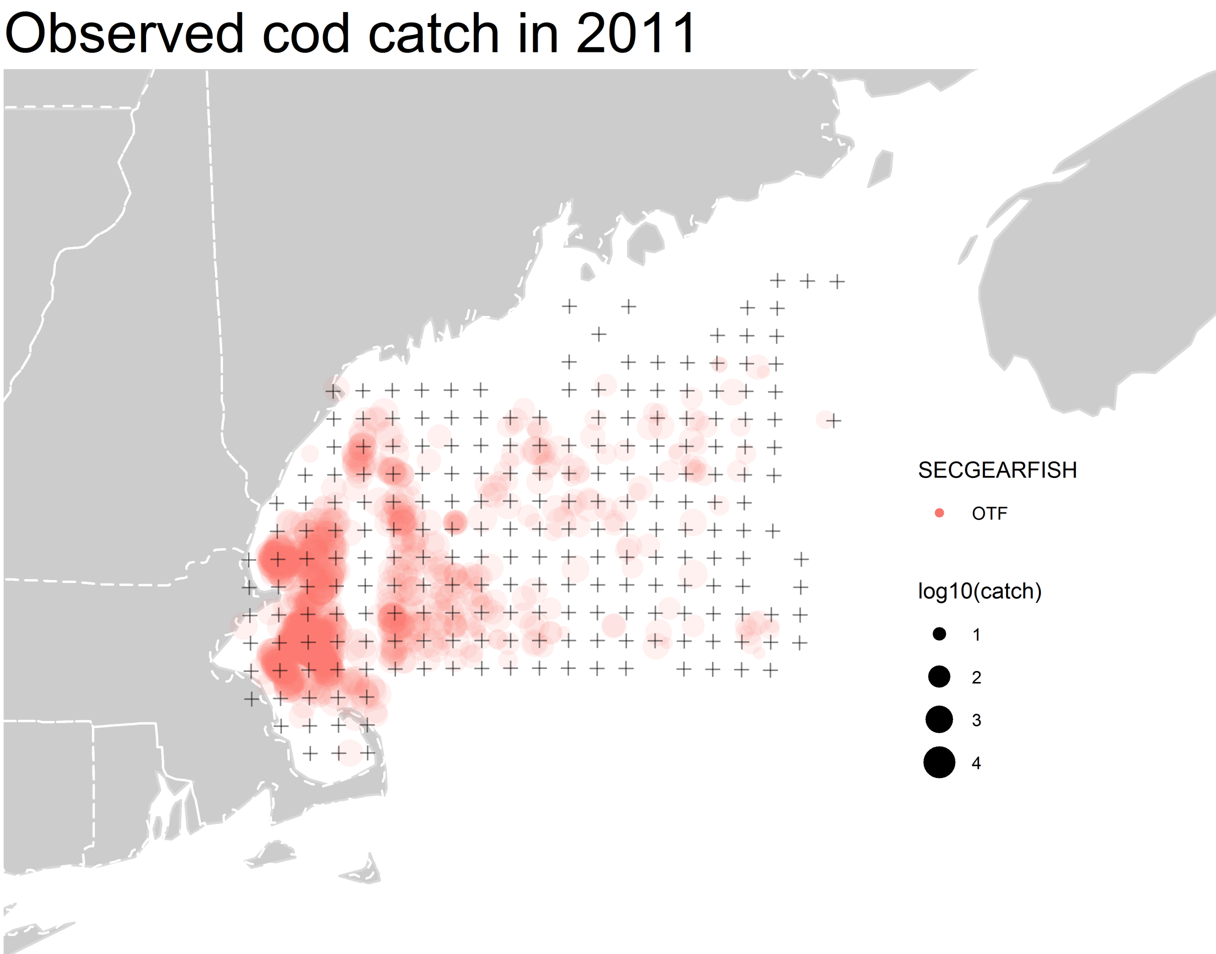

Figure S1: Cod catch (discards + landings) on observed trips by sector vessels using otter trawls in the Gulf of Maine during 2011. Crosses represent the 15-km resolution grid used in the predictive model.

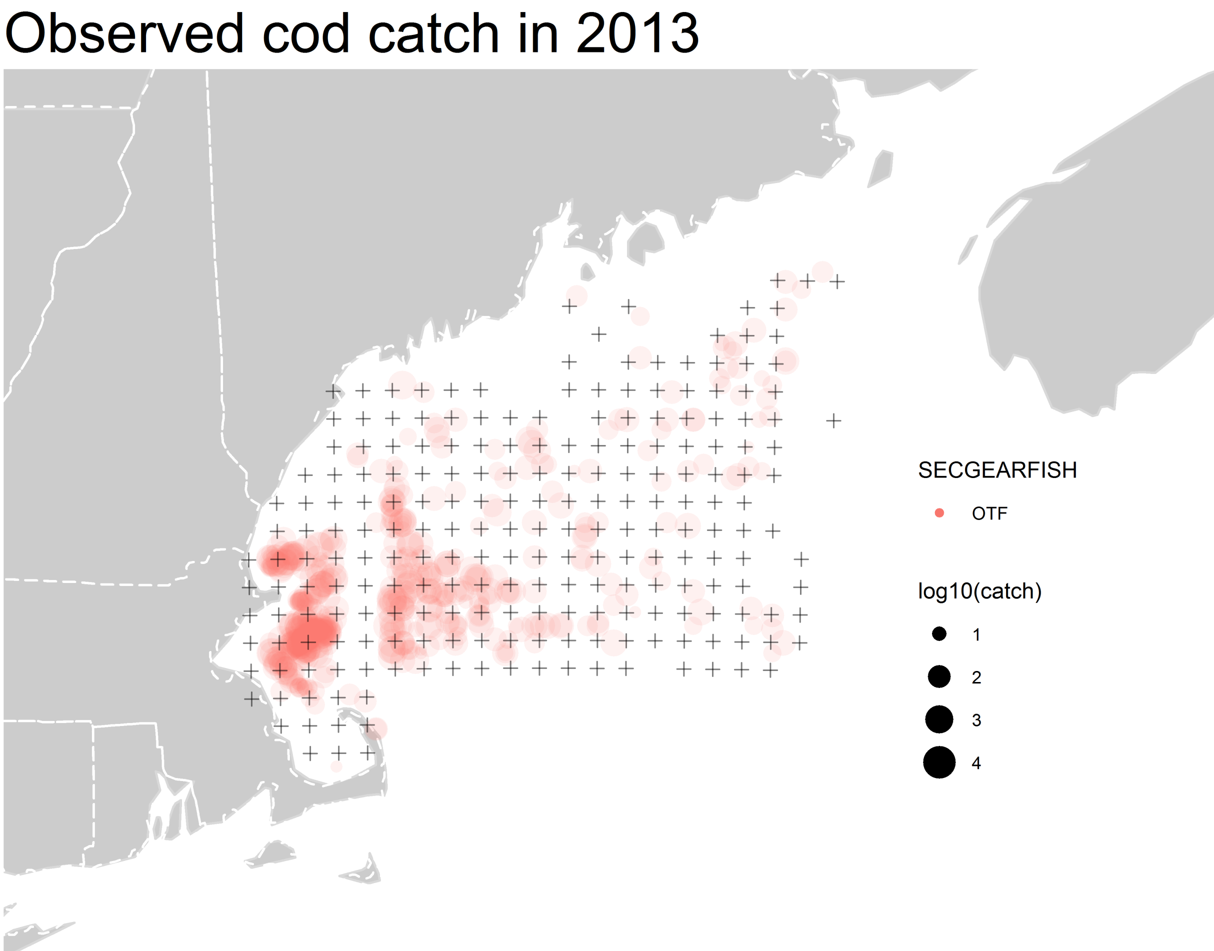

Figure S2: Cod catch (discards + landings) on observed trips by sector vessels using otter trawls in the Gulf of Maine during 2013. Crosses represent the 15-km resolution grid used in the predictive model.

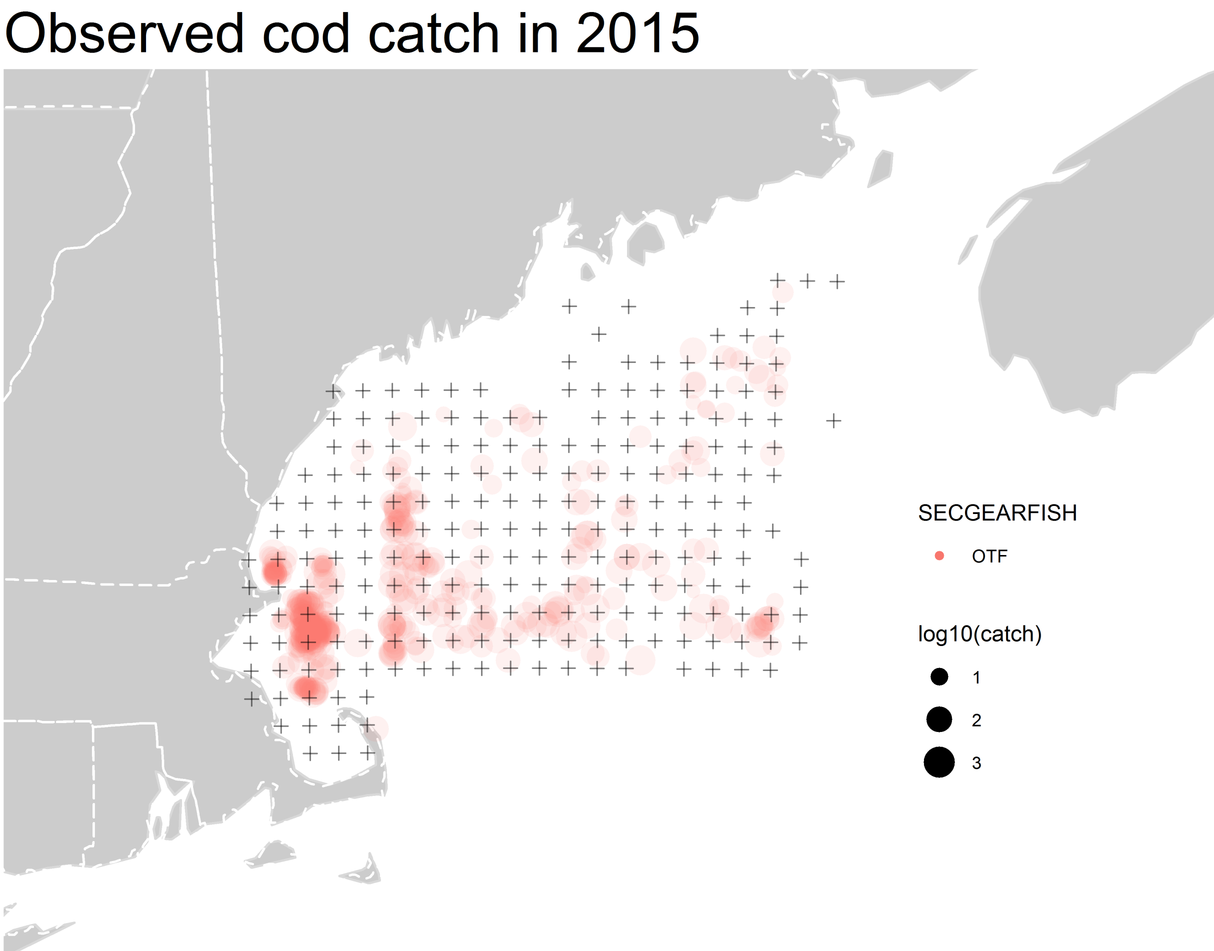

Figure S3: Cod catch (discards + landings) on observed trips by sector vessels using otter trawls in the Gulf of Maine during 2015. Crosses represent the 15-km resolution grid used in the predictive model.

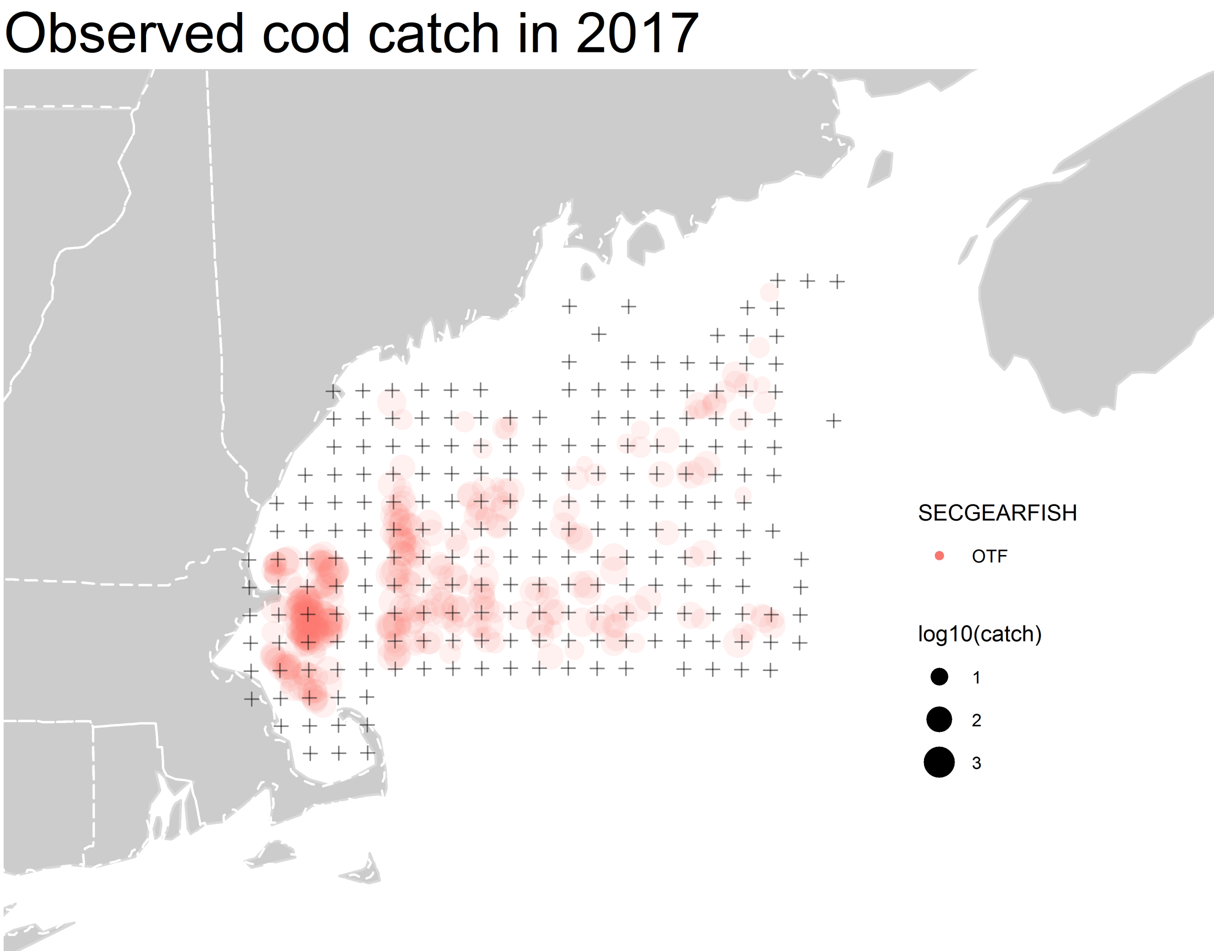

Figure S4: Cod catch (discards + landings) on observed trips by sector vessels using otter trawls in the Gulf of Maine during 2017. Crosses represent the 15-km resolution grid used in the predictive model.

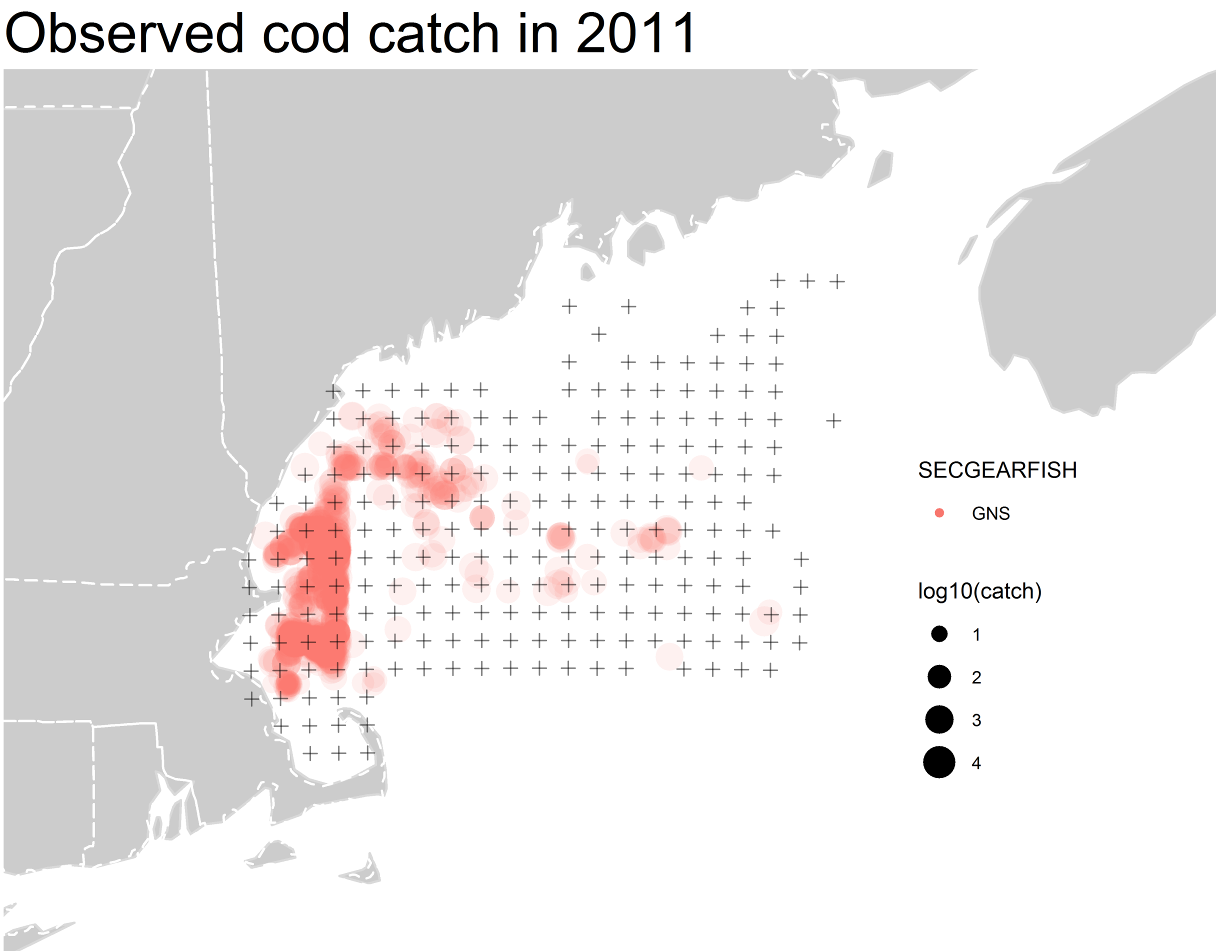

Figure S5: Cod catch (discards + landings) on observed trips by sector vessels using gillnets in the Gulf of Maine during 2011. Crosses represent the 15-km resolution grid used in the predictive model.

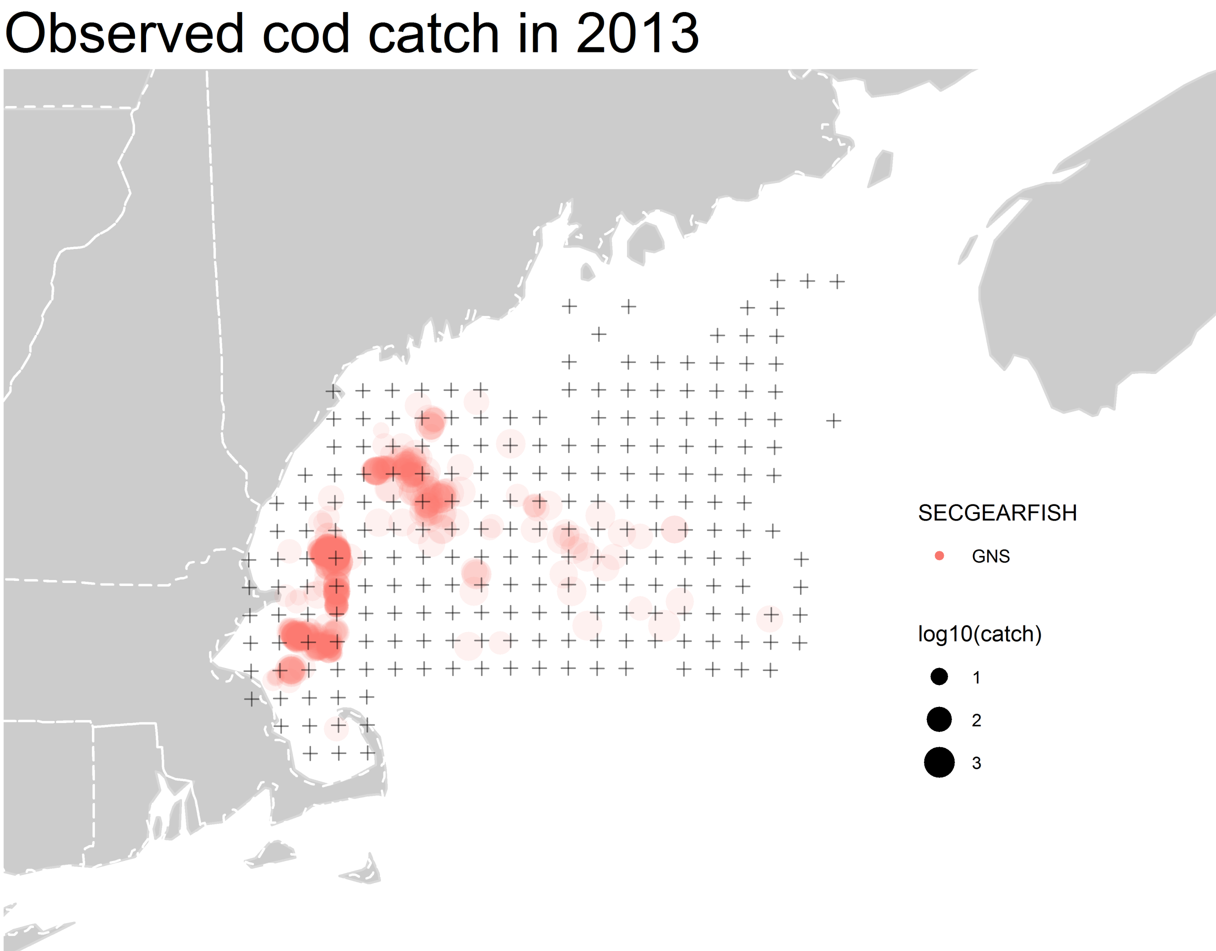

Figure S6: Cod catch (discards + landings) on observed trips by sector vessels using gillnets in the Gulf of Maine during 2013. Crosses represent the 15-km resolution grid used in the predictive model.

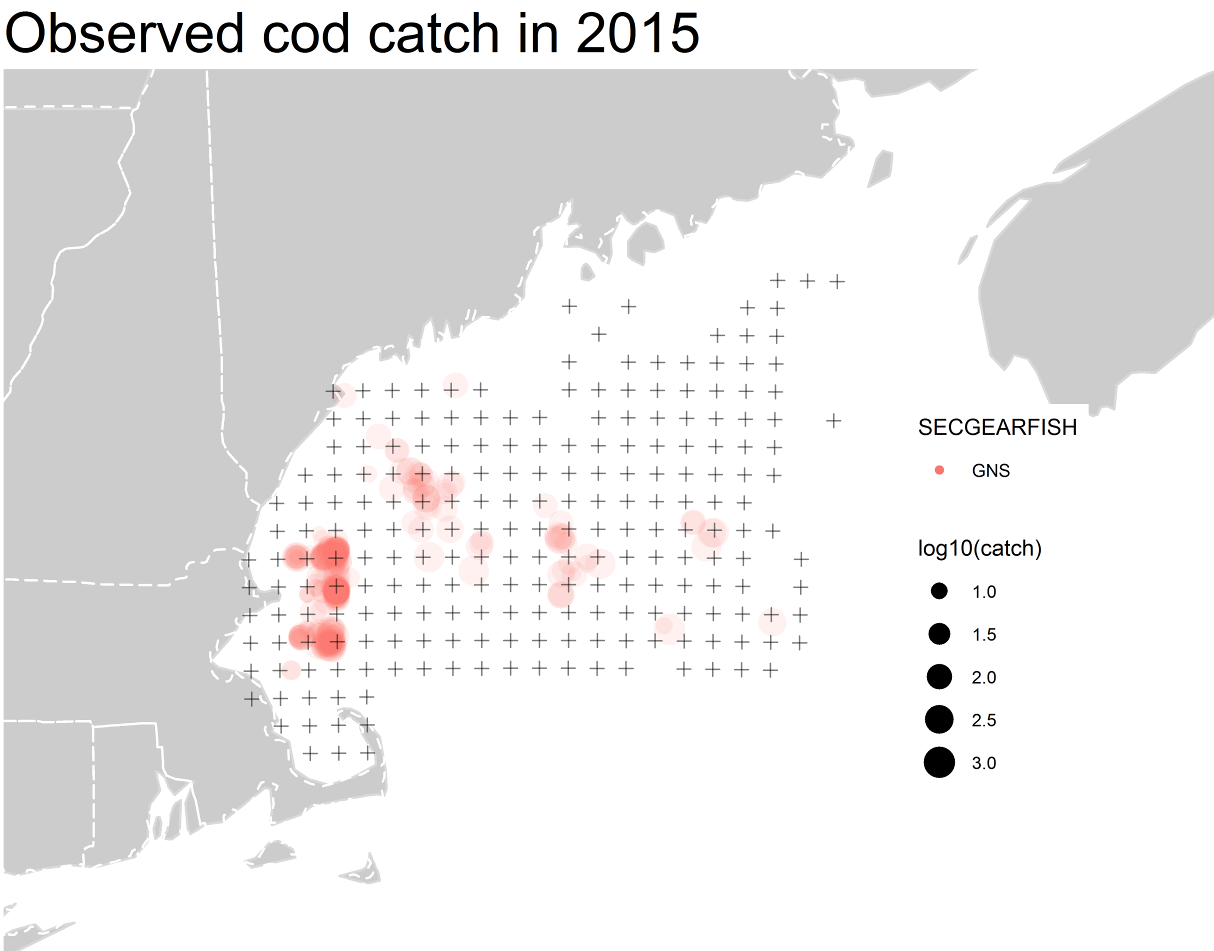

Figure S7: Cod catch (discards + landings) on observed trips by sector vessels using gillnets in the Gulf of Maine during 2015. Crosses represent the 15-km resolution grid used in the predictive model.

Observed cod catch in 2017

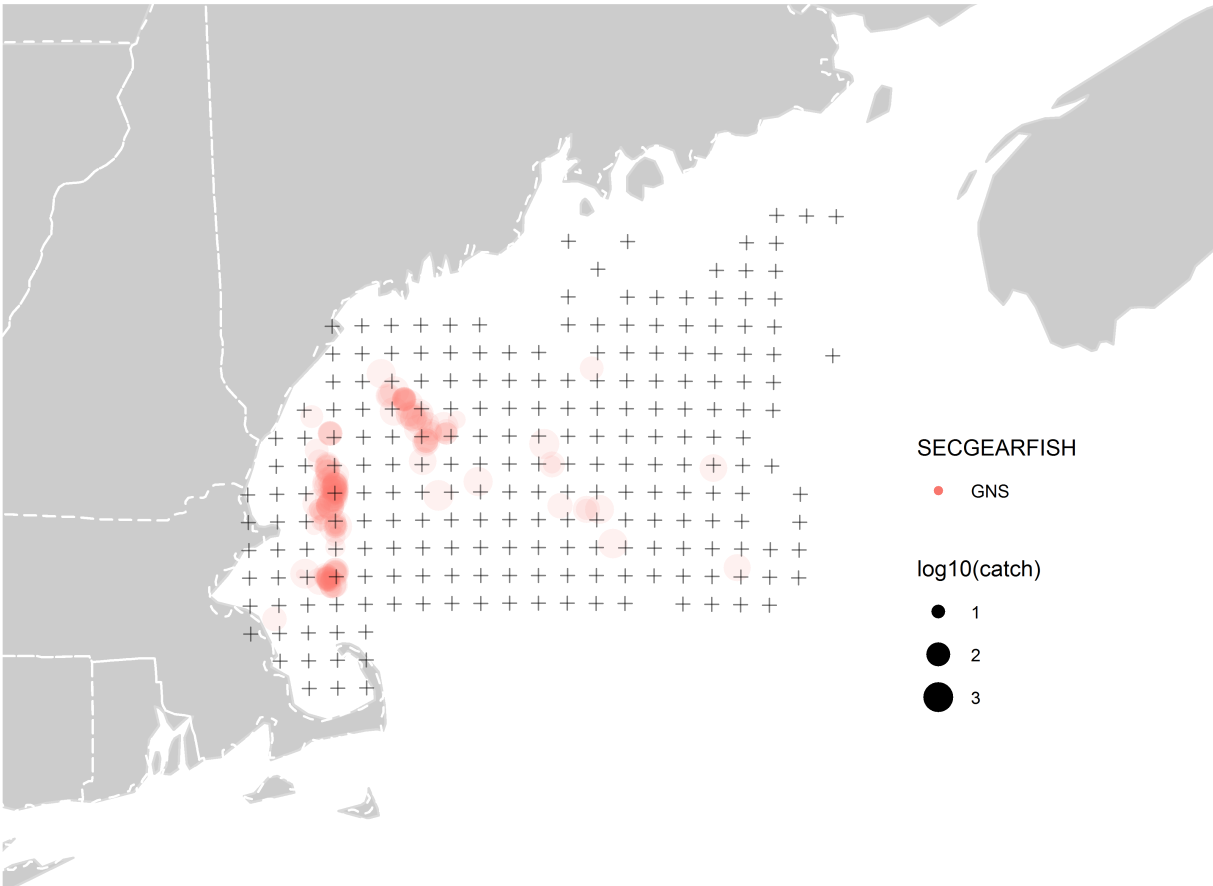

Figure S8: Cod catch (discards + landings) on observed trips by sector vessels using gillnets in the Gulf of Maine during 2017. Crosses represent the 15-km resolution grid used in the predictive model.

Supplement 2 - Parameter estimates

Table S1: Parameter estimates for GOM cod catch. The fixed effects (beta) correspond to the following: 1) intercept; 2) kept all; 3) pollock; 4) haddock; 5) winter flounder; 6) yellowtail flounder; 7) trip length; 8) squared trip length; 9) vessel tonnage; 10) squared vessel tonnage. The variance (standard deviation) estimates correspond to random effects for vessel (nu), space (s), time (t), and residual (e). The phi parameters are scale values of the distance function for decreasing covariance in space (phi.s = km) and time (phi.t = days).

gear	year	par	mean	sd	lower95	median	upper95
OTF	2011	beta[1]	4.564	0.784	2.922	4.597	6.042
OTF	2011	beta[2]	1.319	0.048	1.224	1.319	1.413
OTF	2011	beta[3]	-0.003	0.053	-0.107	-0.003	0.102
OTF	2011	beta[4]	-0.089	0.036	-0.158	-0.088	-0.018
OTF	2011	beta[5]	-0.109	0.049	-0.206	-0.109	-0.013
OTF	2011	beta[6]	0.030	0.051	-0.069	0.030	0.131
OTF	2011	beta[7]	0.100	0.108	-0.112	0.099	0.314
OTF	2011	beta[8]	-0.043	0.049	-0.140	-0.043	0.051
OTF	2011	beta[9]	-0.036	0.101	-0.238	-0.035	0.158
OTF	2011	beta[10]	-0.142	0.056	-0.252	-0.142	-0.031
OTF	2011	sigma.e	0.472	0.074	0.561	0.690	0.779
OTF	2011	sigma.nu	0.414	0.058	0.553	0.642	0.731
OTF	2011	phi.s	71.146	24.394	35.915	66.471	130.715
OTF	2011	sigma.s	2.588	0.876	1.171	1.557	2.185
OTF	2011	phi.t	80.373	49.598	16.349	69.918	201.457
OTF	2011	sigma.t	0.070	0.078	0.055	0.217	0.517
OTF	2013	beta[1]	4.522	0.589	3.327	4.529	5.694
OTF	2013	beta[2]	0.750	0.095	0.561	0.750	0.936
OTF	2013	beta[3]	0.583	0.111	0.364	0.584	0.800
OTF	2013	beta[4]	0.086	0.075	-0.060	0.085	0.235
OTF	2013	beta[5]	-0.020	0.116	-0.248	-0.020	0.206
OTF	2013	beta[6]	0.286	0.113	0.066	0.286	0.507
OTF	2013	beta[7]	0.203	0.176	-0.143	0.204	0.542
OTF	2013	beta[8]	-0.216	0.101	-0.414	-0.216	-0.018
OTF	2013	beta[9]	-0.131	0.145	-0.419	-0.128	0.153
OTF	2013	beta[10]	-0.013	0.092	-0.192	-0.014	0.169
OTF	2013	sigma.e	0.638	0.097	0.662	0.801	0.907
OTF	2013	sigma.nu	0.413	0.074	0.524	0.641	0.751
OTF	2013	phi.s	41.183	16.574	19.711	37.688	84.857
OTF	2013	sigma.s	1.175	0.392	0.780	1.054	1.462
OTF	2013	phi.t	67.192	46.842	7.971	57.068	183.913
OTF	2013	sigma.t	0.635	0.484	0.399	0.706	1.375
OTF	2015	beta[1]	3.862	0.454	2.921	3.868	4.740
OTF	2015	beta[2]	0.548	0.099	0.353	0.548	0.745
OTF	2015	beta[3]	0.302	0.126	0.056	0.303	0.554
OTF	2015	beta[4]	-0.032	0.085	-0.199	-0.032	0.134
OTF	2015	beta[5]	-0.045	0.141	-0.324	-0.045	0.235
OTF	2015	beta[6]	0.463	0.152	0.164	0.463	0.761
OTF	2015	beta[7]	0.007	0.197	-0.377	0.007	0.392
OTF	2015	beta[8]	0.020	0.099	-0.174	0.021	0.214
OTF	2015	beta[9]	-0.116	0.172	-0.459	-0.114	0.215
OTF	2015	beta[10]	-0.057	0.095	-0.241	-0.058	0.132

OTF	2015	sigma.e	0.666	0.115	0.627	0.825	0.924
OTF	2015	sigma.nu	0.395	0.080	0.496	0.627	0.746
OTF	2015	phi.s	25.414	15.310	7.338	21.598	66.064
OTF	2015	sigma.s	0.339	0.169	0.298	0.558	0.851
OTF	2015	phi.t	118.338	54.685	43.179	107.951	253.060
OTF	2015	sigma.t	0.388	0.266	0.327	0.564	1.037
OTF	2017	beta[1]	3.936	0.579	2.740	3.942	5.079
OTF	2017	beta[2]	0.463	0.128	0.211	0.464	0.715
OTF	2017	beta[3]	0.171	0.131	-0.083	0.171	0.431
OTF	2017	beta[4]	0.315	0.085	0.146	0.316	0.480
OTF	2017	beta[5]	-0.048	0.178	-0.397	-0.048	0.300
OTF	2017	beta[6]	0.493	0.174	0.158	0.493	0.833
OTF	2017	beta[7]	-0.248	0.211	-0.655	-0.250	0.167
OTF	2017	beta[8]	0.186	0.110	-0.030	0.186	0.397
OTF	2017	beta[9]	-0.056	0.185	-0.419	-0.057	0.303
OTF	2017	beta[10]	-0.084	0.143	-0.361	-0.085	0.199
OTF	2017	sigma.e	0.885	0.103	0.817	0.942	1.035
OTF	2017	sigma.nu	0.503	0.099	0.573	0.705	0.844
OTF	2017	phi.s	55.695	30.616	7.670	51.016	128.652
OTF	2017	sigma.s	0.194	0.172	0.032	0.389	0.793
OTF	2017	phi.t	111.238	51.655	36.305	102.270	233.774
OTF	2017	sigma.t	0.599	0.396	0.396	0.706	1.275
GNS	2011	beta[1]	4.874	0.711	3.386	4.894	6.247
GNS	2011	beta[2]	0.391	0.037	0.319	0.392	0.463
GNS	2011	beta[3]	0.305	0.046	0.215	0.305	0.395
GNS	2011	beta[4]	0.251	0.029	0.193	0.251	0.309
GNS	2011	beta[5]	-0.016	0.043	-0.100	-0.016	0.068
GNS	2011	beta[6]	0.007	0.050	-0.092	0.007	0.105
GNS	2011	beta[7]	-0.179	0.122	-0.419	-0.179	0.056
GNS	2011	beta[8]	0.062	0.021	0.022	0.062	0.103
GNS	2011	beta[9]	-0.031	0.069	-0.166	-0.031	0.105
GNS	2011	beta[10]	-0.079	0.034	-0.144	-0.078	-0.013
GNS	2011	sigma.e	0.323	0.082	0.407	0.568	0.696
GNS	2011	sigma.nu	0.360	0.053	0.516	0.597	0.688
GNS	2011	phi.s	39.096	15.541	19.710	35.216	78.313
GNS	2011	sigma.s	1.863	0.643	0.988	1.314	1.867
GNS	2011	phi.t	86.421	44.190	30.928	76.352	196.155
GNS	2011	sigma.t	0.623	0.362	0.451	0.729	1.246
GNS	2013	beta[1]	4.459	0.430	3.579	4.469	5.296
GNS	2013	beta[2]	0.188	0.065	0.061	0.188	0.315
GNS	2013	beta[3]	0.611	0.095	0.422	0.611	0.799
GNS	2013	beta[4]	0.123	0.051	0.022	0.123	0.222
GNS	2013	beta[5]	0.219	0.078	0.065	0.220	0.373
GNS	2013	beta[6]	-0.225	0.091	-0.403	-0.225	-0.046
GNS	2013	beta[7]	-0.051	0.182	-0.410	-0.051	0.300
GNS	2013	beta[8]	0.024	0.045	-0.063	0.024	0.112
GNS	2013	beta[9]	-0.144	0.148	-0.439	-0.142	0.143
GNS	2013	beta[10]	0.047	0.057	-0.064	0.047	0.161
GNS	2013	sigma.e	0.475	0.090	0.539	0.692	0.802
GNS	2013	sigma.nu	0.685	0.117	0.693	0.822	0.969
GNS	2013	phi.s	24.671	13.834	9.652	20.761	64.388
GNS	2013	sigma.s	0.677	0.307	0.539	0.780	1.228
GNS	2013	phi.t	77.602	51.374	12.157	66.315	205.718
GNS	2013	sigma.t	0.246	0.231	0.176	0.425	0.929

GNS	2015	beta[1]	4.357	0.619	3.113	4.350	5.637
GNS	2015	beta[2]	0.075	0.070	-0.061	0.075	0.212
GNS	2015	beta[3]	0.571	0.096	0.383	0.571	0.758
GNS	2015	beta[4]	0.283	0.070	0.143	0.283	0.421
GNS	2015	beta[5]	-0.067	0.115	-0.294	-0.068	0.157
GNS	2015	beta[6]	0.153	0.130	-0.102	0.154	0.409
GNS	2015	beta[7]	0.305	0.261	-0.202	0.302	0.828
GNS	2015	beta[8]	-0.062	0.066	-0.195	-0.062	0.070
GNS	2015	beta[9]	-0.219	0.127	-0.476	-0.215	0.022
GNS	2015	beta[10]	0.100	0.046	0.009	0.099	0.191
GNS	2015	sigma.e	0.531	0.098	0.558	0.733	0.841
GNS	2015	sigma.nu	0.386	0.137	0.359	0.616	0.822
GNS	2015	phi.s	44.825	26.631	10.498	39.094	111.540
GNS	2015	sigma.s	0.368	0.339	0.155	0.520	1.096
GNS	2015	phi.t	87.385	49.409	22.135	77.556	207.843
GNS	2015	sigma.t	0.814	0.570	0.438	0.814	1.533
GNS	2017	beta[1]	4.870	0.584	3.772	4.849	6.088
GNS	2017	beta[2]	0.111	0.093	-0.071	0.111	0.293
GNS	2017	beta[3]	0.758	0.137	0.491	0.758	1.026
GNS	2017	beta[4]	0.130	0.120	-0.103	0.131	0.365
GNS	2017	beta[5]	0.526	0.173	0.188	0.526	0.870
GNS	2017	beta[6]	-0.567	0.183	-0.926	-0.566	-0.214
GNS	2017	beta[7]	0.072	0.365	-0.635	0.068	0.797
GNS	2017	beta[8]	-0.020	0.118	-0.255	-0.019	0.208
GNS	2017	beta[9]	0.017	0.189	-0.371	0.025	0.370
GNS	2017	beta[10]	0.013	0.077	-0.137	0.012	0.169
GNS	2017	sigma.e	0.660	0.119	0.646	0.813	0.944
GNS	2017	sigma.nu	0.742	0.236	0.587	0.848	1.125
GNS	2017	phi.s	43.795	25.690	8.319	39.230	106.607
GNS	2017	sigma.s	0.356	0.403	0.105	0.485	1.214
GNS	2017	phi.t	89.952	50.106	21.919	80.157	212.261
GNS	2017	sigma.t	0.456	0.431	0.179	0.576	1.272

Supplement 3 - Total pollock catch predictions

Table S2: Reported vs. model-predicted pollock catch (mt) for **observed** trips, with percentage of reported by which posterior mode differs.

			Posterior distribution				
Gear	FY	Reported catch	Mode	2.5%	50%	97.5%	% Diff.
OTF	2011	918.34	1033.47	785.78	1071.88	1421.69	13
	2013	548.34	460.57	341.19	493.03	722.94	-16
	2015	316.95	322.34	224.57	342.43	526.34	2
	2017	388.20	451.66	303.87	491.37	766.13	16
GNS	2011	562.31	664.21	528.18	671.78	855.61	18
	2013	331.07	368.62	303.99	377.69	470.74	11
	2015	135.68	165.07	97.35	187.61	342.10	22
	2017	63.26	77.20	38.84	98.95	256.69	22

Table S3: Reported vs. model-predicted pollock catch (mt) for **unobserved** trips, with percentage of reported by which posterior mode differs.

			Posterior distribution				
Gear	FY	Reported catch	Mode	2.5%	50%	97.5%	% Diff.
OTF	2011	1871.59	1793.86	1414.39	1856.95	2418.36	-4
	2013	1935.48	1430.84	1031.71	1520.90	2183.48	-26
	2015	1159.73	1100.77	801.81	1142.12	1596.86	-5
	2017	1641.09	2397.78	1638.53	2595.74	4082.72	46
GNS	2011	1642.61	2018.28	1621.21	2045.43	2602.62	23
	2013	1125.62	1501.24	1190.50	1542.43	1989.79	33
	2015	564.31	1614.06	744.25	1995.07	4911.52	186
	2017	311.01	447.34	235.18	539.05	1099.93	44

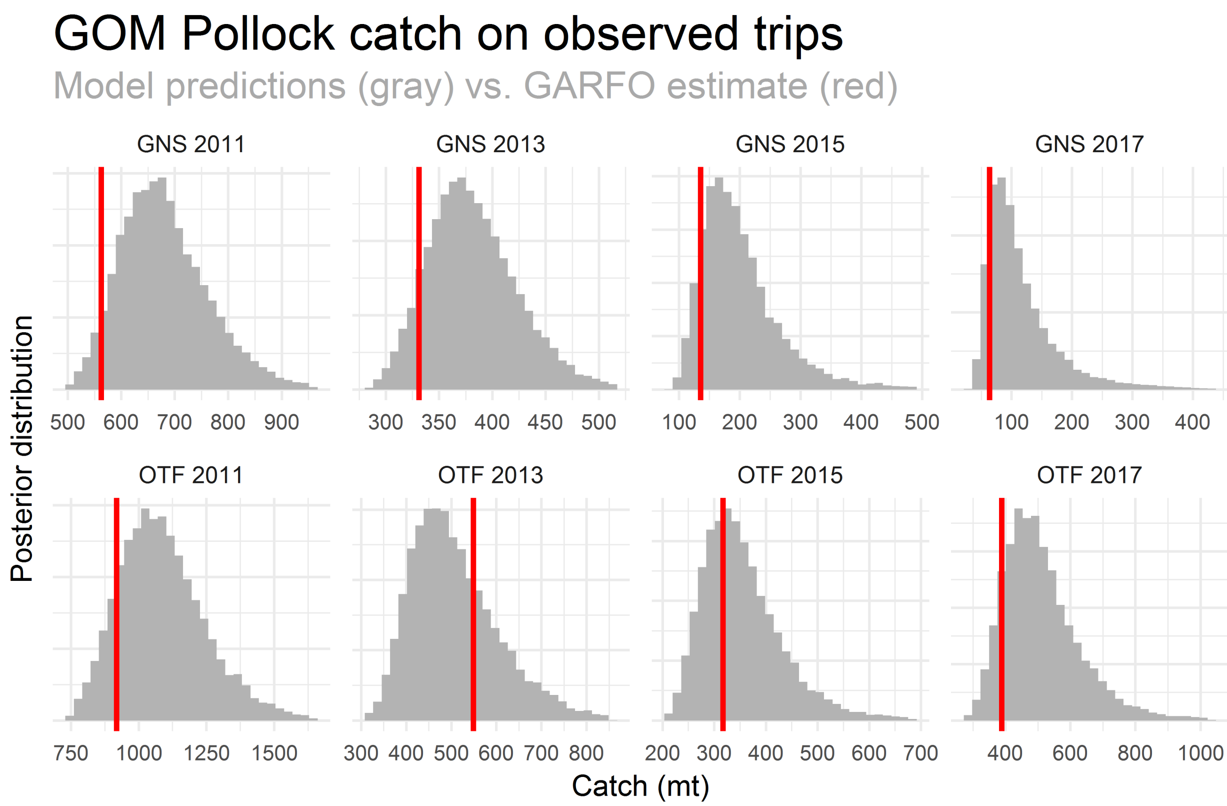

Figure S9: Model predictions of total pollock catch (landed + discarded) compared to reported catch (red) on **observed** trips. While observed trips were used to fit the models, estimates of ϵ_i (residual variation) were not used to make predictions. Gear types included otter trawls (OTF) and gillnets (GNS).

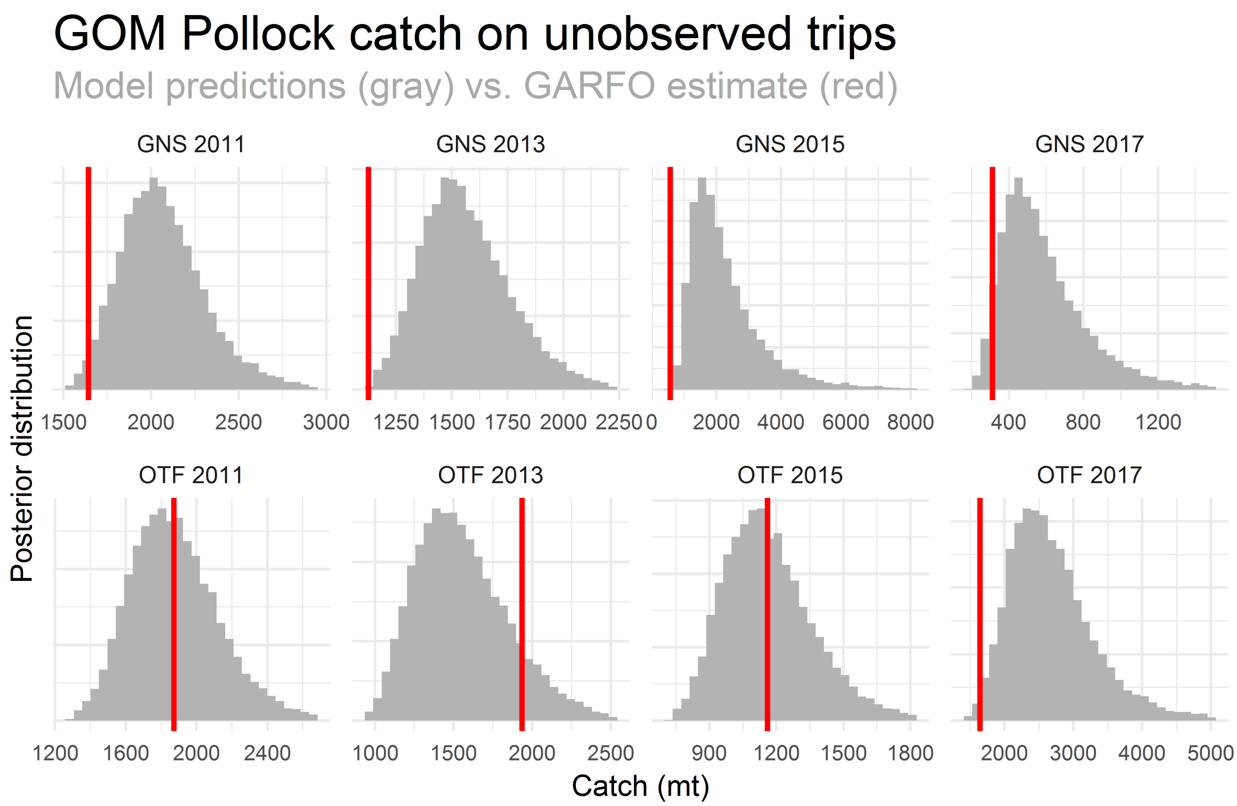

Figure S10: Model predictions of total pollock catch (landed + discarded) compared to reported catch (red) on **unobserved** trips. Parameter estimates of fixed and structured random effects from the models for observed trips were used to make predictions. Gear types included otter trawls (OTF) and gillnets (GNS).

Comparison of sector vessel landings effort ratios between observed and unobserved trips by gear and broad stock area

Paul Nitschke
4/10/2019

Introduction

With insufficient catch monitoring, incentives - produced from the multispecies (groundfish) fishery output control sector-based management system - can cause observer effects. Incentives, which vary both spatially and temporally, to fish differently when on observed trips will change with the degree of stock specific constraints. These constraints on the fishery should be reflected in the lease prices for stock specific quota, if the system operates as designed, such that fishing effort decreases as stock constraints increase when lease prices make fishing less profitable. Monitoring coverage at-sea based on the current precision standard assumes observed trips are representative of unobserved trips. However, stronger incentives exist to avoid constraining stocks on observed trips as lease prices increase. Therefore, as a stock becomes more constraining to a sector, the incentives for an observer effects increase. However, there are gear targeting, spatial, temporal, and logistical limits to avoiding constraining stocks in a multispecies fishery. If constraining stocks - that produce incentives for observer effects - lead to unseen legal size discards on unobserved trips, then this should result in differences in stock landings-per-unit-effort between observed and unobserved trips in a multispecies fishery.

Objective

The objective of this analysis is to compare landings to effort ratios on observed and unobserved trips in the groundfish fishery to determine whether the landings composition changed in the presence of an observer. This analysis assumes that any potential differences in the landing to effort ratios are not caused by an observer deployment effect.

Methods

A comparison of allocated groundfish stock landings to effort ratios was done between observed and unobserved trips by broad stock area (Figure 1) and by gear type (gillnet and trawl gear). Two ratios were examined:

$$Ratio = \sum landing / \sum Kept\ all\ and\ \sum landing / \sum days\ absent$$

The analyses were done by broad stock area to account for differences in quotas and incentives for species that are managed as multiple stocks (winter flounder, yellowtail flounder, cod, and haddock).

<u>Multi-Stock Broad Stock Area Definition</u>
Gulf of Maine cod = Gulf of Maine (GOM) broad stock area
Georges Bank cod = Georges Bank (GB), 521, and Southern New England (SNE) broad stock areas
Gulf of Maine haddock = GOM broad stock area
Georges Bank haddock = GB, 521, and SNE broad stock areas

Gulf of Maine/Cape Cod yellowtail flounder = GOM and 521 broad stock areas
Georges Bank yellowtail flounder = GB broad stock area
Southern New England yellowtail flounder = SNE broad stock area
Gulf of Maine winter flounder = GOM broad stock area
Georges Bank winter flounder = GB broad stock area
Southern New England winter flounder = SNE and 521 broad stock areas

Potential effects from unit stocks (witch flounder, American plaice, pollock, redfish, white hake) should be reflected in all broad stock areas. However, the landing of a unit stock in a particular broad stock area could be low.

Data was selected using dealer data where a direct match of a dealer trip can be made with a vessel trip report (VTR) trip for both area and effort in the AA tables (Alevel = A and Elevel = A). The dealer data was further limited to trips by trawl and gillnet gear which landed at least some allocated groundfish (kept > 0). Trips were limited to groundfish sector vessels within each year that have been observed at least once over the course of a year. Common pool vessels and Sector IX were omitted from the comparison. Sector IX data was omitted due to known misreporting within this sector.

Effort was defined using two different metrics for the ratio comparisons:

1. An effort proxy was defined as sum of kept catch of all species (K_{all}), similar to how effort is defined for discard estimation in monitoring and assessments and,
2. Days absent (DA) on a trip was also used as a proxy for relative trip effort.

Gillnet gear ratios were only compared for the Gulf of Maine broad stock area where most of the groundfish gillnet effort occurs. The Southern New England (SNE) broad stock area was not included in the analysis due to the lack of groundfish effort.

Results

Tables 1-6 compare observed and unobserved groundfish landings to effort ratios by broad stock area. Tables 1-3 compare the raw ratios from observed and unobserved trips, while Tables 4-6 compare the ratios on a relative basis (unobserved relative to observed trips; unobserved ratio / observed ratio).

Differences in the landing ratios between observed and unobserved trips suggest that observed trips are not representative of unobserved trips. The tables are color coded to help illustrate potential patterns in the data. Yellow cells consistently landed more fish on observed trips relative to unobserved trips among effort metrics (K_{all} and DA) and between gear types (gillnet and trawl) within a broad stock area, while gray cells saw more fish on unobserved trips relative to observed trips. The comparisons among gear types only apply to the Gulf of Maine, where catch ratios were compared for both trawls and gillnets. The results from the Gulf of Maine stock area suggests that there were more cod landings seen on observed trips relative to unobserved trips despite incentives to avoid cod on observed trips due to low ACLs from 2015 to 2017 (Table 7). This difference was consistent across effort metrics (K_{all} and DA) and gear types. However, the magnitude of the difference was at times relatively small. In the GB and the 521 broad stock areas, it seems that more haddock are landed on unobserved relative to observed trips. The differences in the haddock ratios may have less to do with the influences of haddock which was not constraining but perhaps more a function of other potentially constraining stocks on these trips. However, a clear strong constraining stock could not be clearly identified in GB or the 521 broad stock areas with these ratios.

Discussion

The management system was designed to limit fishing effort as the catch of a stock approaches the catch limit. However, if these economic incentives are instead leading to discarding of legal size fish, fishing effort and mortality may not be fully reduced as designed. In addition, if legal size discarding is occurring on unobserved trips, this behavior should be reflected in differences in the stock landing to effort relationships. Observer effects caused from constraining stocks should also produce biases for non-constraining stocks in the multispecies fishery. These effects will also change with changes in quotas over time and among stock areas. In addition, the true constraint of a stock specific quota for the fishery also depends on appropriateness of the implemented quota relative to the true abundance. Constraints for limiting stocks in poor condition should limit fishing effort over the course of the fishing year in order to promote rebuilding of the stock. A stock quota set too low relative to the true abundance should produce a greater constraint on effort. This would therefore also result in higher incentives for observer effects. Therefore, interpretation of the discrepancies in the landing to effort ratios between observed and unobserved trips can be complicated by multiple factors.

Quota constraints - which produce incentives for observer effects - do seem to produce differences in the landings-per-unit-effort between observed and unobserved trips, assuming that observers are deployed randomly on trips. However, the magnitude of the difference among the ratio comparisons are difficult to interpret. Since there are also incentives to avoid constraining stocks on observed trips, there are likely different degrees of incentives by permit percent sector contribution (PSC). Incentives can change over time and stock area, the constraints' depend on the true underlying stock abundance/distribution, and the fishery gear targeting ability. Therefore, the magnitude of the differences in the landings to effort relationships between observed and unobserved trips is likely not an accurate estimation of the true extent of the potential missing removals.

Conclusion

In summary, discrepancies exist between observed and unobserved trips, when comparing landing to effort ratios. These differences suggest that observed trips are not representative of unobserved trips. Interpretation of the magnitude of these differences is uncertain due to the potential inherent biases caused by incentives to avoid limiting stocks on observed trips.

Table 1. Gulf of Maine stock area allocated groundfish stock landings comparison of observed and unobserved landings to effort ratios from 2011 to 2017. Flatfish (relative to roundfish) are not caught well with gillnet gear and are not shown.

Gulf of Maine trawl kept to kall ratios.

year	number of trips	Observed	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	873	ob	0.21	0.07	0.03	0.20	0.08	0.01	0.15	0.03	0.02
2011	2300	un	0.22	0.07	0.02	0.21	0.10	0.01	0.14	0.03	0.03
2012	1009	ob	0.15	0.06	0.03	0.20	0.13	0.02	0.13	0.05	0.04
2012	3052	un	0.12	0.05	0.02	0.24	0.21	0.02	0.10	0.04	0.04
2013	543	ob	0.09	0.09	0.02	0.23	0.14	0.02	0.13	0.05	0.05
2013	2121	un	0.06	0.07	0.02	0.27	0.22	0.01	0.12	0.04	0.03
2014	519	ob	0.06	0.07	0.02	0.26	0.20	0.02	0.11	0.04	0.04
2014	1630	un	0.05	0.07	0.02	0.23	0.26	0.01	0.11	0.03	0.03
2015	331	ob	0.02	0.10	0.07	0.16	0.26	0.01	0.10	0.04	0.03
2015	1275	un	0.01	0.08	0.06	0.14	0.36	0.01	0.10	0.03	0.02
2016	262	ob	0.02	0.08	0.12	0.11	0.27	0.01	0.08	0.03	0.03
2016	1347	un	0.01	0.07	0.13	0.15	0.27	0.01	0.08	0.02	0.02
2017	237	ob	0.02	0.06	0.17	0.14	0.17	0.01	0.11	0.03	0.01
2017	1677	un	0.01	0.06	0.14	0.16	0.26	0.01	0.10	0.02	0.01

Gulf of Maine trawl kept to days absent ratios.

year	number of trips	Observed	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	873	ob	742	247	98	707	295	25	529	120	77
2011	2300	un	829	265	90	787	385	39	519	129	125
2012	1009	ob	480	192	78	631	392	58	409	150	118
2012	3052	un	462	212	87	936	851	70	415	154	159
2013	543	ob	280	274	75	713	432	56	392	146	160
2013	2121	un	255	293	62	1100	921	59	497	149	138
2014	519	ob	270	312	102	1119	855	70	448	169	153
2014	1630	un	218	352	97	1100	1218	56	509	150	125
2015	331	ob	69	394	267	662	1052	55	406	166	118
2015	1275	un	56	446	314	767	1897	57	515	161	108
2016	262	ob	93	344	488	462	1129	60	337	125	127
2016	1347	un	76	389	752	861	1520	54	482	131	129
2017	237	ob	103	356	1012	817	985	68	661	152	79
2017	1677	un	66	391	984	1093	1808	52	710	122	103

Gulf of Maine gillnet kept to kall ratios.

year	number of trips	Observed	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	1371	ob	0.30	-	0.01	0.35	0.01	-	0.09	-	-
2011	3423	un	0.25	-	0.01	0.40	0.01	-	0.09	-	-
2012	1112	ob	0.20	-	0.00	0.32	0.00	-	0.10	-	-
2012	3298	un	0.17	-	0.00	0.37	0.01	-	0.12	-	-
2013	484	ob	0.10	-	0.00	0.51	0.01	-	0.12	-	-
2013	2094	un	0.08	-	0.00	0.47	0.02	-	0.16	-	-
2014	736	ob	0.09	-	0.00	0.42	0.01	-	0.10	-	-
2014	1831	un	0.09	-	0.01	0.38	0.01	-	0.09	-	-
2015	286	ob	0.04	-	0.00	0.38	0.01	-	0.05	-	-
2015	954	un	0.04	-	0.01	0.39	0.02	-	0.08	-	-
2016	185	ob	0.06	-	0.00	0.19	0.01	-	0.10	-	-
2016	839	un	0.06	-	0.01	0.30	0.01	-	0.10	-	-
2017	144	ob	0.05	-	0.00	0.19	0.01	-	0.06	-	-
2017	863	un	0.04	-	0.01	0.23	0.01	-	0.06	-	-

Gulf of Maine gillnet kept to days absent ratios.

year	number of trips	Observed	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	1371	ob	668	-	27	796	20	-	196	-	-
2011	3423	un	604	-	20	957	22	-	217	-	-
2012	1112	ob	411	-	9	644	9	-	200	-	-
2012	3298	un	374	-	9	783	20	-	254	-	-
2013	484	ob	201	-	6	1046	18	-	250	-	-
2013	2094	un	156	-	5	870	29	-	297	-	-
2014	736	ob	246	-	12	1119	39	-	257	-	-
2014	1831	un	230	-	14	990	33	-	247	-	-
2015	286	ob	110	-	14	1080	39	-	137	-	-
2015	954	un	93	-	22	1038	54	-	221	-	-
2016	185	ob	227	-	15	694	46	-	345	-	-
2016	839	un	161	-	25	827	35	-	266	-	-
2017	144	ob	171	-	12	677	27	-	210	-	-
2017	863	un	127	-	24	773	37	-	194	-	-

Table 2. Georges Bank stock area allocated groundfish stock landings comparison of observed and unobserved landings to effort ratios from 2011 to 2017.

Georges Bank trawl kept to kall ratios.

year	number of trips	Observed	cod	dabs	haddock	pollock	redfish	winter flounder	white hake	witch flounder	yellowtail flounder
2011	105	ob	0.116	0.050	0.325	0.041	0.012	0.127	0.022	0.025	0.078
2011	457	un	0.096	0.038	0.323	0.067	0.039	0.137	0.026	0.021	0.076
2012	79	ob	0.093	0.074	0.085	0.026	0.021	0.182	0.026	0.033	0.072
2012	486	un	0.126	0.057	0.133	0.047	0.039	0.185	0.022	0.030	0.041
2013	59	ob	0.088	0.047	0.126	0.029	0.026	0.273	0.035	0.023	0.014
2013	389	un	0.080	0.039	0.173	0.045	0.076	0.244	0.030	0.020	0.025
2014	61	ob	0.103	0.053	0.289	0.017	0.030	0.127	0.040	0.024	0.004
2014	349	un	0.123	0.051	0.311	0.033	0.070	0.131	0.024	0.017	0.016
2015	33	ob	0.116	0.058	0.185	0.005	0.006	0.182	0.018	0.016	0.018
2015	333	un	0.104	0.032	0.299	0.042	0.067	0.098	0.029	0.015	0.012
2016	27	ob	0.184	0.021	0.153	0.063	0.078	0.063	0.023	0.011	0.001
2016	293	un	0.070	0.027	0.195	0.070	0.159	0.068	0.019	0.010	0.006
2017	40	ob	0.031	0.019	0.096	0.051	0.087	0.039	0.028	0.026	0.003
2017	295	un	0.029	0.024	0.201	0.037	0.199	0.058	0.019	0.015	0.008

Georges Bank trawl kept to days absent ratios.

year	number of trips	Observed	cod	dabs	haddock	pollock	redfish	winter flounder	white hake	witch flounder	yellowtail flounder
2011	105	ob	538	233	1507	192	58	588	104	117	363
2011	457	un	584	229	1968	410	238	832	155	128	465
2012	79	ob	438	346	399	120	99	854	122	156	340
2012	486	un	606	274	640	225	187	887	107	142	196
2013	59	ob	308	165	442	103	92	952	121	81	50
2013	389	un	350	172	754	198	331	1065	132	89	109
2014	61	ob	423	217	1182	69	122	520	162	100	17
2014	349	un	696	285	1752	188	396	739	138	98	90
2015	33	ob	472	236	754	19	23	741	74	65	74
2015	333	un	594	185	1707	237	380	559	164	83	66
2016	27	ob	1117	128	927	382	470	383	139	66	6
2016	293	un	473	181	1324	472	1077	458	128	71	42
2017	40	ob	218	131	671	355	611	276	198	179	21
2017	295	un	232	197	1623	298	1608	466	151	123	67

Table 3. Mix broad stock area (521) allocated groundfish stock landings comparison of observed and unobserved landings to effort ratios from 2011 to 2017. SNE/MA winter flounder was a no possession stock in 2011 and 2012 and therefore are not shown.

Mixed stock statistical area 521 trawl kept to kall ratios.

year	number of trips	Observed	cod	dabs	haddock	pollock	redfish	winter flounder	white hake	witch flounder	yellowtail flounder
2011	153	ob	0.212	0.031	0.048	0.339	0.107	-	0.080	0.039	0.013
2011	558	un	0.295	0.034	0.054	0.233	0.102	-	0.079	0.039	0.021
2012	103	ob	0.141	0.059	0.023	0.277	0.139	-	0.121	0.058	0.003
2012	570	un	0.151	0.054	0.035	0.271	0.141	-	0.102	0.044	0.031
2013	75	ob	0.140	0.079	0.143	0.132	0.084	0.124	0.073	0.041	0.016
2013	549	un	0.117	0.079	0.128	0.139	0.153	0.069	0.083	0.036	0.016
2014	75	ob	0.092	0.089	0.168	0.076	0.129	0.106	0.069	0.040	0.007
2014	472	un	0.121	0.068	0.229	0.103	0.146	0.046	0.064	0.032	0.007
2015	73	ob	0.101	0.062	0.181	0.057	0.245	0.101	0.045	0.026	0.005
2015	400	un	0.107	0.063	0.181	0.078	0.201	0.081	0.044	0.027	0.012
2016	52	ob	0.056	0.062	0.215	0.087	0.143	0.080	0.039	0.027	0.018
2016	373	un	0.084	0.037	0.288	0.086	0.157	0.056	0.035	0.020	0.005
2017	38	ob	0.051	0.027	0.269	0.060	0.084	0.157	0.043	0.019	0.023
2017	420	un	0.039	0.027	0.367	0.087	0.147	0.045	0.053	0.014	0.003

Mixed stock statatisical area 521 trawl kept to days absent ratios.

year	number of trips	Observed	cod	dabs	haddock	pollock	redfish	winter flounder	white hake	witch flounder	yellowtail flounder
2011	153	ob	1235	183	280	1979	624	-	468	228	74
2011	558	un	1773	204	327	1403	616	-	475	236	129
2012	103	ob	758	318	126	1496	747	-	655	315	16
2012	570	un	788	281	184	1413	735	-	530	231	163
2013	75	ob	565	318	575	532	339	502	292	164	64
2013	549	un	511	345	558	605	669	301	362	156	70
2014	75	ob	318	310	583	263	449	366	240	137	25
2014	472	un	585	326	1104	496	704	222	307	154	31
2015	73	ob	365	226	654	206	886	366	165	93	19
2015	400	un	448	264	756	324	838	339	183	114	50
2016	52	ob	259	286	986	400	658	366	181	123	83
2016	373	un	526	233	1797	536	977	346	216	124	31
2017	38	ob	310	164	1633	367	507	953	261	116	140
2017	420	un	306	210	2839	675	1136	346	409	109	24

Table 4. Gulf of Maine stock area allocated groundfish stock landings relative comparison of unobserved landings to effort ratios to observed ratios (unobserved ratios/observed ratios) from 2011 to 2017. Flatfish (relative to roundfish) are not caught well with gillnet gear and are not shown.

Gulf of Maine trawl kept to kall ratios.

year	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	1.03	0.99	0.84	1.03	1.20	1.42	0.90	0.99	1.49
2012	0.75	0.86	0.87	1.16	1.69	0.94	0.79	0.80	1.05
2013	0.68	0.80	0.62	1.15	1.59	0.79	0.95	0.77	0.64
2014	0.72	1.01	0.86	0.88	1.28	0.71	1.02	0.80	0.73
2015	0.63	0.87	0.90	0.89	1.38	0.79	0.97	0.74	0.70
2016	0.60	0.83	1.14	1.38	0.99	0.66	1.05	0.77	0.75
2017	0.54	0.93	0.82	1.13	1.56	0.64	0.91	0.68	1.10

Gulf of Maine trawl kept to days absent ratios.

year	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	1.12	1.08	0.92	1.11	1.30	1.54	0.98	1.07	1.62
2012	0.96	1.10	1.12	1.48	2.17	1.20	1.01	1.02	1.35
2013	0.91	1.07	0.83	1.54	2.13	1.06	1.27	1.02	0.86
2014	0.81	1.13	0.96	0.98	1.42	0.79	1.13	0.89	0.81
2015	0.82	1.13	1.18	1.16	1.80	1.03	1.27	0.97	0.92
2016	0.81	1.13	1.54	1.87	1.35	0.90	1.43	1.05	1.01
2017	0.64	1.10	0.97	1.34	1.84	0.76	1.07	0.80	1.30

Gulf of Maine gillnet kept to kall ratios.

year	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	0.85	-	0.70	1.13	1.03	-	1.04	-	-
2012	0.85	-	0.93	1.14	2.04	-	1.19	-	-
2013	0.86	-	0.95	0.92	1.79	-	1.32	-	-
2014	0.96	-	1.26	0.90	0.86	-	0.98	-	-
2015	0.93	-	1.76	1.05	1.50	-	1.76	-	-
2016	0.91	-	2.06	1.52	0.98	-	0.98	-	-
2017	0.80	-	2.15	1.23	1.47	-	0.99	-	-

Gulf of Maine gillnet kept to days absent ratios.

year	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	0.90	-	0.75	1.20	1.10	-	1.11	-	-
2012	0.91	-	0.99	1.22	2.17	-	1.27	-	-
2013	0.78	-	0.85	0.83	1.61	-	1.19	-	-
2014	0.94	-	1.24	0.88	0.85	-	0.96	-	-
2015	0.85	-	1.61	0.96	1.37	-	1.61	-	-
2016	0.71	-	1.61	1.19	0.77	-	0.77	-	-
2017	0.74	-	1.99	1.14	1.36	-	0.92	-	-

Table 5. Georges Bank stock area allocated groundfish stock landings relative comparison of unobserved landings to effort ratios to observed ratios (unobserved ratios/observed ratios) from 2011 to 2017.

Georges Bank trawl kept to kall ratios.

year	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	0.83	0.75	0.99	1.62	3.14	1.08	1.14	0.84	0.98
2012	1.36	0.78	1.57	1.83	1.85	1.02	0.87	0.89	0.57
2013	0.91	0.83	1.37	1.55	2.89	0.90	0.87	0.88	1.73
2014	1.20	0.95	1.08	1.99	2.37	1.03	0.62	0.71	3.92
2015	0.90	0.56	1.61	9.07	12.02	0.54	1.58	0.91	0.63
2016	0.38	1.26	1.27	1.10	2.04	1.07	0.82	0.96	6.31
2017	0.93	1.30	2.10	0.73	2.28	1.47	0.66	0.60	2.76

Georges Bank trawl kept to days absent ratios.

year	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	1.09	0.98	1.31	2.13	4.12	1.42	1.50	1.10	1.28
2012	1.38	0.79	1.60	1.86	1.88	1.04	0.88	0.91	0.58
2013	1.14	1.04	1.71	1.94	3.62	1.12	1.09	1.10	2.16
2014	1.65	1.31	1.48	2.74	3.26	1.42	0.85	0.98	5.40
2015	1.26	0.78	2.26	12.72	16.85	0.75	2.22	1.28	0.89
2016	0.42	1.41	1.43	1.23	2.29	1.20	0.92	1.07	7.07
2017	1.07	1.50	2.42	0.84	2.63	1.69	0.77	0.69	3.18

Table 6. Mix broad stock area (521) allocated groundfish stock landings relative comparison of unobserved landings to effort ratios to observed ratios (unobserved ratios/observed ratios) from 2011 to 2017. SNE/MA winter flounder was a no possession stock in 2011 and 2012 and therefore are not shown.

Mixed stock statatisical area 521 trawl kept to kall ratios.

year	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	1.39	1.08	1.13	0.69	0.96	-	0.98	1.00	1.69
2012	1.08	0.92	1.51	0.98	1.02	-	0.84	0.76	10.37
2013	0.84	1.00	0.90	1.05	1.82	0.56	1.15	0.88	1.01
2014	1.32	0.76	1.36	1.36	1.13	0.43	0.92	0.81	0.92
2015	1.06	1.01	1.00	1.37	0.82	0.80	0.96	1.06	2.28
2016	1.49	0.60	1.34	0.99	1.09	0.70	0.88	0.74	0.27
2017	0.77	1.00	1.36	1.44	1.76	0.28	1.23	0.74	0.13

Mixed stock statatisical area 521 trawl kept to days absent ratios.

year	cod	dabs	haddock	pollock	redfsh	winter flounder	white hake	witch flounder	yellowtail flounder
2011	1.44	1.11	1.17	0.71	0.99	-	1.02	1.03	1.74
2012	1.04	0.88	1.46	0.94	0.98	-	0.81	0.73	10.02
2013	0.90	1.08	0.97	1.14	1.97	0.60	1.24	0.95	1.09
2014	1.84	1.05	1.89	1.89	1.57	0.60	1.28	1.12	1.28
2015	1.23	1.17	1.16	1.58	0.95	0.93	1.11	1.22	2.63
2016	2.03	0.81	1.82	1.34	1.49	0.95	1.19	1.01	0.37
2017	0.99	1.28	1.74	1.84	2.24	0.36	1.57	0.94	0.17

Table 7. Groundfish US ACLs from 2010 to 2020.

	Annual Catch Limit (US ACL)										
stock	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
GB cod	3,620	4,540	4,861	1,907	1,867	1,886	730	637	1519	1741	
GOM cod	8,088	8,545	6,700	1,470	1,470	366	473	473	666	666	666
GB Haddock	42,768	32,611	29,260	27,936	18,312	23,204	53,309	54,574	46,312	55,249	
GOM Haddock	1,197	1,141	958	274	641	1,375	3,430	4,285	12,409	11,803	9,626
GB Yellowtail Flounder	1,021	1,416	547.8	209	318	240	261	201	206	103	
SNE Yellowtail Flounder	470	641	936	665	665	666	256	256	65	66	66
CC/GOM Yellowtail Flounder	822	992	1,104	523	523	524	409	409	490	490	490
Plaice	3,006	3,280	3,459	1,482	1,442	1,470	1,235	1,272	1,649	1,532	1,420
Witch Flounder	899	1,304	1,563	751	751	751	441	839	948	948	948
GB Winter Flounder	1,955	2,118	3,575	3,641	3,493	1,952	650	683	787	787	787
GOM Winter Flounder	231	524	1,040	1,040	1,040	489	776	776	428	428	428
SNE/MA Winter Flounder	605	842	603	1,612	1,612	1,607	749	749	700	700	700
Redfish	7,226	7,959	8,786	10,462	10,909	11,393	9,837	10,514	10,986	11,208	11,357
White Hake	2,697	3,138	3,465	3,974	4,417	4,484	3,572	3,467	2,794	2,794	2,794
Pollock	18,929	16,166	14,736	14,921	15,304	15,878	20,374	20,374	38,204	38,204	38,204
Northern Windowpane Flounder	161	161	163	144	144	144	177	170	86	86	86
Southern Windowpane Flounder	225	225	381	527	527	527	599	599	457	457	457
Ocean Pout	253	253	240	220	220	220	155	155	120	120	120
Halibut	69	76	83	96	106	97	119	119	100	100	100
Wolffish	77	77	77	65	65	65	77	77	84	84	84

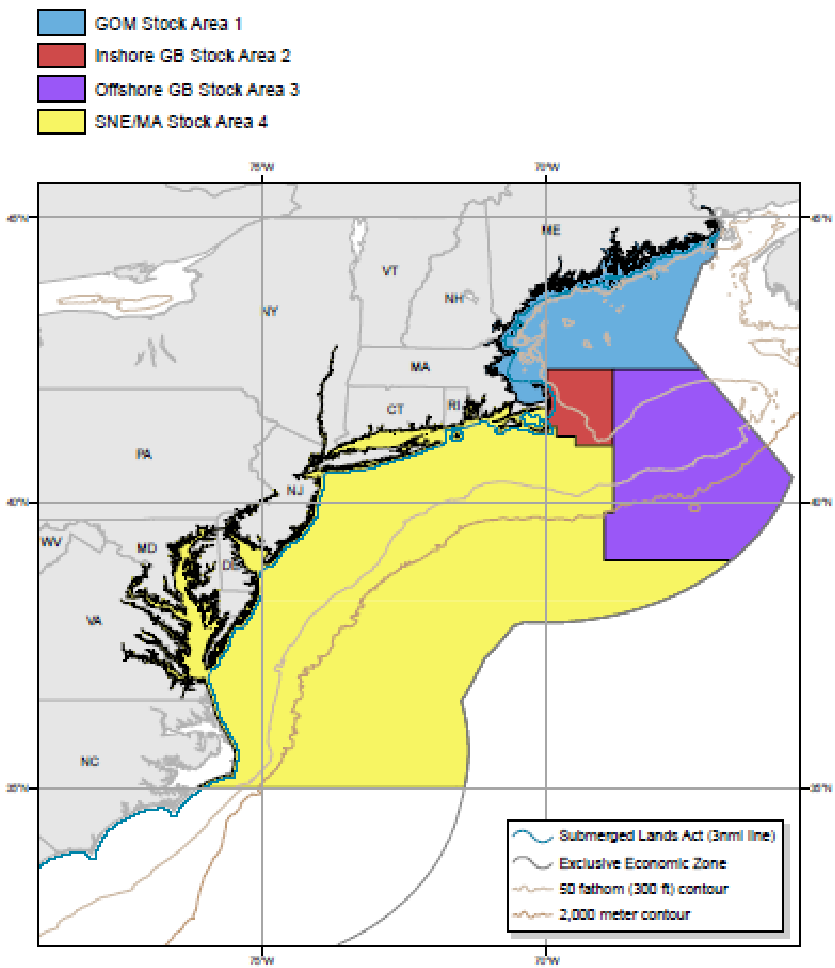

Figure 1. Multispecies broad stock area map. Inshore Georges Bank (GB) stock area 2 is statistical area 521.

Groundfish Plan Development Team
April 15, 2019

Groundfish Plan Development Team Conclusions

Based on Monitoring Analyses Conducted

1a) Modeling discard incentives for Northeast Multispecies (groundfish) stocks

- Stocks landed with a positive discard incentive may indicate bias in the total catch estimate for that stock.
- In general, yellowtail flounder and cod stocks have the highest modeled discard incentives over time, but these are highly variable on a year to year basis.
  - All three (Georges Bank, Southern New England/Mid-Atlantic, and Gulf of Maine) yellowtail flounder stocks had higher discard incentives in earlier years (2010, 2012).
  - Both (Gulf of Maine and Georges Bank) cod stocks had higher discard incentives in recent years (2015-2017).
- Stocks with consistently low discard incentives include those with relatively low quota price to ex-vessel price ratios, including pollock, redfish, and Georges Bank haddock.
- Quota prices as a ratio of ex-vessel price drives modelled discard incentives. This ratio is the strongest theoretical predictor of bias.
- Utilization (catch: annual catch limit) is weakly related to quota price and varies by stock.
- The model can only identify when landings or trips comply with the discarding prohibition, even when it may not be economically rational to do so. The model cannot quantify the proportion of trips or catch that does not comply with the discarding prohibition.
- More precise estimates of quota prices will enhance the ability to model discard incentives under current conditions.
- There may be other social, cultural, or normative factors that may influence individuals' decisions to comply with discard rules that we do not account for in this analysis.

1b) Evaluating the Observer Effect for the Northeast U.S. Groundfish Fishery

- This analysis demonstrates that fishing vessels in the Northeast multispecies (groundfish) fishery alter their behavior in response to human observers (distinct from selection bias/observer deployment effects). The analysis documents a consistent pattern of different fishing behaviors when an observer is on board.
- Data generated on observed trips are not representative of the whole fleet.
  - Generally, the most pronounced effects are seen across trip duration, kept catch, kept groundfish, and trip revenue.
  - Observer presence has the smallest effect on the number of groundfish market categories and non-groundfish average prices, but even in these instances differences are observed.
  - The data show a trend for three key metrics, in almost all circumstances, such that when an observer is onboard, vessels appear to:
    1. Retain fewer fish,
    2. Fish for less time and,
    3. Obtain lower revenues.

- Persistent differences such as higher average groundfish prices with an observer on board (trawl vessels) and emerging differences like a greater number of market categories retained with an observer (gillnet vessels) indicate that the composition of catch on observed trips is different than unobserved trips.

1c) Predicting Gulf of Maine cod catch on Northeast Multispecies (groundfish) sector trips, implications for observer bias and fishery catch accounting

- By modeling patterns of cod catch across space, time, and other attributes of fishing effort on observed trips, predictions of expected catch on unobserved trips were compared to the reported catch on these trips.
    - For gillnet trips, predicted cod catch was increasingly higher than reported catch from 2013 to 2017. Differences between predicted and reported catch on trawl trips were variable across time without an apparent trend. For both gear types, the proportion of total catch consisting of cod decreased over time, suggesting less targeting.
    - There is some evidence that the magnitude of unreported cod catch (potentially illegal discarding) could have been >60% of reported catch on unobserved trips.
- An important caveat is that conclusions depend on validity of the model structure and predictions. If unmeasured attributes of effort (e.g. tow speed) and/or relationships between effort predictors and catch outcomes differ between observed and unobserved trips, predictions may not be valid. Differences in catch outcomes are assumed to be attributed to post-catch behavior (compliance, or lack thereof, with discarding regulations) and not pre-catch behavior (how the gear was fished).
- Results from models for pollock suggested a lack of model fit compared to those for cod, making conclusions equivocal for this species.

1d) Comparison of sector vessel landings effort ratios between observed and unobserved trips by gear and broad stock area

- Discrepancies exist between observed and unobserved trips, when comparing landing to effort ratios. Differences in the landing ratios between observed and unobserved trips suggest that observed trips are not representative of unobserved trips. This analysis assumes there are no observer deployment effects.
- For the Gulf of Maine broad stock area, this analysis demonstrates there were slightly more cod landings seen on observed trips relative to unobserved trips despite incentives to avoid cod on observed trips due to low ACLs from 2015 to 2017. This difference was consistent across effort metrics (K_{all} and DA[1]) and gear types.
- For the Offshore Georges Bank broad stock area and Inshore Georges Bank broad stock area (Statistical Reporting Area 521), more haddock are consistently landed on unobserved trips relative to observed trips. The differences in the haddock ratios may have less to do with the

[1] K_{all} = sum of kept catch of all species, similar to how effort is defined for discard estimation in monitoring and assessments; DA = days absent on a trip, a proxy for relative trip effort

influences of haddock which was not constraining but perhaps more a function of other potentially constraining stocks on these trips targeting haddock.

- Documented differences in the stock landing to effort relationships reflects differences in discarding of legal sized fish on unobserved trips relative to observed trips.
- Interpretation of the magnitude of these differences is uncertain due to the potential inherent biases caused by incentives to avoid limiting stocks on observed trips.
- The magnitude of the differences in the landings to effort relationships between observed and unobserved trips is likely not an accurate estimation of the true extent of the potential missing removals.

Overall Groundfish Plan Development Team Conclusions Based on the Analyses

- All three analyses that compare observed and unobserved trip data conclude that observed trips are not representative of unobserved trips. The dimensions where observed trips differ from unobserved trips include:
    - Gulf of Maine cod catch rates,
    - Groundfish landings to effort ratios,
    - Trip duration,
    - Pounds of kept groundfish,
    - Pounds of total kept catch, and
    - Trip revenue.
- Documented differences in the stock landing to effort relationships reflect differences in discarding of legal sized fish on unobserved trips relative to observed trips.
- Despite removing Sector IX data from these analyses, fishery-wide bias is still demonstrated.
- The discard incentive model describes one mechanism to explain differences between observed and unobserved trips: the sector system increases the incentive to illegally discard legal-sized fish on unobserved trips.
- Discard incentives have varied across time and stock area. After full sector implementation, the accountability of discards and the application of sector/gear specific discard rates to unobserved trips, together with the potential catch of constraining stocks, increased the incentive to not comply with retention regulations.
- Given these conclusions, the current precision standard is not an appropriate method to set at-sea monitoring coverage levels because the assumption that observed trips are representative of unobserved trips is false.
- These analyses cannot quantify the differences between observed and unobserved trips in a way that allows for either a mathematical correction to the data or a survey design that resolves bias.
- Non-compliance with the requirement to land legal-sized fish of allocated stocks (excluding LUMF[2]) undermines any sampling design and should be addressed.
- While direct evidence of the incidence and magnitude of non-compliance is not captured, the documented differences in behavior are substantial enough to warrant concern that non-compliance is occurring, especially in view of incentives to be non-compliant while unobserved.
- Revisions to the monitoring program should consider ways to increase compliance or account for non-compliance. Substantially increasing the management uncertainty buffer might account for this non-compliance but would not improve our understanding of true removals and would result

[2] LUMF = legal-sized un-marketable fish

in foregone revenue for the fishery. Alternatively, increased monitoring and catch accounting may be one way to increase compliance and may be necessary to provide accuracy of catch.

- The analyses support more comprehensive monitoring in the fishery.

New England Fishery Management Council

Scientific and Statistical Committee Sub-Panel

Peer Review Report for the Groundfish Plan Development Team Analyses of Groundfish Monitoring

Conducted April 24 and 25, 2019 in Providence, Rhode Island

Prepared by the Peer Review Panel: Dr. Dan Holland[1], Dr. Lisa Kerr[2], Dr. Jason McNamee[3] (chair), and Dr. Hiro Uchida[4]

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[4] University of Rhode Island

Executive Summary

A sub-panel of the Scientific and Statistical Committee ("the peer review panel") was convened on April 24 and 25, 2019 to review four analyses along with a conclusions statement conducted by the New England Fishery Management Council's (NEFMC) Groundfish Plan Development Team (PDT). The analyses were conducted to look at the potential effects on harvest and discards in the Northeast Multispecies (here after "groundfish") fishery when an at-sea observer is present on a fishing trip relative to when no observer is present. This is important because sector program accountability and estimation of discards is largely derived from observed trips, so if there are differences in fishing behavior on those trips, this could impact the effectiveness of management of this fishery.

The first analysis modeled incentives to discard in the groundfish fishery. The analysis is done at the trip level, but results are presented on an annual species/stock level. The analysis shows that, while on average there are no positive incentives to discard for any species across years, there are positive discard incentives for a proportion of trips for some species/stocks, notably for cod and yellowtail flounder stocks in certain years. There are reasons to believe that the estimated discard incentives are conservative such that even when the estimated incentive is not above zero, there may still be incentives to discard that are not captured by the model. The analysis was not able to estimate the frequency of trips or the magnitude of catch that may be subject to positive discard incentives and thus cannot quantify the magnitude of the problem. Rather it provides an indicator of where and when discarding may have been incentivized, and therefore indicates that discarding in this fishery is economically incentivized in some instances. This could help managers focus efforts on to the areas of the fishery where the main problems likely exist.

The second analysis examined whether fishing vessels in the groundfish fishery alter their behavior in response to human observers. The measures examined in this analysis cover a broad range of impacts that are relevant for observer-related fisheries management policy. The analysis found statistically significant differences in many measures (but not all) between unobserved and observed fishing trips of the same vessels, strongly suggesting that fishers do alter their fishing behavior when a human observer is onboard. However, since a key difference is shorter duration of unobserved trips, this may explain at least part of the differences in other variables such as kept catch.

The third analysis used observed trips to model cod (and pollock) catch while accounting for typical effort attributes in addition to spatial and temporal covariance in catch. The approach creates a predictive model, which was used to predict total cod catch (kept + discarded) on observed trips, and then was also used to predict catch for unobserved trips, which were then compared to catch reports from the National Marine Fisheries Service (NMFS). The method indicated differences between the predictions of unobserved catch and the catch as reported by NMFS. This finding suggests a potential for unreported catch on the unobserved trips if it is assumed that observed trips can adequately represent unobserved trips. This method has an ability to predict unobserved discards controlling for differences in spatial distribution of unobserved trips relative to observed trips and showed promise for informing the Council quantitatively in their deliberations on Amendment 23 with some additional refinement and testing.

The final analysis compared species/stock landings to effort and total catch ratios on observed and unobserved trips in the multispecies groundfish fishery to determine whether there is evidence of an observer effect. The analysis assumes that differences are due to the observer effect and are not due to the deployment effect, so this is an important consideration when interpreting results from this method. The reviewers appreciated the parsimony of this approach, but felt it needed a little more refinement before it could be used by managers. The method did indicate the potential for differences between observed and unobserved trips, and therefore it corroborated the other results from the other analyses.

Generally, the reviewers appreciated all of the work done by the PDT and felt that the analyses, taken comprehensively, create a weight of evidence that disproves the null hypothesis, namely that there is no effect from the presence of an observer on a fishing trip. In other words, the work taken collectively show that there is an observer effect, and therefore managers need to account for this when basing management off information derived from observed trips. The analyses suggest that estimates of discards on unobserved trips derived from discards rates on observe trips may not be accurate, and likely to be an underestimated reflection of actual discards. In their current form the analyses do not offer a specific quantification of the problem, but the methods show promise for being able to focus efforts on to the most problematic species in the fishery, and some of them also show promise for being able to quantify the magnitude of the issue with additional work. The following report details these findings.

Table of Contents

Report

I. Methods to explore discard incentives of groundfish stocks

a. Reviewer Summary Comments:

This paper models' incentives to discard catch of groundfish stocks based on the estimated economic incentives to retain or discard the catch. The analysis is done at the trip level and, for each species, subtracts the benefits of retaining catch (mainly ex-vessel value) from the cost of retaining catch (mainly quota leasing costs) to estimate the incentive to discard. The discard incentive measure is standardized by the ex-vessel value of catch so might be thought of as the monetary incentive to discard per dollar value of retained catch. Results are presented on an annual species/stock level. The analysis shows that, while on average there are not positive incentives to discard for any stock or year, there are positive discard incentives for a proportion of trips for some species/stocks, notably for cod and yellowtail flounder stocks in certain years. There are reasons to believe that the estimated discard incentives are conservative such that even when the estimated incentive is not above zero, there may still be incentives to discard. The presentation of methods and results is clear, and the methodology and assumptions made are generally sound as are the conclusions drawn from the analysis. The analysis is applied only to unobserved trips but could and should be applied to observed trips. The analysis is not able to estimate the frequency of trips or magnitude of catch that may be subject to positive discard incentives and thus cannot quantify the magnitude of the problem. Rather it provides an indicator of where discarding may have been incentivized.

b. Terms of Reference:

1. Are the methods adequately described and based on sound analytic techniques and statistical principles?

The methods for this paper are generally well described and based on sound theoretical and analytic techniques. As with most economic models that represent human decision making as a purely economic and rational process, there are several assumptions made in the model that may not strictly hold. In addition, the model does not represent the potential heterogeneity of decision makers that may alter what costs and benefits of landing fish are included in decision making. However, the assumptions made are generally reasonable and clearly stated, and their rationale is described.

The paper should be clearer about the type of decision maker that is represented. The decision of a vessel owner might be different from a hired captain based on differences in costs and benefits considered. For example, a hired captain or crew member on a boat that does not deduct the cost of quota when determining crew share might not consider the quota cost and thus would have a lower incentive to discard than is estimated here. Alternatively, a captain who is also the owner of the vessel and the quota might consider the net value of the fish after both crew share and quota costs are deducted and thus have a higher incentive to discard than is estimated. It appears the model best represents the viewpoint of a hired captain or crew member that expects quota costs to be deducted off the top and their compensation to reflect a share of the difference between ex-vessel value and quota cost. To the extent it is known, it would be useful to discuss how prevalent this type of decision-making is, e.g., how prevalent is it to deduct the value of quota from ex-vessel value before calculating crew share for hired captains and crew?

Other background that is not made clear in the paper is that observed trips were excluded from the analysis. The analyst stated in post presentation discussions that only data from unobserved trips was used, and this should be clarified in the paper. It is not clear why observed trips should be excluded as these trips seem likely to be a substantial source of data on trips where discard incentives existed for legal size fish but where those fish were retained due to the presence of the observer.

2. Are important uncertainties in the data and the analyses (possibly including the effects of year to year variations in fishing practices) identified, and are the impacts of these uncertainties on the analyses adequately described?

There are many uncertainties in the data and analysis, but they are generally identified in the paper and the impacts of these uncertainties are discussed. The most important uncertainty is the accuracy of quota prices that are a key factor in the decision to land or discard fish. The analysts noted in discussions after the presentation that it is the magnitude of the margin between ex-vessel price and quota price that is the primary determinant of the estimated discard incentive. Quota prices are based on reported data on quota leases (i.e., annual catch entitlement (ACE) sales) within and between sectors and provide the best representation available of quota value; however, they undoubtedly depart somewhat from the perceived opportunity cost of quota in the mind of the decision maker deciding whether to discard or retain fish. Quota prices are mostly based on quarterly estimates but there may be variations in market values within quarters.

More fundamentally, there may be a variety of reasons for decision makers to use something other than the market price of quota in making their determination of whether to discard or land fish. A basic assumption of the model is that there are known market prices for quota, and that the decision maker uses these prices to estimate the cost of landing fish. The analysis assumes away any impact that the quota holdings of the vessel at the time of landing, or the expected need for future quota, might have on the discard decision. It basically assumes the quota can be bought for that price upon landing the fish and that the same quota price will continue to prevail. This is a reasonable assumption if the quota market is efficient, information on quota prices is readily available, transactions costs are low, and decision makers are rational. However, the assumed value of quota to the individual may in fact be affected by quota endowments and expectations of whether vessel owners/decision makers will or will not need to seek quota on the market at some point and what prices may be at that time. For decision makers that expect to have to lease quota to cover catch of otherwise discarded fish, there may be a risk premium applied to account for the risk of not being able to acquire quota in a timely fashion. This would increase the discard incentive. There might be pressure from vessel/quota owners/holders to limit the landings of stocks for which quota is limiting. On the other hand, a vessel owner with extensive quota holdings might be less concerned about quota prices and might assume a lower quota value in the discard decision.

As noted in the paper, a positive discard incentive does not necessarily mean discarding will occur. There are many reasons including moral values and social norms that might motivate landing of fish when discard incentives are positive. Furthermore, sectors may have implemented programs that change incentives, either by increasing the likelihood of detection and penalty for illegal discarding, or by changing incentives. An example of the latter would be if the sector maintains a pool of quota available to cover catch that can be purchased with certainty at a price lower than ex-vessel price or the prevailing market price of quota.

Overall the uncertainties and caveats of the analysis are well described, and the reader can draw their own conclusions. It seems likely the analysis is conservative in estimating the discard incentive. A key factor that may make the estimates of the discard incentives conservative is risk. If a captain (or decision maker) is uncertain they will be able to acquire quota to cover the fish they would otherwise discard and may be forced to stop fishing, they may add a risk premium to the cost of quota considered in Equation 2 from the document (see page 3), which will tend to increase the discard incentive. Because the estimates of discard incentives may have a conservative bias, it may be that discard incentives did exist in some cases where the estimated discard incentive is less than zero.

3. Are the analyses conducted at the appropriate temporal and spatial scale such that the existence of regional or seasonal differences in monitoring performance can be identified?

To the extent possible, the analysis is done at an appropriate temporal and spatial scale. The primary limiting factor is the data used to estimate quota values. These are generally quarterly estimates but sometimes annual estimates. However, the prices or expected prices could vary within quarters, by sector or by individual. This creates uncertainties in the analysis, but the decisions of the analysts appear appropriate.

It might be of interest to disaggregate the analysis and presentation of results to the sector level or some other grouping of vessels for which we might expect heterogeneity in incentives or behavior in relation to incentives. For example, different ports may have different ex-vessel prices. Some sectors may have different internal quota prices or a pool of quota that can be accessed at a known price. It might also be useful to present results on a quarterly basis. This might better identify times and stocks where discard incentives were positive.

4. What are the strengths and weaknesses of the methods? Are there constraints that would hinder the use of the catch monitoring analyses?

As the PDT notes in their own summary conclusions: "The model when it is applied to unobserved trips can only estimate a discard incentive when landings or trips comply with the discarding prohibition, even when it may not be economically rational to do so." The method is useful in showing that incentives to discarding did likely exist in certain circumstances. It is, however, unable to quantify the frequency or magnitude of actual discards. The analysis almost certainly underestimates the percentage of trips where discard incentives existed to the extent that there are trips where catch was discarded and thus was not included in the analysis. We know, as the paper notes, that fish were landed in compliance with regulations despite a positive incentive to discard it. What we don't know is how often catch was discarded.

A simpler analysis might also be informative. Simply comparing ex-vessel prices (by grade and perhaps port) to quota lease prices would probably be almost as good an indicator of incentives to discard. It would not indicate the percentage of trips or catch for which incentives exist, but the current method underestimates this anyway since it does not apply the estimate to discarded catch. It would be possible, using this suggested method, or the method used in the analysis reviewed, to estimate the percentage of catch from observed trips where a discard incentive existed. This would be a useful exercise though it may also underestimate the percentage of catch subject to positive discard incentives to the extent that behavior on observed trips is different and leads to lower catch of fish with positive discard incentives.

5. Are the conclusions of the Plan Development Team supported by the analyses (see 1e)?

The conclusions of the PDT related to this analysis are reasonable and capture most of the key conclusions and caveats associated with the analysis. None of the conclusions of the PDT seem inappropriate, and the limitations of the analysis are acknowledged. The PDT notes that a positive discard incentive may indicate a bias in landings data, but they do not state that the analysis definitively proves the existence of substantial discards. They note that the analysis cannot quantify the proportion of trips where discards did occur or the amount of discards. As the PDT notes, more precise estimates of quota prices would enhance the ability of the model to identify where discard incentives existed.

6. Are there recommendations for improving the analyses, or for additional research or data collection that can help address improving groundfish monitoring?

A key to this analysis and a limiting factor is good approximations of the opportunity cost of quota that was used in making the decision to land or discard the fish. As noted by the PDT, better or more complete quota lease price data would help this. However, even with better estimates of market value of quota, the value assumed by the decision maker may depart from market value for reasons described above. This is probably an unresolvable problem.

The primary determinant of the discard incentive is the margin (or lack of margin) between ex-vessel price and quota price. It would be useful to include a chart or table comparing quarterly average ex-vessel price for various grades or the lowest grade and quarterly average quota lease price for stocks where discard incentives were relatively higher (though perhaps still negative on average). It appears that in most cases quota prices do not exceed average ex-vessel value, but the question remains as to whether this is the case for the lowest market grade. The table or chart suggested would provide an indication of where incentives for high grading exist, namely where higher grades of the species might be profitable to retain while lower grades of fish are not.

The analysis did not include data on observed trips. It would be useful to analyze these trips and compare the results with those from the unobserved trips already analyzed.

It might be useful to more carefully analyze trips where incentives to discard were positive or closer to zero to determine what drove these higher incentives in relation to the average incentive for that period and stock. For example, we might find that those trips tended to land a substantial amount of small or lower grade fish, or perhaps unmarketable fish. This would indicate a high grading issue rather than an incentive to discard all catch of that species. It might also identify heterogeneity across groups (e.g. ports with lower ex-vessel prices that have higher discard incentives).

Editorial comments for authors:

Throughout this paper and some of the other documents reviewed, authors refer to quota and quota price instead of ACE and ACE prices. If this is a standard convention in discussions in the Council arena, this may be appropriate. However, referring to ACE and ACE sales or trades would be more accurate than referring to quota and quota lease.

Pg. 1 paragraph 2: It is not clear what the authors mean by "we lack the terminology to communicate precisely what we are estimating." Please clarify this.

Pg. 2. 2nd paragraph, 2nd sentence. There is not necessarily an incentive to discard in all quota-based fisheries. It depends whether quota is limiting and how limiting it is and the cost of avoidance.

Pg. 2 last sentence of paragraph 3: Those less able or willing to discard may gain from a lower quota price. Quota owners lose from lower quota value to the extent that they lease rather than use quota and to the extent that discarding undermines the long term value of the quota.

Pg. 8, 1st full sentence. The value of forgone future catches of jointly caught stocks should be captured in the quota price unless quota price is being kept down by discarding or other factors (e.g. unwillingness to "gouge" in lease transactions as found by Holland (2013)).

II. Methods to evaluate observer effects in the groundfish fishery

a. Reviewer Summary Comments:

This analysis demonstrates that fishing vessels in the groundfish fishery alter their behavior in response to human observers. The analysis looked at eight measures: namely (1) trip duration, (2) kept catch, (3) kept groundfish, (4) kept non-groundfish, (5) total revenue, (6) groundfish average price, (7) opportunity cost of quota, and (8) number of groundfish market categories included in kept catch. These measures cover a broad range of impacts that are relevant for observer-related fisheries management policy. The analyses were conducted separately for four stanzas (one pre-sector stanza and three post-sector stanzas) and also by fishing gear (gillnet and trawl). Additionally, the approach was unique in how it chose its sequence of trips for analysis, which the reviewers appreciated. The analyses found statistically significant differences in many measures (but not all) between non-observed and observed fishing trips of the same vessels, strongly suggesting that fishers do alter their fishing behavior when a human observer is onboard.

b. Terms of Reference:

1. Are the methods adequately described and based on sound analytic techniques and statistical principles?

Yes. The core method used to construct the comparison pairs of non-observer and observer trips followed the procedure of Benoit and Allard (2009) and was explained well.

The only suggestion the reviewers have is to clearly state that the comparisons were made also with the same vessels. This is clear in Equation 3 from the document (see page 3), however only if one pays close attention to the use of subscripts. The term "exact matching" is used in the matching method literature and does not necessarily point to same-entity matching. Use of the same vessel for constructing the sequence of UUU and UOU trips as well as conducting the comparisons is the key feature of this study and what makes the analysis so clean, and thus deserves to be emphasized.

2. Are important uncertainties in the data and the analyses (possibly including the effects of year to year variations in fishing practices) identified, and are the impacts of these uncertainties on the analyses adequately described?

Yes. The use of four stanzas and constructing the UUU/UOU sequences that are within 45 days apart minimizes the temporal unobservable impacts on the analyses, such as seasonal and other environmental effects. Depending on the time of year, the 45-day decision is an important uncertainty in the analysis, as this could be a biologically meaningful period of time at the change of a season (for instance). However, the analyst made this decision as a trade-off between minimizing the amount of time while keeping enough data to analyze, which is justified. The use of the same vessels for the trip sequence and comparison controls for unobservable fixed effects unique to a vessel.

3. Are the analyses conducted at the appropriate temporal and spatial scale such that the existence of regional or seasonal differences in monitoring performance can be identified?

Yes, as described above.

4. What are the strengths and weaknesses of the methods? Are there constraints that would hinder the use of the catch monitoring analyses?

The strengths of the method used are as described above. Not as weaknesses but more as suggestions to make the results more robust, the reviewers have following suggestions.

For each of the eight measures, state the expected direction(s) of change or impacts of the human observer being present. The paper should explain not just that some behavioral changes were detected, but also whether those changes make sense. Some measures may be ambiguous, i.e., the impacts can go both ways, which is fine and makes a stronger case for having the "two-sided problem" section in the document. Also, along this line of thought, it would be helpful to link the five reasons for behavioral change outlined on p.2 to the eight measures.

Related to the comment above, it is strongly recommended that some of the measures be standardized by the trip duration. For example, a "kept catch" measure might be expected to go up, ceteris paribus, with an observer because there will be no illegal discarding but could also go down if vessels avoid areas with higher target catch but also higher catch of unwanted species. The results show, for trawls and gillnets, that kept catch was lower on observed trips. This may be due, at least in part, to the decline in trip duration. Revenue on observed trips also was lower than unobserved trips, which is in line with a priori expectation, but it also could be an artifact of shorter trip duration. It was discussed during the presentation that if all detected differences are stemming from shortened trip duration then there is no behavioral change that regulators need to be concerned about. Economic intuition tells us that is highly unlikely (i.e., there are likely to be behavioral changes in discarding and fishing location choice), but to make that point clearer and stronger these measures need to be standardized in a meaningful way. This may be partially accomplished by looking at changes in kept catch per day, but if catch increases nonlinearly with duration (e.g., because steam and search time are a lower proportion of trip length) we might expect kept catch to decline more than proportionately with duration. Alternatively, vessel monitoring system (VMS) data may be utilized to distinguish the tow/fishing time from steaming or searching time and it could be used to standardize the measures.

5. Are the conclusions of the Plan Development Team supported by the analyses (see 1e)?

Yes, but they will be strengthened by standardizing the measures as described above.

6. Are there recommendations for improving the analyses, or for additional research or data collection that can help address improving groundfish monitoring?

See item #4 above about standardizing the measures. Additionally, for clarification purposes, it will be helpful to define "opportunity cost of quota" (or simply linking the reason #5 described on p.2 of the document), along with how this was calculated.

Conjectures (or anecdotes) on the differences between the trawl and gillnet in the context of pre-harvest behavioral manipulation should be explicitly explained for the two following reasons. One is it motivates why the analysis should be conducted separately between these two fishing gear types. Another is it may be the core factor of why some results, i.e., behavioral responses to observed trips, are different.

The reviewers were told that more than the presented eight measures were analyzed but some were excluded from the report primarily because no statistically significant differences were detected. Some of them, however, would merit inclusion. Herfindahl-Hirschman Index (HHI) is one example; HHI is a measure of concentration and in this context can be used to measure whether the variety of fish species landed is more "concentrated" in handful of species. Intuitively, we think fishers will attempt to alter the composition of fish caught (e.g., less bycatch) through a strategic choice of fishing location in response to an observer on board. HHI is a measure that can detect such behavioral change.

Lastly, during the presentation the authors explained why they chose the max days between the fishing trips within a sequence (UUU or UOU) to be 45 days, and how they tested for both shorter and longer durations. The reviewers feel this discussion merits inclusion as it would more strongly justify the choice of 45-days.

III. Methods to predict groundfish catch in the presence of observer bias

a. Reviewer Summary Comments:

This method used observed trips in the Gulf of Maine (GOM) stock area to model expected cod catch while accounting for typical effort attributes (e.g., total kept catch, vessel size, trip length) in addition to spatial and temporal covariance in catch. The approach creates a predictive model, which was used to predict total cod catch (kept + discarded) on observed trips, to test the performance of the model. The predictive model was then used to predict catch for unobserved trips. Both predictions were compared to the summed predictions across a fishing season to the catch estimates for sectors reported by NMFS.

The method did a fair job of predicting catch for the observed trips, which is the dataset that the model was developed on, showing that the modeling approach has value and predictive power for the data used. The method also indicated discrepancies for the prediction of unobserved catch relative to the catch as reported by NMFS. This finding suggests a potential for unreported catch on the unobserved trips if it is assumed that observed trips can adequately represent unobserved trips with regard to "pre-catch" behavior, meaning a fisherman will operate in the same manner prior to catching fish on a fishing trip whether an observer is present or not. Pre-catch behavior was also modeled using several attributes of effort (e.g., kept all, location) that were expected and shown to influence catch outcomes.

Due to its current configuration, the method is likely conservative in its predictions (i.e. will produce lower expected catches than is true), because it is not proven that "pre-catch" behavior is similar between trips that are observed and unobserved. In particular for the case of otter trawl, even with short notice of a trip being observed, a fisherman could alter behavior more easily than a gillnet operation, which likely already has gear set before leaving the dock. There are still modifications that a gillnet operation could make, like shortening trips and only hauling certain strings of gear that they believe will be less likely to have unwanted species, but there are less options for modification for gillnetters relative to otter trawl.

The review panel offered suggestions on ways to improve the model. Generally, these had to do with the addition of new explanatory variables (potentially some of the information generated for the other methods examined during this review), additional data sources (vessels with cameras, VMS data, Industry-Based Survey (IBS) cod survey), and potential ways to include trips that did not land cod.

This method has an ability to predict unobserved discards controlling for differences in spatial distribution of unobserved trips relative to observed trips. The approach was novel and interesting, and showed some promise for informing the Council quantitatively in their deliberations on Amendment 23 with some additional refinement and testing. For these reasons the review panel believes additional effort should be invested in this approach.

b. Terms of Reference:

   1. Are the methods adequately described and based on sound analytic techniques and statistical principles?

Yes. The approach uses well defined statistical modeling principles, the documentation of the equations and underlying assumptions was thorough, and the model choices (e.g. error distribution) and other underlying theoretical aspects of the model were well justified for the hypothesis being tested.

Spatial and temporal covariance are two of the more interesting aspects of this approach. This was an area that was highlighted as worthy of additional investigation as far as how these aspects were parameterized, however even in their current state, these aspects of the model provide valuable insight into the issue of potential things that could influence observer bias and are based on sound principles and techniques.

There is one potentially important problem with the model specification that could cause bias and inconsistency in model predictions. The explanatory variables include a variable for all kept catch (namely, "kept_all"). Part of this catch is cod, which is the dependent variable for the model. This is likely to lead to correlation between the residuals in the model and the variable kept_all. For observations where cod is a large proportion of the total catch, the residual is likely to be increasingly negative (the model will likely be underpredicting the cod catch). This may account for the fact that the model, when applied to observed trips, tended to underpredict catch.

   2. Are important uncertainties in the data and the analyses (possibly including the effects of year to year variations in fishing practices) identified, and are the impacts of these uncertainties on the analyses adequately described?

Yes. As highlighted by the analyst, other statistical distributions for expected catch on a trip (e.g., quasi-Poisson, negative binomial) could have been used. These alternate distributions may provide a better fit to the catch data; however, the analyst made a good case as to why he used the selected distributional assumption, namely that the random error term was useful at capturing over-dispersion in the predictions. This could be an area of further exploration.

As noted, the most unique aspect of the analysis was the temporal and spatial aspects of the model. The scale chosen for the spatial and temporal knots were not explored beyond those presented. Other choices should be investigated with a focus on finding the best trade-off between more refinement in the number of "knots" but not decreasing sample size to the point of adding an unreasonable amount of uncertainty in to this part of the analysis. This portion of the analysis also highlighted the limitations of using VTR data only as the data source in particular for the spatial information. VMS data might offer a refinement of this aspect of the data.

The reduction in effort and observer coverage across time was also an area highlighted as an uncertainty. The reviewers suggested adding more years of information to the model and the analyst noted that this would leverage parameter pooling across years and might yield more accurate parameter estimation, the current configuration only used a small subset of years. A final note was that this model makes inferences from observed trips on to unobserved trips. This is important with respect to testing the hypothesis that there are likely differences between these two treatments, however this is an important uncertainty as you might never be able to know the full extent of the issue through this process. The reviewers offered additional analyses and modifications that might help address some of these uncertainties and are presented in this section (see #6 below).

3. Are the analyses conducted at the appropriate temporal and spatial scale such that the existence of regional or seasonal differences in monitoring performance can be identified?

Yes. In particular, the temporal scale of two weeks is likely adequate to capture things like seasonality in species abundance. The spatial resolution should be investigated to see if there could be more refinement, however there is a balance between refinement of the scale and loss of information in the data, so this should be investigated further.

4. What are the strengths and weaknesses of the methods? Are there constraints that would hinder the use of the catch monitoring analyses?

Strengths of the analysis include: it is predictive; it quantifies the potential difference between observed and unobserved trips; it is based on sound principles and statistical techniques; it accounts for heterogeneity in catch due to differences in space and time; it is able to account for biases of underlying data sources; and, as currently configured, it does not need additional or unique data sources.

Weaknesses of the analysis include: it was developed mainly for cod at this point; it is limited in some aspects by available data; it is computationally intensive; there is variability in the predictions for otter trawl that need further investigation; its use as a predictive tool will be bolstered by more data informing potential changes in "pre-catch" behavior and more refinement in spatial information; and more work on justifying the co-occurrence species is needed.

The model may be conservative in predicting cod catch on unobserved trips if fishermen were generally attempting to avoid cod catch on observed trips used to parameterize the model. This is partially controlled for with the spatial correlation terms, but fishermen could have employed other methods or information to avoid cod catch on observed trips.

5. Are the conclusions of the Plan Development Team supported by the analyses (see 1e)?

Yes, all of the comments about this method made by the PDT are noted in the documentation of the analysis or in this review of the method. The one caveat to this statement is with regard to the last statement made on the analysis for pollock by the PDT. This was done to show robustness of the method; however, the reviewers don't believe that as much time was invested in this analysis, nor should there be an expectation that the same covariates that are useful for cod are useful for pollock. With a more species-specific model, the power of this method for use on other species should improve.

6. Are there recommendations for improving the analyses, or for additional research or data collection that can help address improving groundfish monitoring?

The reviewers made several recommendations for improvement to the model. These include eliminating cod from the right-hand side of the model either by replacing kept_all with a new parameter comprised of kept_all minus cod catch or by eliminating kept_all and adding additional species catch variables but leaving cod out. Investigating new and/or additional covariates to help better inform the model could also improve the model performance. The reviewers suggested trying covariates that help in the prediction based on changes in population size such as using acceptable biological catch (ABC), or spawning stock biomass in the model as available or appropriate. Additionally, the reviewers thought that adding in some of the information generated by the other methods reviewed, such as using the discard incentive work might also be helpful. The reviewers suggested running the analysis across multiple years and to better refine the species selected as appropriate covariates in the model coupled with potentially finding ways to use these co-occurring species to bring in tows with no cod catch and develop an index such as employed in the development of a Jaccard Index (Jaccard 1901). The reviewers suggested using other data sources beyond observer data such as the Massachusetts IBS for cod and/or using data from vessels with cameras. Some other factors noted by the reviewers were that model validation was needed. The method was validated with respect to its predictive capacity, but should also be tested against an independent dataset, such as a fishery independent survey dataset). The reviewers also suggested running the model without discarded catch, and finally that the description of the results should try to better characterize the most likely outcome and uncertainty around that most likely outcome as many will likely be unfamiliar with the Bayesian approach to describing solutions and results.

IV. <u>Methods to evaluate groundfish catch ratios</u>

a. Reviewer Summary Comments:

The objective of the study was to compare ratios of stock-specific landings to effort and total catch on observed and unobserved trips in the multispecies groundfish fishery to determine whether there is evidence of an observer effect. The hypothesis of the study was that if constraining stocks lead to illegal discards, this should be evident in differences in the stock-specific ratios of landings to effort and total catch between observed and unobserved trips. The study assumes that differences are due to the observer effect (i.e., observed trips do not represent unobserved trips) and not due to the deployment effect (i.e., observers are not randomly distributed among fishing trips). Landings ratios were characterized at an aggregate level by gear type and broad stock area over an annual time step for both observed and unobserved trips. The reviewers appreciated the parsimony of this approach, but felt it needed a little more refinement as described below before it could be used by managers.

b. Terms of Reference:
    1. Are the methods adequately described and based on sound analytic techniques and statistical principles?

Yes, the methods for this study are relatively straightforward and clearly described, although some aspects of the study would benefit from additional description.

The reviewers suggest that the report more clearly explain that the calculation of ratios of landing to total catch or effort ratios was conducted at the aggregate gear-area level rather than individual trip level. For example, the equation should include subscripts for species, area, and gear type, and a subscript on the sum function indicating summing across trips. Additionally, the description of the data should be clarified, and the "AA table" should be specifically defined.

While there is no statistical analysis of the differences in landings ratios, color coding is used to identify patterns that are consistent across landings ratios. Further description of criteria for what constitutes the identification of a pattern should be included as this plays an important role in interpretation of the results. The analyst should describe the rationale for assigning results using the yellow and gray color assignment and make clear that these do not indicate statistical significance.

2. Are important uncertainties in the data and the analyses (possibly including the effects of year to year variations in fishing practices) identified, and are the impacts of these uncertainties on the analyses adequately described?

The uncertainties in the data and analyses are not discussed extensively in the report, although it was noted that Sector IX trips were excluded from the analysis because they are known to be subject to misreporting. A key uncertainty not addressed in the study was the large differences in the sample size of observed to unobserved datasets, which introduces potential issues for the validity of the comparison of landings ratios. A more detailed description of the breakdown of data by finer spatial resolution and time step (season or month) would allow a more thorough evaluation of whether the observed samples were representative and comparable to unobserved samples. However, a more statistically robust treatment of the data is recommended (further detail is provided below).

3. Are the analyses conducted at the appropriate temporal and spatial scale such that the existence of regional or seasonal differences in monitoring performance can be identified?

The analyses appear to be conducted at the appropriate temporal and spatial scale. The analyses are conducted at the broad stock area (Gulf of Maine, Georges Bank, mixed stock statistical area 521) over the years 2011-2017. This allows for identification of regional and annual differences in observer effect but does not allow for seasonal differences to be identified. A more detailed description of the spatial and temporal distribution of the data would allow a comprehensive evaluation of whether the analysis could be conducted at a finer spatial or temporal scale. The limited number of observed trips included in the analysis suggests this may not be possible.

4. What are the strengths and weaknesses of the methods? Are there constraints that would hinder the use of the catch monitoring analyses?

Strengths of the analysis include**:** The study provides an evaluation of the observer effect in the groundfish fishery by gear type and area across years. The analysis was conducted at the species/stock level which allowed for evaluation of the relative importance of the observer effect for certain stocks (e.g. Gulf of Maine cod). This study enabled identification of the direction of the observer impact (i.e. landings ratios on observed trips are greater/less than unobserved trips) and the relative magnitude of the effect through the ratio of observed to unobserved landings ratios (ratio of ratios). However, it stops short of characterizing the magnitude of the observer effect in quantities of pounds of fish landed (or discarded).

Weaknesses of the analysis include**:** The characterization of the results of this study seems to be narrow in scope and there is an opportunity to expand on this. An expanded description of the findings in the text and presentation of results in figures, rather than table format, would be helpful. For example, plots of landings ratios across years, may be easier for the reader to resolve patterns than the table format. The conclusions of this study could be strengthened through approaches that would allow for characterization of the variance between observed and unobserved landings ratios and explicit statistical testing for an observer effect. There is unequal sample size between observed and unobserved trips, with unobserved trips being an order of magnitude greater in number than observed trips. This unequal sample size could result in unequal variance that would challenge the ability to draw robust conclusions about an observer effect. Bootstrap resampling of trips could resolve this issue and could provide a good alternative to derive confidence intervals around the ratio estimates. This would allow for evaluation of whether observed landings ratios fall outside the bootstrap estimates of unobserved landings ratios. Alternatively, statistical testing of an observer effect could be addressed by conducting the analysis at the trip level and employing a generalized linear model or generalized mixed model (which may accommodate unbalanced design) to test for the effect of year, area, observer, and vessel factor (e.g. size/tonnage). Care should be taken in selection of the statistical distribution for modeling trip-level ratios however, since the distributions of ratios are likely to be highly skewed.

5. Are the conclusions of the Plan Development Team supported by the analyses (see 1e)?

In general, the conclusions of the PDT are consistent with the results of the analysis. The PDT concluded that: 1) there are discrepancies between the observed and unobserved trips, 2) more cod landings were seen on observed vs. unobserved trips in the Gulf of Maine stock area, and 3) less haddock landings were seen on observed vs. unobserved trips. The PDT cautioned against interpretation of the magnitude of the differences and indicated that the results were not likely an accurate estimation of the true extent of the potential missing removals. The study identifies absolute and relative differences in landings to effort ratios between observed and unobserved trips and may be useful in informing identification of patterns across years, species, and area. However, without characterization of the variance of observed and unobserved landings to effort ratios and statistical testing of differences it is challenging to draw robust conclusions. This study is helpful in identifying the problem, but it is challenging to use this in characterizing the magnitude of the problem. Also, the paper is helpful in that is supports findings of other papers.

However, the review panel would recommend further research to strengthen the robustness of this analysis.

6. Are there recommendations for improving the analyses, or for additional research or data collection that can help address improving groundfish monitoring?

The conclusions of this study could be strengthened through additional analysis that would allow for characterization of the variance between observed and unobserved landings ratios and statistical testing of the observer effect. To characterize variance, the reviewers suggest conducting bootstrap resampling of trips. This would allow for evaluation of whether observed landings ratios fall outside the bootstrap estimates of unobserved landings ratios.

Furthermore, the reviewers suggest calculating landings ratios at both the individual trip and aggregated gear level. This would allow for different types of statistical analysis to be applied to the dataset. For example, utilizing data at the trip level would allow for application of a generalized linear model or generalized mixed model to test for observer effect as well as the influence of other factors, such as year, area, and vessel factors.

The analyst could take a next step toward characterizing the magnitude of the illegal discard problem by calculating what the landings would have been based on the ratio of observed to unobserved trips on a species basis. This could provide perspective on the magnitude of the discard problem; however, the reviewers suggest that the analyst is the best judge as to whether calculation of magnitude is appropriate based on knowledge of the data and analysis.

V. Term of Reference 8

a. Reviewer Summary Comments:

This was a term of reference for all of the methods and was titled "Are the data, methods, and analytic tools sufficient for the Council to identify and analyze monitoring alternatives for the Northeast Multispecies Fishery Management Plan Amendment 23 management action?" The reviewers felt that this term of reference was cross cutting for all of the methods, therefore it was given its own section and answered in a way that is comprehensive across all of the methods examined.

b. Reviewer Comments:

Each of the methods has strengths and weakness, but together the set of studies provide substantial support to conclude that there are differences both in discarding behavior and in fishing behavior between observed and unobserved trips. The analyses suggest that discard estimates from observed trips should not be used to estimate discards from unobserved trips, or at minimum not without some adjustments. In addition, this suggests it is not appropriate to determine a level of observer coverage that should be deployed by considering the coefficient of variation of discard estimates from observer coverage since observed trips are not representative of unobserved trips. Furthermore, these studies suggest that the direction of the impact of the observer effect on landings (positive or negative) appears to vary by species/stock.

The analyses do not quantify the magnitude of the problem of unaccounted discards. Both PDT analyses reviewed in section III (*methods to predict groundfish catch in the presence of observer bias*) and section IV (*methods to evaluate groundfish catch ratios*) of this report both could be used to provide estimates of the total quantity of unreported discards relative to annual catch limits (ACL) or ABCs with some additional refinement.

By way of some potential pathways for the Council to use this information, the reviewers offer the following comments. First, if the percentage of the ACL that is discarded on unobserved trips is not large (e.g. less than 10%) then it might be feasible to use the section III (*methods to predict groundfish catch in the presence of observer bias*) approach to estimate discards on unobserved trips and use this to determine an appropriate buffer between the ABC and ACL to account for management uncertainty.

Second, if discards are a large proportion of the ACL, then the above approach is unlikely to be successful and may be counterproductive. What we mean by this is that the increased buffer would have to be large and would aggravate the illegal discard problem, which could make estimating discards for unobserved trips more difficult and uncertain. In this situation, rather than attempting to estimate the discards, the analysis reviewed in section I (*methods to explore discard incentives of groundfish stocks*) suggests that there may be a need for increased monitoring and enforcement or increased penalties to deter illegal discarding. It would be useful to apply the discard incentive analysis to observed trips to see if a higher percentage of landed catch has positive discard incentives which would indicate more clearly the likelihood that discarding is occurring on unobserved trips. However, this would still suffer from the problem that observed trips' catch composition may differ from unobserved trips due to differences in fishing behavior.

In conclusion, the reviewers note that unaccounted mortality from the fishery is one of several contributors to issues in our understanding of groundfish populations. Resolving to better understand this potential bias will be a step forward in improving our understanding of groundfish populations and will contribute to improved accounting of fishery mortality in our management process.

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Benoît H. P., Allard J. 2009. Can the data from at-sea observer surveys be used to make general inferences about catch composition and discards? Canadian Journal of Aquatic Sciences 2009; 66:2025-2039.

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Appendices

Appendix 1 – Terms of Reference

New England Fishery Management Council
50 WATER STREET | NEWBURYPORT, MASSACHUSETTS 01950 | PHONE 978 465 0492 | FAX 978 465 3116
John F. Quinn, J.D., Ph.D., *Chairman* | Thomas A. Nies, *Executive Director*

MEMORANDUM

DATE: April 12, 2019

TO: Scientific and Statistical Committee Subpanel for Groundfish Monitoring

FROM: Tom Nies, Executive Director

SUBJECT: **Terms of Reference – Review of Groundfish PDT Information and Analyses of Groundfish Monitoring Issues**

Background

The New England Fishery Management Council has organized this review to ensure that any new and novel analyses of Amendment 23 issues and management alternatives get sufficient independent review.

Terms of Reference

1. For each of the Plan Development Team's four analytic methods listed below (1a – 1d), please address the questions in numbered sections 2 through 8 below:
    a. Methods to explore discard incentives and estimate prohibited discards of groundfish stocks.
    b. Methods to evaluate observer effects in the groundfish fishery.
    c. Methods to predict groundfish catch in the presence of observer bias.
    d. Methods to evaluate groundfish catch ratios.
    e. Groundfish PDT conclusions based on the analyses conducted

2. Are the methods adequately described and based on sound analytic techniques and statistical principles?
3. Are important uncertainties in the data and the analyses (possibly including the effects of year to year variations in fishing practices) identified, and are the impacts of these uncertainties on the analyses adequately described?
4. Are the analyses conducted at the appropriate temporal and spatial scale such that the existence of regional or seasonal differences in monitoring performance can be identified?
5. What are the strengths and weaknesses of the methods? Are there constraints that would hinder the use of the catch monitoring analyses?
6. Are the conclusions of the Plan Development Team supported by the analyses (see 1e)?
7. Are there recommendations for improving the analyses, or for additional research or data collection that can help address improving groundfish monitoring?
8. Are the data, methods, and analytic tools sufficient for the Council to identify and analyze monitoring alternatives for the Northeast Multispecies Fishery Management Plan Amendment 23 management action?

1. **Groundfish Plan Development Team (PDT) Analyses to be Reviewed**
    a. Methods to explore discard incentives and estimate prohibited discards of groundfish stocks
    b. Methods to evaluate observer effects in the groundfish fishery
    c. Methods to predict groundfish catch in the presence of observer bias
    d. Methods to evaluate groundfish catch ratios
    e. Groundfish PDT conclusions based on the analyses conducted
    f. Presentations

2. **Additional background materials**
    a. Draft Alternatives for Amendment 23/Groundfish Monitoring
    b. Gulf of Maine cod hotspot analysis by the Groundfish PDT

Appendix 2 – Review Agenda

New England Fishery Management Council
50 WATER STREET | NEWBURYPORT, MASSACHUSETTS 01950 | PHONE 978 465 0492 | FAX 978 465 3116
John F. Quinn, J.D., Ph.D., *Chairman* | Thomas A. Nies, *Executive Director*

Meeting Agenda

New England Fishery Management Council

Peer Review of
Groundfish Plan Development Team Analyses of Groundfish Monitoring

Hotel Providence
139 Mathewson Street, Providence, RI 02903
Telephone: (401) 861-8000

Day 1- Wednesday, April 24, 2019

10:00	Welcome, introductions and agenda review (Chair)
10:15	Review of Terms of Reference (Chair)
10:30	Groundfish Plan Development Team (PDT) Presentations and Panel Questions • Overview (Cournane) • Methods to explore discard incentives and estimate prohibited discards of groundfish stocks (Errend) • Methods to evaluate observer effects in the groundfish fishery (Demarest) • Methods to predict groundfish catch in the presence of observer bias (Linden) • Methods to evaluate groundfish catch ratios (Nitschke) • Groundfish PDT conclusions based on the analyses conducted (Cournane)
12:30	LUNCH
1:15	Presentations and Panel Questions (*continued*)
3:30	Opportunity for public comments
3:45	Review Panel discussion *
5:30	Adjourn

- ***Note: The Chair may take public comments throughout the Review Panel discussion as appropriate.***

Day 2- Thursday, April 25, 2019

8:30	Review Panel comments and development of Review Panel report *
1:30	Adjourn

- ***Note: The Chair may take public comments throughout the Review Panel discussion as appropriate.***

This meeting is physically accessible to people with disabilities. This schedule is subject to change. If you have questions, please call the Council office for final confirmation of meeting times, dates and locations.

Amendment 23

To the

Northeast Multispecies Fishery Management Plan

Appendix V

Cost Efficiency Analysis of Fisheries Monitoring for Catch Accounting in the Northeast Multispecies (Groundfish) Fishery

A Cost Efficiency Analysis of Fisheries Monitoring for Catch Accounting in the Northeast Multispecies (Groundfish) Fishery

Chad Demarest[1], Anna Henry[2], Greg Ardini[1], Samantha Werner[1]

Updated September 15, 2019

[1] Northeast Fisheries Science Center, National Oceanic and Atmospheric Administration. 166 Water St., Woods Hole, MA 02543-1026.

[2] North Pacific Fishery Management Council. 605 West 4th, Suite 306., Anchorage, AK 99501-2252.

CONTENTS

SUMMARY

This report aims to illustrate differences in the costs associated with, and the underlying qualities of, data generated by various catch monitoring technologies in the commercial groundfish fishery in the Northeast US. For at-sea catch monitoring, our comparison primarily focuses on human at-sea monitors/observers (ASM) and electronic monitoring with video recording cameras (EM). Three EM models, census, audit and compliance, are analyzed . We compare single-year ASM costs by gear, vessel length, and homeport state to costs for EM technologies averaged over five years, the typical lifespan of EM onboard equipment. We provide a brief discussion of the cost and data quality associated with dockside monitoring of landings (DSM). For each monitoring technology, we report on two aspects of data quality: internal validity and external validity (Schram 2006). Internal validity refers to the error associated with sampling using the monitoring technology and external validity is associated with how those data are applied to catch monitoring. Understanding the qualities of data generating processes is integral to designing an efficient and effective monitoring system.

INTRODUCTION

Purpose of report

This report focuses on differences in costs and qualities of data generated by three technologies suitable for independent catch monitoring in the Northeast US commercial groundfish fishery: 1) human at-sea monitors/observers (ASM), 2) electronic monitoring with video recording cameras (EM) and 3) dockside monitoring of landings (DSM). Each of these technologies are designed to address different aspects of catch accounting that are potentially subject to independent verification. They each differ in the data they provide, the quality of those data, their up-front and life cycle costs, and their impact on various components of the fishing fleet. We estimate the costs associated with each technology and provide comparable cost estimates across technology platforms, both fleet-wide and disaggregated by various fleet components (e.g. gear type, vessel length categories, vessel principal port and state).

Cost efficiency analysis is best thought of as an optimization problem, where the objective is to minimize costs subject to a constraint. In this case, the constraint is a minimum coverage level capable of generating precise and unbiased catch data. The most cost efficient monitoring program is the one that provides data at or above this “precise and unbiased” threshold, at the lowest possible cost.

To provide an accurate comparison of monitoring technologies we must understand not only how the potential range of costs vary, but how the data they provide vary, and how the aspects of program design influence these differences in costs and data quality. For the latter, we report on two aspects: internal and external validity (Schram 2006). Internal validity refers to the error associated with sampling using the monitoring technology (i.e. is the monitoring program measuring what it’s supposed to measure and how precise are those measurements?) External validity is associated with how those data are applied to catch monitoring (i.e. can the data be generalized beyond the collected sample?) This information is integral to designing an efficient and effective monitoring system.

Fishing fleet characteristics

We restrict our analysis to vessels making groundfish trips, identified using a definition from the NEFSC Report on the Performance of the Northeast Multispecies (Groundfish) fishery:

> A groundfish trip is defined as a trip where the vessel owner or operator declared, either through the vessel monitoring system (VMS) or through the interactive voice response system, that the vessel was making a groundfish trip. This includes trips on which groundfish DAS were used, including monkfish (Lophius americanus) trips that used groundfish DAS (Murphy et al 2018).

Some of these trips may not have landed groundfish but are still subject to groundfish monitoring requirements. Trips exempted from current ASM requirements (eg. NEMS Framework 55-exempted trips) are excluded (NEFMC 2016). Figures 1 and 2, and Tables 1 and 2 summarize fleet characteristics for the vessels used on our analysis.

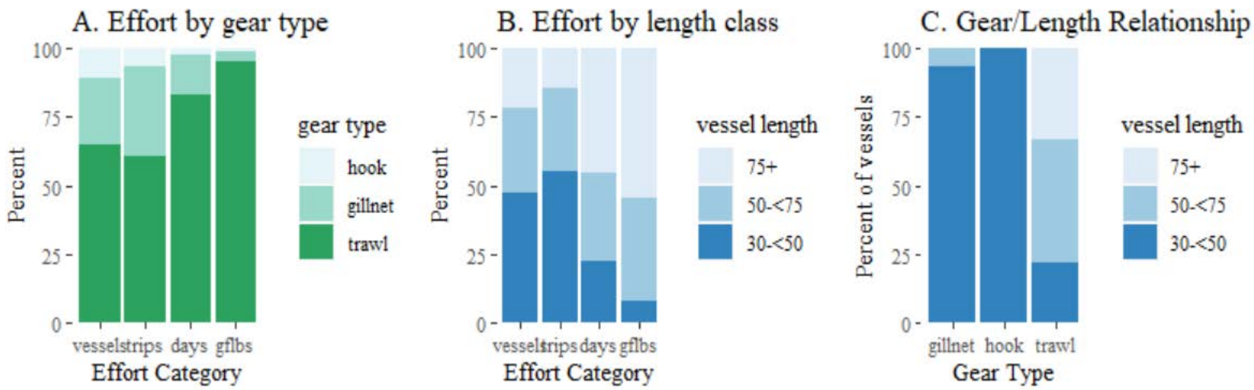

Figure 1, Percent of effort by gear type (A) and length class (B). Percent of vessels in each gear type by length class (C). Data are from FY 2017.

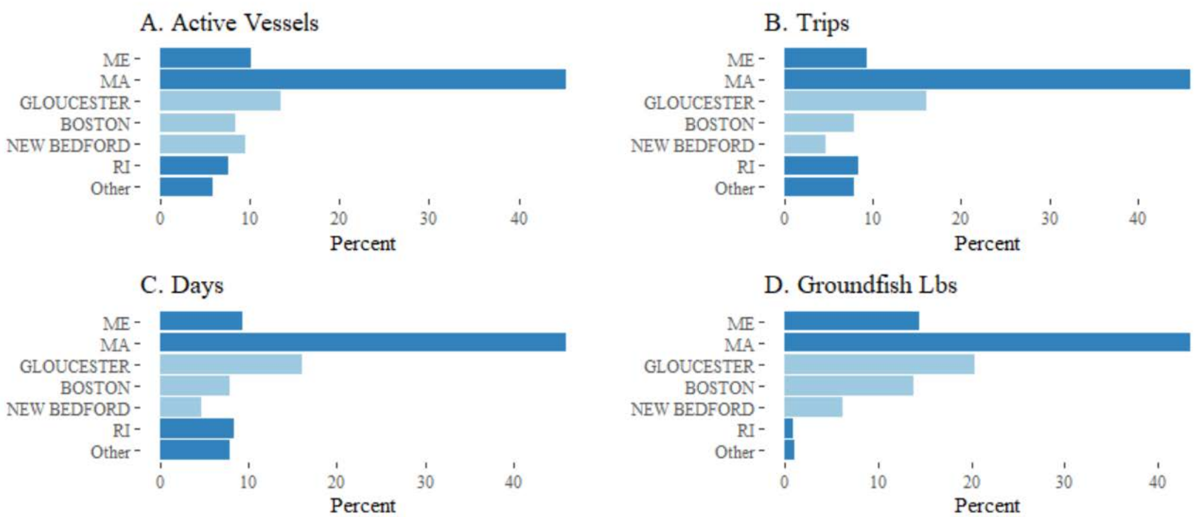

Figure 2. A-D. Percent of effort by Principal Port State (dark shade) or Principal Port (light color). Principle Port declared on permit application. Data are from FY 2017.

Table 1. Number of active vessels by length, gear, and trip state, FY13-17. Vessels that fished across categories in a given year were placed in the category of maximum number of trips.

Vessel Length	**2013**	**2014**	**2015**	**2016**	**2017**
30 - <50	107	101	86	92	94
50 = <75	82	82	80	72	61
75+	45	43	43	43	42
Gear Type					
Gillnet	57	60	50	45	47
Handgear/Longline	10	8	8	19	20
Trawl	167	160	151	143	130
Trip State					
MA	144	144	134	132	130
ME	29	27	23	25	26
RI	37	29	31	27	23
OTHER	26	28	22	24	19

Table 2. Number of groundfish trips by length, gear, and landed state, FY13-17.

Vessel Length	**2,013**	**2014**	**2015**	**2016**	**2017**
30 - <50	4,646	4,057	3,199	3,057	3,305
50 = <75	2,472	2,232	2,213	1,755	1,829
75+	987	1,064	972	960	834
Gear Type					
Gillnet	3,234	3,082	2,097	1,981	1,870
Handgear/Longline	134	55	97	232	401
Trawl	4,644	4,200	4,109	3,488	3,632
Trip State					
MA	4,807	4,268	4,170	3,994	3,963
ME	901	878	532	427	571
RI	916	752	809	644	638
OTHER	1,318	1,293	735	646	673

Monitoring in catch share fisheries

Catch share management[3] requires information on the quantity, species and capture location of all fish that are retained (landed and sold) and discarded on every trip. This combination of information is necessary to account for the total amount of fishery removals by stock at the sector level, a process referred to as "catch accounting." Presently, catch accounting uses a combination of self-reported data provided by industry (fishermen, sector managers or dealers) and independent data provided by fisheries monitors (Table 3). Fishery landings are recorded by vessel captains in Vessel Trip Reports (VTRs), by commercial fish dealers in Dealer Reports, and, on some proportion of trips, by contracted Observers in the Northeast Fisheries Observer Program (NEFOP) or At-Sea Monitors (ASM)[4]. Dealer reports are the primary source of pounds landed for catch accounting purposes. Fishery discards are required to be recorded by vessel captains on all trips, and by onboard fishery observers when present. Captain-reported discards are not currently used for catch accounting, and trip-level discard estimates are calculated on the basis of discards recorded on observed trips. Landings are not independently monitored, nor are discards on unobserved trips. Observers record kept catch weight estimates for the sole purpose of creating a ratio of kept catch to discards, which are used by NOAA's Greater Atlantic Regional Fisheries Office (GARFO) to estimate a ratio of discards to landings for each strata of sector, stock area and gear type. This Discard Ratio (D/K, discards divided by kept catch) is applied to unobserved trips, by strata, to estimate pounds of discards on those trips. The estimated discards are added to the landings on unobserved trips for the total amount of fish deducted from the sector's catch allocation (NOAA Fisheries 2010). Observer estimates of kept catch may be informally compared to VTR and dealer data, but are not formally utilized to verify either dealer or captain's reports. Table 3 summarizes current data sources for catch accounting.

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[3] Since 2010 New England groundfish have been managed through an output control system known as catch share management (also referred to as sector management). Vessels voluntarily enroll in a sector that contractually agrees to specific fishing protocols and are allocated a portion of the overall quota, or catch share based on the catch history of their membership. Vessels are mandated to discard fish under minimum size limits and are required to land all legal sized fish they catch. Throughout the fishing year each member's landings and discards are counted against the sector quota. The sector system is a voluntary system and vessels that elect not to join sectors can continue operating under the prior days at sea management system. These vessels are termed the "common pool" and account for a relatively small portion of total ground fishing effort. The common pool accounted for 23% of active groundfish vessels, 12% of groundfish trips, and 2% of groundfish revenue in FY2015 (Murphy et al 2018).

[4] NEFOP is a government-funded regional observer program that covers multiple fisheries. NEFOP observers collect catch data and biological information to inform stock assessments and bycatch estimation. NEFOP coverage levels are determined annually based on the number of sea days needed to achieve a coefficient of variation of 30% (CV30) of discard estimates for 14 fish and invertebrate species groups (Wigley and Tholke 2017). For the purpose of this report NEFOP is a sunk cost, as the NEFOP coverage fulfills a statutory requirement to determine discards of all species (not just groundfish). NEFOP observers also collect important biological samples required for stock assessments that cannot be completed by other monitoring technologies. Monitoring specifically for groundfish catch accounting is completed by the ASM program with the main goal of providing information on sector quota utilization. ASM monitors collect information on area fished, gear used and species and amounts of landings and discards.

*Table 3. Fishing information provided by data source for catch accounting purposes. I=Independent data, S=Self-reported data. *Location is independently reported but fishing activity is not.*

	Fishing information provided								
			Kept Catch		Discard		Landing		
Data Source	**Gear**	**Fishing Location**	**quantity**	**species**	**quantity**	**species**	**quantity**	**species**	**Biological info**
At Sea Monitors (ASM)	I	I	I	I	I	I			
Northeast Fisheries Observer Program (NEFOP)	I	I	I	I	I	I			I
Dealer Reports							S	S	
(Electronic) Vessel Trip Reports (eVTR/VTR)	S	S	S	S	S	S			
Vessel Monitoring System (VMS)	S	I*							

Importance of monitoring

Monitoring provides an independent data source for verification of self-reported data. Much of the data used in the current catch accounting system are self-reported, and these data are not always perfectly reliable. Investigations of self-reported stock area on VTRs showed that on trips covering multiple areas, VTRs match observer reported stock area less than 50% of the time. For some stocks, this area misreporting implied a potential relative error in annual landings apportionment of up to 10 times when compared to landings estimated from independent stock area sources (Palmer 2017). Fishing location is just one aspect of self-reported data that may lack in accuracy. Recent enforcement investigations provide evidence that species and amounts of landings have also been misreported. One of the most prolific figures in New England groundfish recently plead guilty and was sentenced for filing reports falsifying the species of over 780,000 pounds of groundfish landings (Cramer 2017).

Accurate catch accounting information in the New England groundfish fishery is important for at least four reasons. First, there is a regulatory mandate to end overfishing (MSA 2007). At a basic level, this mandate cannot be met without accurate knowledge of the total removals of fish by stock. Second, overfishing limits are determined through stock assessments, which are reliant on fishery-dependent catch data as well as fishery-independent survey data. Stock assessments as employed in the Northeast assume that catch is known "without error," a false assumption. Third, prevention of overages, through accountability measures (AMs), require monitoring to ensure they are implemented appropriately. Accountability Measures are fishing restrictions that are implemented to constrain or prevent catch for components of the fishery that have removals beyond the allowable catch. In groundfish sectors, overages of allocated stocks require sectors to payback the overage in the following year. For non-allocated stocks, gear restricted areas are typically enacted when a fishery-wide overage occurs. Timely, accurate catch information insures against allowing overages to occur without consequence or preemptively punishing segments of the fleet that are undeserved. Fourth, catch accounting information is important for the proper function of the inter-sector catch allocation lease market. Without adequate monitoring, fishermen have an incentive to highgrade or discard certain groundfish stocks if they do not have quota available or if the cost of leasing quota will exceed the revenue generated from landing (Batsleer et al, 2015). If, due to lack of monitoring, fishermen are only required to have enough quota to cover the fish that they land, rather than their total catch, the price signals provided by the lease market will not adequately allocate fishing effort in space and time. This drives cost and revenue inequities between rule followers and rule breakers, and between active fisherman who may benefit from muted price signals, and fisherman who chose to lease out their allocations, who will lose income when lease prices fail to represent those consistent with true (fully monitored) demand. Furthermore, catch data are critical inputs into stock assessments. In fact, a feedback loop exists: quota allocations are based on stock assessments, which are based in varying degrees on catch monitoring. If catch is inadequately monitored, assessment quality may decline or fishing mortality signals may be missed, resulting in the need for lower future catch allocations, higher relative demand for constraining stock quotas, and increased highgrading and discarding incentives that mute price signals and exacerbate problems created by a poorly functioning market for catch allocations.

Catch monitoring technologies

Three components of catch are important to groundfish fishery administration, each potentially subject to independent monitoring: landings, discards and the stock area from which the harvest was extracted. This report focuses primarily on technologies for monitoring discards.

Landings

As previously mentioned, dealer reports are the official data source for landing. Compliance with reporting requirements may be imperfect due to imprecision, loss of data from illegally discarded unmarketable or low-value fish, or intentional data manipulation. We discuss dockside monitoring (DSM) only as a tool for monitoring landings, and therefore this technology is not strictly a part of our cost efficiency analysis as no alternative methods of landings verification (e.g., so-called “weighmaster” systems, targeted enforcement) are assessed. To our knowledge, no formal assessment of the precision or bias associated with landings data has been produced, and, beyond DSM, a full suite of options for independent verification of landings has not been investigated.

Discards

For monitoring discards, we focus on the use of human observers under the ASM program and on a few strategies employing electronic monitoring using cameras. Critically, monitoring discards includes both accurately characterizing the size and species of fishery-wide discards and ensuring compliance with mandatory discarding and retention regulations. These duel priorities imply that discard monitoring must provide relatively precise and unbiased estimates of true at-sea discarding.

At-Sea Monitoring

Since 2010, the ASM program has been the sole method of estimating discards and ensuring compliance with mandatory discard and retention regulations. Monitoring coverage rates in the NEFOP and ASM program vary year to year (Table 4). ASM coverage rates are calculated by GARFO and are set such that when combined with NEFOP they are likely to provide discard estimates of each groundfish stock with a precision of CV30 or better (GARFO ASM 2017). Annual realized coverage rates can fall short of target rates due to a number of factors, including noncompliance with the pre-trip notification system (PTNS), a lack of available observers and trip cancellations by vessels.

A sub-committee of the New England Fishery Management Council’s Science and Statistical Committee reviewed several reports designed to investigate the precision and bias associated with discard data collected by human observers in the groundfish fishery, and found that estimates generated by the program to date (ie. partial fleet coverage) were likely to be biased and inaccurate (NEFMC 2019). We report cost estimates for varying levels of partial fleet coverage, but for cost efficiency purposes the cost of full coverage is the appropriate value to compare to other technologies. Defining full coverage for human observers is not straightforward. Because the NEFOP program operates somewhat independently, and has averaged 9.1% coverage over the previous three years, a lower bound of full coverage implies approximately 91% of all trips. Noting that observers do not observer every tow of a trip , even this may not provide coverage that is directly equivalent to that provided by other technologies (Table 6).

Table 4. Target and realized observer coverage rates, by fishing year. Reprinted from Table 4 in NOAA, GARFO ASM Requirements Summary FY2019.

Fishing Year	NEFOP target coverage	ASM target coverage	Total target coverage	Realized coverage
2010	8%	30%	38%	32%
2011	8%	30%	38%	27%
2012	8%	17%	25%	22%
2013	8%	14%	22%	20%
2014	8%	18%	26%	25.7%
2015	4%	20%	24%	19.8%
2016	4%	10%	14%	14.8*
2017	8%	8%	16%	14.1%
2018	5%	10%	15%	n/a

Electronic monitoring using cameras

Electronic monitoring (EM) has been researched as a potential alternative to human fisheries observers for over a decade (i.e. Ames et al 2005, McElderry 2005, White 2006). EM systems have been approved and are currently in use in numerous fisheries, including groundfish fisheries on the US West coast (Fed Reg 2016)) and in British Columbia Canada (Stanley 2011). In New England, pilot projects for the use of EM in the groundfish fishery have been conducted since 2010 (NEFSC 2010-14), and this technology has been used by segments of the fleet as a replacement for ASMs under experimental fishing permits.

Electronic monitoring is a broad term that is often used to describe systems of varying complexity from anything that utilizes electronic data entry or collection to systems that use electronics to identify and quantify catch. For the purposes of this report, electronic monitoring refers to a camera-based system that collects video footage of fishing operations and electronically records other vessel activity and location data. This type of EM system includes, at minimum, two cameras (most vessels require more), a control box, user interface, a GPS receiver, a hydraulic pressure transducer, and a drum rotation sensor (Figure 6). In general, EM units shall be configured to provide GPS location and date at all times while the vessel is at sea, video imagery of all fishing operations with adequate resolution for species identification and estimate of fish size (depending on program design and requirements) and video imagery of transit operations with adequate coverage and resolution to determine if discarding is occurring.

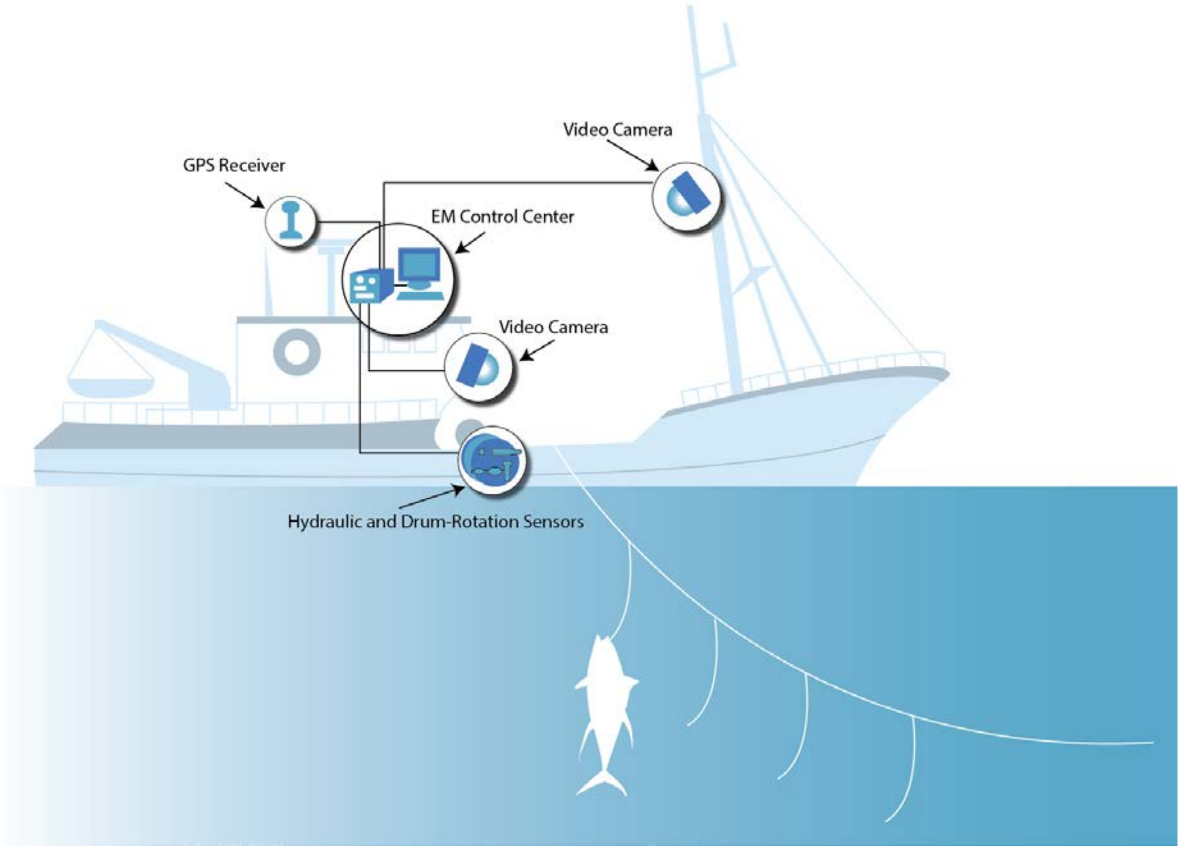

Figure 3. NOAA schematic of general EM setup.

EM models and program designs vary depending on the goals and objectives of the data collection. In New England, the goal has been accounting species and quantity of allocated groundfish discards. We investigate three EM models: 1) A census model where EM video is reviewed and used to directly identify and quantify discards. 2) An audit model where fishermen fill out electronic vessel trip reports (eVTRs) or other approved logbooks for each haul and discards are calculated directly from logbooks; a portion of the EM video is reviewed to verify and validate the accuracy of the logbook reports. 3) A compliance model where a majority of the catch is retained and EM footage is used to determine if discarding occurs but there is no attempt to quantify discards using video review[5]. Each system has various advantages and disadvantages (Table 5) and may be more or less suitable for different gear types and/or catch quantities.

[5] Maximum retention is not a one-size fits all definition. In the current EFP pilot project in the groundfish fishery, maximum retention consists of retention of all allocated groundfish, whether legal or sub-legal size. Non-allocated groundfish continue to be discarded.

Table 5. Basic Electronic Monitoring program designs and associated advantages and disadvantages.

Program design	Discard data source	Disadvantages	Advantages
Census	EM footage	high footage review time specific catch handling protocols	high data quality
Audit	logbook	specific catch handling protocols	lower footage review time fishermen participation in data incentives for catch handling
Compliance	EM footage (presence/absence only)	no discard quantity/composition information	lower footage review time normal catch handling protocols

Assignment of catch to stock area

The groundfish fishery regulations cover four species with multiple sub-stocks: cod, haddock, winter flounder and yellowtail flounder. These four species comprise 12 independent catch allocations, each generating it's own quota lease prices. As noted in Table 3, stock area catch allocation is primarily driven by self-reported VTR data. Given differences in quota lease prices for the same species, there are incentives to report catch into areas where it may not have been caught. Two mechanisms are at play. First, regulations allow reporting of catch in the area where a haul was ended and not necessarily the area where the fishing took place. Second, captains may strategically report catch into areas where they spent little time fishing. Palmer (2017) shows that inaccurate assignment of catch to stock area may be a significant problem for this fishery. Little research has yet been published comparing the efficacy of either human observers or EM for accurate stock area assignment, though it is generally assumed that both EM and human observers at high fleet-wide coverage rates will improve stock-specific catch data. Other cost-efficient technologies for improving the assignment of catch to stock area are not investigated here, noting that this is an important avenue for future research.

METHODS AND MODELS

At-Sea Monitors (ASM)

Using methods described in Ardini, et. al. (2019), sea day costs were attributed based on contracted rates specified in service agreements between sectors and monitoring provider companies for FY16-18, on an annual basis. [6] Sea day rates are generally calculated to cover all provider costs associated with providing ASM monitors, such that overall costs of program management (hiring, paperwork, reporting, etc.), as well as observer training, are built in to the sea day rates. Observer travel costs are based on percentages received from the ASM providers (Ardini et al 2019). The at-sea costs and travel costs were combined to give total ASM costs.

Current ASM coverage rates only place monitors on a relatively small portion of overall groundfish trips (see Table 2 for yearly ASM coverage rates). To compare ASM costs with different monitoring schemes, which may provide more complete monitoring coverage, we estimate ASM costs at coverage rates up to 100% ASM coverage, recognizing that NEFOP coverage exists in the groundfish fishery and comprehensive monitoring will likely imply an ASM coverage rate equal to 100 minus the NEFOP coverage rate. Over the fishing years 2016-2018, 9% of groundfish trips have been covered by a NEFOP observer.

ASM contracted rates have been negotiated on a yearly basis. Since there has been limited variability in ASM coverage rates, there is some level of uncertainty regarding how costs change when coverage is increased or decreased. We expect that higher coverage rates will decrease observer travel costs since there will be a greater pool of available observers to cover trips. We are less certain how a change in coverage may affect seaday rates. We estimate costs at increased rates as a function of the current contracted rates, with the following assumptions: Seventy percent of the sea day cost is fixed to cover the actual cost of having a monitor at sea, 10% scales based on the number of trips covered, 10% scales based on the total number of observers required to cover the specified level of coverage and 10% of the cost scales based on the coverage rate. Total cost is specified as

$$\sum_{t=1}^{n}\left[(0.7C_t)+(0.4C_t\square(obs_o/obs_r)_t)\right],$$

(Equation 1)

where *C* is the total cost of the trip estimated at the negotiated sea day rates averaged across the FY16-18 contracts, obs_0 is the number of observers at the FY17 coverage rate and obs_r is the number of observers needed for the number of days observed.

For each 10% coverage rate interval we select a pool of trips for the given year. We repeat selections 20 times, so as to have 200 selections of trips for each fishing year (10 coverage rates, 20 pool selections for each. We then repeat this process for each of the five fishing years (2013-2017). For 100% coverage, every groundfish trip is selected, though even at 100% trip coverage, some hauls will be unobserved

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[6] A majority of ASM costs have ultimately been reimbursed by NOAA. For July 2016 through April 2017, 85% of monitoring costs were reimbursed. For the entirety of FY17,, the reimbursement rate was 85% https://www.greateratlantic.fisheries.noaa.gov/mediacenter/2017/06/16_asmreimbursement2017.html

(Table 6). ASM observers are able to observe virtually every haul on single day trips, but miss ~15% of hauls on multi-day trips.

To estimate the number of observers required for higher ASM coverage rates, we fit a simple linear function to combined ASM and NEFOP observer data from FY10-17 to determine the number of observers required annually to cover the various number of fishing days by month and provider (Figure 4). The slope of the regression line indicates that each additional day observed at the sector/month level results in .096 additional observers. Dividing 1 by this number yields an additional observer hired for every 11 days observed. This function slightly underestimates the number of ASM observers at lower coverage rates. For our purposes we use the number of ASMs used in FY17 (47) as our lower bound.

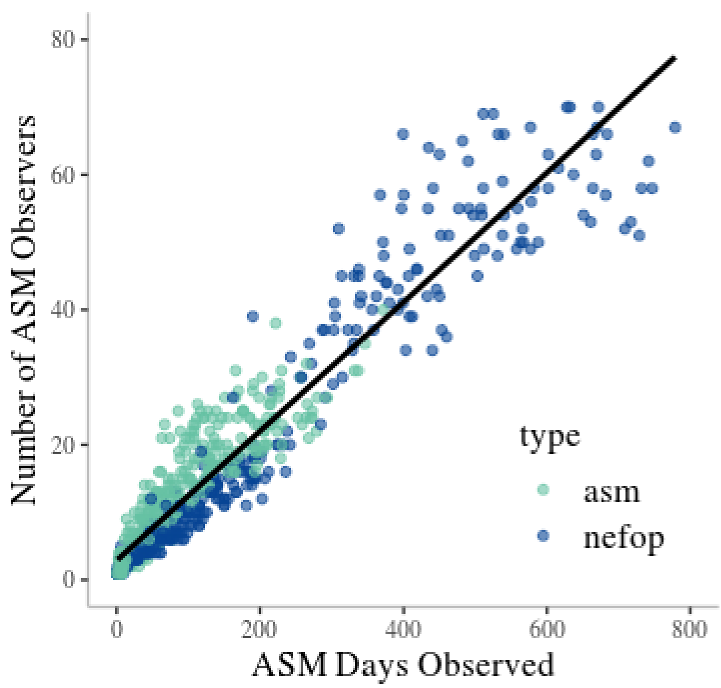

Figure 4. Total number of observers per fishing year to cover number of days by month and observer program using data from FY10 through FY17. Fit with linear function Y~2.8742+0.0957DA with an R-sq of 0.91).

Table 6. Percent of hauls unobserved on ASM covered trips by fishing year (Source: NOAA NEFSC Fisheries Sampling Branch. NEFSC protocols require that a minimum of 75% of all trawl hauls are observed).

Fishing Year	% hauls unobserved on single day trips	% hauls unobserved on multi day trips
2010	2%	14%
2011	2%	14%
2012	1%	13%
2013	2%	14%
2014	1%	15%
2015	2%	14%
2016	1%	16%
2017	1%	15%
2018	2%	20%

Electronic Monitors (EM)

Based on a literature review of existing EM programs and pilot projects, we developed a standardized survey to collect cost data from EM providers (see Appendix). The goal was to provide enough context of the fishery to allow respondents to provide specific cost information at a level of detail sufficient for modeling the costs component costs of many different management designs. Using data from these surveys and subsequent conversations with providers, we developed provider-specific cost functions for four separate EM program aspects: 1) Equipment, 2) Field services, 3) Data review, 4) Data storage. To maintain confidentiality, for each component cost function we ran 1,000 simulations that randomly select input variables from the four providers. One drawback of this method is that it washes out a lot of the variance in potential costs, particularly the common situation where providers optimize around different component of cost. Combining what should be inseparable components centralizes out around a mean cost that may not adequately capture the true cost from any one provider. Further, the actual range of potential costs will have greater variance than our estimates. We cannot maintain proper data confidentiality while still representing the cost actual variance because provider-level costs may be easily inferred. Last, we add additional uncertainty to model variables that we have lower confidence in based on conversations from program participants and/or actual data from pilot programs.

Equipment

One-time EM equipment costs are estimated per-vessel, and include all hardware and software required for a fully functioning EM system. These do not include labor or travel costs for installation, which are included in the field services costs. We assumed three cameras are required for a system on all vessels with hook gear, and for all vessels that are less than 40 feet long. Four cameras are required for vessels using all other gear types greater than 40 feet in length[7].

[7] Based on specifications as noted in vessel monitoring plans for the three New England pilot projects.

One-time equipment costs were estimated as

$$\sum_{v=1}^{n}\left(SC_v + nC_{lg_v} + S_v + Sp_{l_v} + Hd_v + O_v\right).$$

(Equation 2)

Where *SC* is the System Cost (including two cameras, a control box, user interface, a GPS receiver, a hydraulic pressure transducer, and a drum rotation sensor) , *n* is the number of additional cameras beyond three (taking a value of one or zero as four is the maximum number of cameras needed, depending on vessel length (*l*) and gear type (*g*)), *C* is the cost of additional cameras, *S* is the cost of Software, *Sp* is the cost of spare parts, scaled by the vessel length (*l*), *Hd* is the cost of 3 hard drives and *O* is all other costs required for an equipment system or install, indexed across each vessel, *v*. Uncertainty is added as a CV of 0.1 for the cost of spare parts and other costs, as these are variable.

Field services

Field services include all field-based technical support such as equipment installation and maintenance, travel to and from vessels, support and feedback in case of equipment malfunction and data transfers. Where other aspects of an EM program such as equipment costs or data storage costs scale linearly with effort or are otherwise invariant, field services costs are highly variable based on the fleet's geographic composition, program design, and the desired level of operator interaction. These costs are also impacted by the enthusiasm for participation by the fleet—if vessels are committed to the process, it will run more efficiently. If they are not, costs will increase as installations are rescheduled, or proper care and maintenance of on-board EM systems do not occur. Field services are one of the most difficult aspects of EM costs to model. Further, field services, more than other aspects of EM costs, change with time. Costs are front loaded in the first year of programs when equipment installations occur and captains are getting familiar with the systems and processes and require more support.

We estimate field services separately for year one and subsequent years. Year one field service costs are represented as *I*+*M*+*O* where *I*=Install costs, *M*=Maintenance costs and *O*=Other costs. Year one costs are higher because they include system installation costs as well as frequent return visits to check on systems and make adjustments.

Subsequent year field service costs include maintenance costs (which decline by half in year two, by a third in year 3 and by a quarter in year four, after which they are fixed) and other costs, fixed for each year and include on-call phone response to service events plus costs for data transfer to and from the vessel.

Install costs are the sum of labor and travel costs. We assume two technicians are required, one at a random range of the lower hourly wage provided in our survey and one at a random range of the higher survey-provided hourly wage. Thus,

$$\sum_{v=1}^{n}(h_{cl_v}e + 2) * w_{h_v} + (h_{cl_v}e + 2) * w_{l_v},$$

(Equation 3)

where h_{cl} is the hours per install scaled by the number of cameras in the system and the vessel length, *e* is an error of CV0.1 associated with that hour estimate w_h is a randomly selected high hourly wage and

w_l is a randomly selected low hourly wage, indexed by vessel. We assume each vessel requires a fixed two hours of organizational and prep time. This may include coordinating with the captain or developing a vessel install plan.

Travel costs are estimated similarly for install and maintenance. We assume technicians are traveling from one of six ports: Portland, ME, Gloucester, MA, Boston, MA, Chatham, MA, New Bedford, MA or Point Judith, RI. We used the R package gmapsdistance to identify which of these six ports was closest to the vessel homeport and the associated distance and travel time. We assume travel costs are reimbursed at the technicians hourly rate, mileage is reimbursed at $0.54/mile, per diem is between $40 and $61and lodging is between $120-$150/night. As per federal travel regulations, lodging is only incurred if the technician is traveling over 50 miles. We assume installs are scheduled back to back in each home port. This likely overestimates install efficiency. Maintenance and scheduling assumptions may, however, underestimate efficiency and we believe these assumptions are therefore unbiased.

Maintenance costs are estimated assuming: 1) Vessels require a visit from a technician at a rate of every 7th trip with a maximum of three visits per vessel. 2) Each maintenance check takes 4 hours and is performed by the technician at the lower hourly wage rate. 3) Two vessels can be checked per location per day but a technician spends a maximum of three days in a row in a port. 4) Technicians travel to and from their base port to the vessel's home port after each three day stay is completed.

Other costs include one technician on-call for phone response to service events and the cost to mail hard drives from the vessel after every trip plus an additional half hour for handling and tracking data. Many pilot programs mail hard drives after two or three trips are completed, which could be implemented as a cost savings measure but also increases the likelihood of lost or corrupted data.

Review Costs
Video footage review is a substantial component of overall EM program costs. There are two common methods for estimating video review costs. The first is a "ratio method," which estimates the amount of time required for an analyst to review a set amount of footage based on a ratio of review time to total video footage. This estimate is multiplied by the hourly wage of an analyst to estimate cost. However, the ratio of review time to footage time is highly variable and is impacted by many factors, themselves quite variable, which include, but are not limited to, the skill and experience of the reviewer, the catch handling capabilities of the crew, the quality of the video footage, the gear type and the species composition (both total number and type of species) of the catch, and the program design (personal communication, Amanda Barney). Using data from pilot projects in the region, we estimate a regression to relate review time to these other variables. Importantly, the variable that had the largest impact on review times was the individual vessel (standardizing for catch composition, gear type, trip length, etc).

Another challenging feature of review costs is estimating the amount of footage requiring review. One aspect depends on the design of the program and whether transit times are reviewed, or if only haul back and catch handling/sorting require review. Another aspect is estimating the relationship between fishing effort and sorting/catch handling time.

We estimate review costs as

$$\sum_{g=1}^{3}\sum_{t=1}^{n}\left(Rs_{gt} * Td_{gt} + Rf_{gt} * Fd_{gt} + P_{gt}\right) * L_{gt},$$

(Equation 4)

where *Rs* is the review ratio for transit time, *Td* is transit time (duration), *Rf* is the review ratio for fishing time, *Fd* is the fishing duration, *P* is footage/data preparation time and *L* is the hourly rate for a reviewer. The total cost is the sum of these costs, indexed across each trip, *t* and gear type *g*. These are estimated separately for each program design. The review ratio method assumes that review costs scale linearly.

An alternative method to estimate review costs, not used here, would assume that they do not scale linearly and,rather, are subject to specific thresholds of video footage at which point more analysts are hired. Numerous providers state that this is how they approach budgeting for review costs (personal communication, Alaska EIS). We were unable to produce credible estimates of such thresholds, but felt it was important to mention that the linearity assumed in the ratio method may overestimate costs.

Fishing duration estimation

Observers collect data on fishing duration (the time fishing gear is in the water) for observed trips, but there are no equivalent data for unobserved trips. Other effort proxies such as total trip duration and number of hauls are reported for all trips on VTRs. To estimate time fishing, we used observer data from 2013-2017 and model, by gear type, the relationship between fishing time and total trip duration (see appendix for detailed modeling information). These models were used to estimate fishing duration for all FY17 trips. Figure 5 compares predicted estimates to actual fishing duration for observed trips in the FY17 data.

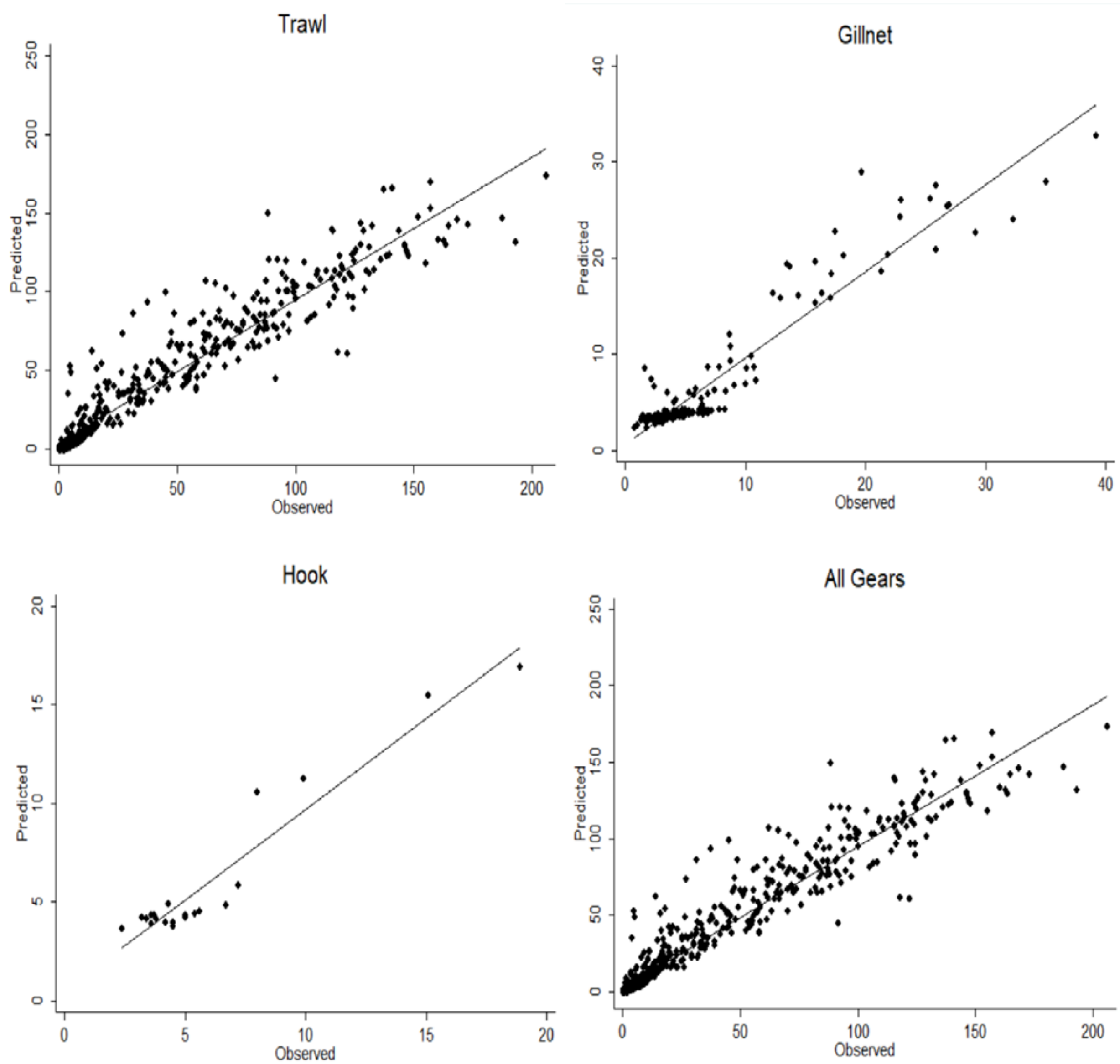

Figure 5. Fishing time (duration) in hours from observer data, plotted against fishing times predicted from linear models using all observed groundfish trips in FY17. One to one line is added for comparison. Trawl N=490, R^2=0.91; Hook N=22, R^2=0.92; Gillnet N=206, R^2=0.90

For estimates of *Rs*, *Rf*, *P* and *L*, we randomly select from a uniform distribution between the minimum and maximum estimates provided in the cost surveys. Review ratios differ by program type based on the data collected and recorded. Census programs require the most review time, followed by audit programs, and trailed by compliance programs, which enable substantially faster video review.

Data storage

There are two main options for storing data: cloud storage and on site servers. On site storage can be a less expensive option when the exact amount of data to be stored is known and servers of the appropriate size can be built; or when data locations are remote and (slow) internet speeds or other expenses prohibit sending data to the cloud. Additionally, federal data redundancy requirements impose costs for on site server storage that could require building the same storage center in two locations. Our cost estimates assume EM data will be stored in the cloud. Estimating prices for cloud based storage is relatively straightforward and many companies, such as Amazon and Google, list their price structures publicly (Table 9).

Estimating the volume of data created is more complex, as it is a function of numerous technical variables and policy decisions. Video footage data volume is primarily based on four variables:

1). Resolution (pixel dimensions) - Also referred to as frame size this is the amount of pixels an image contains. It is specified as the number of horizontal pixels by the number of vertical pixels. For example a resolution of 1280x720 is the minimum resolution to be considered high definition.

2). Frame Rate (frames per second) - The number of individual frames in each second of video recorded.

3). Bit rate (MBPS-mega bits per second) - The number of bits that are processed in a unit of time or the amount of data used for each second of video. For example most DVDs are 4-8 MBPS while a Blu-ray is 25 MBPS. Most cameras record at varying bit rates and allow you to set a maximum bit rate.

4). Subject (what you are recording) - video records a still image and software converts that to moving images. Two videos of the same duration taken with the same camera with identical resolution, frame rate and bit rate can create different amounts of data depending on how they are rendered and the content of their images. For example a two minute recording of a blank wall will be much smaller in size than a two minute recording of a kayaker going through whitewater. These variables also impact the quality of the video, noting that this is also related to external variables such as lens cleanliness and the amount of ambient light. A more complete description of the data usage associated with different subjects can be found in the Appendix.

EM video quality specifications are mostly in the form of performance requirements specifying data needs and objectives (i.e. systems must be able to “Identify, count, and assign a catch disposition--kept or discarded--for individual catch items” or “Obtain an accurate estimated length per catch item, sufficient to obtain a weight estimate from length:weight keys” (NMFS 2016).

The latest draft specifications from the Northeast Fisheries Science Center adopt some minimum technical specifications: “Camera resolution must be a minimum of 1,280 x 720 (720p) for enhanced identification and measurement during video review” and “Each camera must record at a speed of no less than 15 unique frames per second when the use of a video monitoring system is required” (NMFS 2016).

Additional policy specifications will impact how much data volume is created.

- What qualifies as data? Will all footage from the entire fishing trip need to be retained and stored, or just haul back and sorting time?
- What are the retention duration requirements, and where do they apply? Is video footage considered a federal record that must be retained for seven years, or do retention requirements apply only to the data derived from the video?
- How often do data need to be accessed or stored? What are the access requirements, and who will manage access?

Under particular specifications, shipboard systems could be developed triggering hydraulic sensors such that video is recorded only during necessary times (e.g. when the gear is hauled back with a set additional time after for catch handling). If not all footage is considered a federal record, or if resulting data tables meet the records retention requirement, shipboard systems could be simplified to record everything.

Table 7. Cloud data storage/access pricing (https://cloud.google.com/pricing/, https://aws.amazon.com/glacier/pricing/, accessed 11/16/17)

Provider	**Storage**	**put**	**get**	**Access**
Amazon Glacier	per GB/Month	per 1,000 requests	per 1,000 requests	per GB
	$ 0.004	$ 0.05	$ 0.025	$ 0.0025
Google Coldline	per GB/Month	per 10,000 requests	per 10,000 requests	per GB
	$ 0.01	$ 0.05	$ 0.004	$ 0.05

The cost of storage is mainly a function of datavolume , *V*, defined as the footage duration multiplied by the GBPH. For our estimations we assumed fishing footage would be captured at a higher quality than transit footage. More information on data storage and quality can be found in the Appendix. Assuming Amazon and Google provide similar services, we use Amazon's price structure as it is slightly less expensive, particularly if there is no need for frequent data access, unlikely in most management scenarios.

We estimate annual storage costs as: $S+P+G+A$,

where S is the storage cost defined as V*0.04*12, P is the put fee which, assuming there are no more than 1,000 annual requests is a constant of $0.06 ($0.005*12months), G is the get fee which, assuming there are no more than 1,000 annual requests is a constant of $0.30 ($0.025*12months) and A is the access cost defined as $0.0025*$V_a$ where V_a .is the volume of data that must be accessed. We assume only 10% of the total data needs to accessed on an annual basis, estimating V_a as 0.10V.

MONITORING DISCARDS

The quality of data produced is an important consideration when comparing relevant costs between monitoring technologies. For example, the improvements in data quality associated with increases in ASM coverage vs. EM video review rates are not equivalent, making direct comparison difficult. To approximate feasible program designs with equivalent data quality we compare costs of an ASM program at 91% coverage with the three EM programs. Proportion of video reviewed is the primary driver of EM program cost, and to keep things simple we use the following review rates in our cost models: audit 15%, census 50%, and compliance 100%.

At-Sea Monitors

Marginal (per-day) ASM costs are estimated to decline as coverage increases, primarily driven by operational efficiencies from a larger cadre of available observers. Cost per day ranges from a median of $590 at 10% coverage to $518 at 100% coverage, noting that unless NEFOP rates decline to zero, 100% ASM coverage is not a feasible outcome. NEFOP coverage has averaged 9.1% over the previous three years, and the daily rate estimated for 91% ASM is $524 (Figure 6).

We present total ASM costs at 10% coverage intervals (Figure 7). Costs in earlier years are higher, driven by more fishing effort . Variability in ASM costs for a given year and coverage rate is a function of the trips selected during simulation and the per-day ASM costs, which we model as declining slightly at coverage levels above 50%. The cost estimates for 100% ASM coverage for a single year range from $6.9m (FY17) to $9.6m (FY13) (Table 8). However, with NEFOP coverage, an 100% ASM coverage would not be necessary to achieve universal fleet-wide coverage.

Over the five-year period, 91% ASM coverage averaged $7.6m annually and comprehensive ASM coverage cost was $6.4m in 2017. At FY 2013 effort levels, 91% ASM coverage is estimated to have cost $8.8m (Table 9) Average per-vessel costs vary substantially by size class and gear type, driven by the number of days fished in any any given year (Table 10). At 91% coverage, the largest vessels have an predicted per-vessel average cost of $67k per year while the smallest are predicted to average $15k (Table 11). These averages mask tremendous variability, as, again, ASM costs are driven by days fishing more than gear type or vessel size.

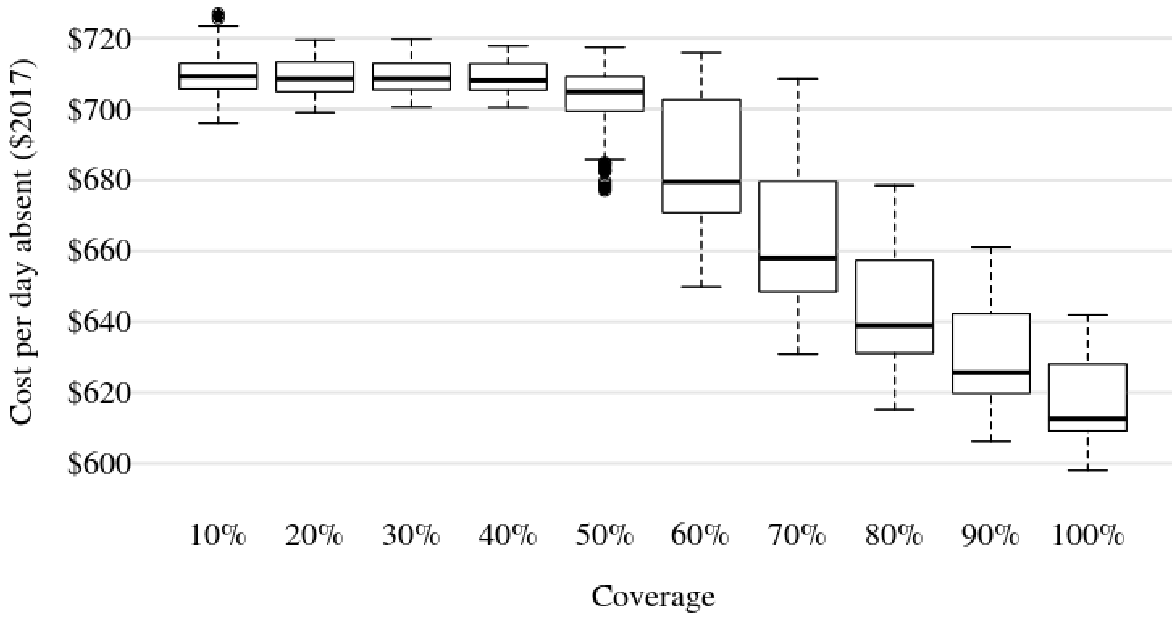

Figure 6. ASM cost per day at various coverage levels, estimated using FY13-17 effort data

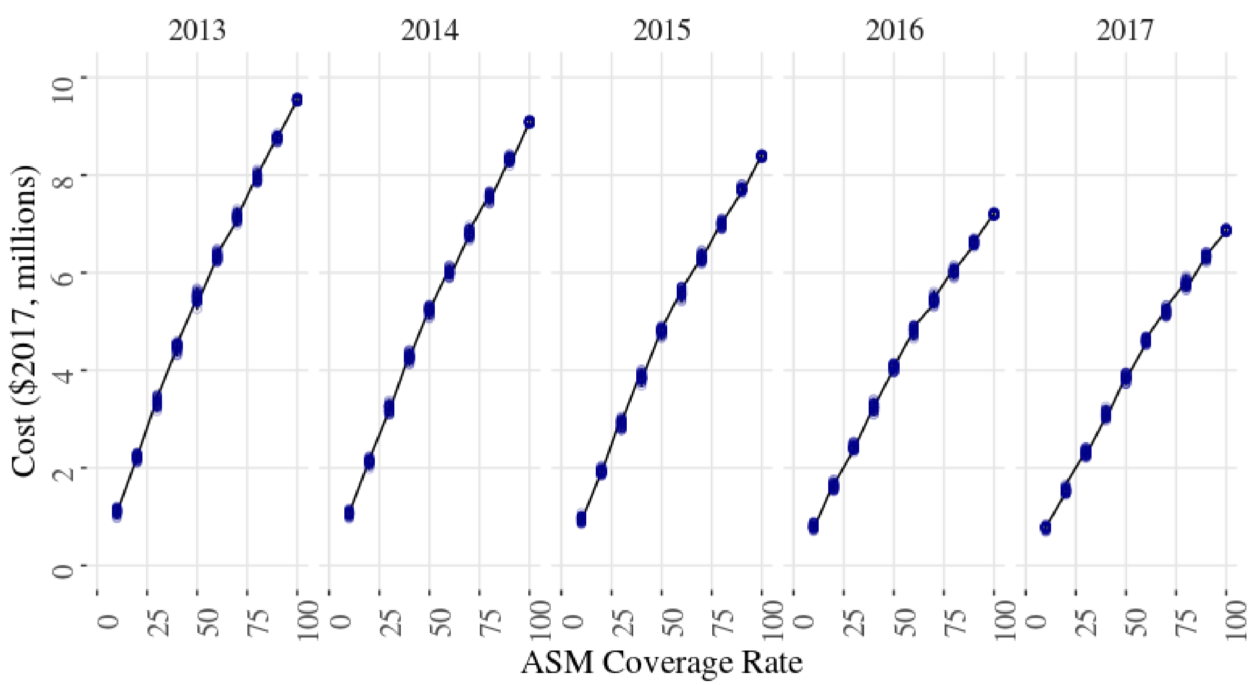

Figure 7. Fleet-wide ASM costs estimated from FY13-17 fishing effort

Table 8. Median estimated ASM costs for fishing years 13-17 at 10% coverage rate intervals ($2017, millions)

Coverage rate	**2013**	**2014**	**2015**	**2016**	**2017**
10	1.1	1.1	1.0	0.8	0.8
20	2.2	2.1	1.9	1.6	1.5
30	3.4	3.2	2.9	2.4	2.3
40	4.5	4.3	3.9	3.2	3.1
50	5.5	5.2	4.8	4.1	3.9
60	6.3	6.0	5.6	4.8	4.6
70	7.1	6.8	6.3	5.4	5.2
80	7.9	7.6	7.0	6.0	5.8
90	8.8	8.3	7.7	6.6	6.3
100	9.6	9.1	8.4	7.2	6.9

Table 9. Median estimated ASM costs for fishing years 13-17 at 91% coverage rate ($2017, millions)

	2013	**2014**	**2015**	**2016**	**2017**
91% coverage	8.84	8.4	7.78	6.68	6.39

Table 10. Mean estimated per-vessel ASM costs for fishing years 13-17 at 10% coverage rate intervals ($2017, thousands)

Length class	Coverage rate	2013	2014	2015	2016	2017
>=30’, <50’	10	2.4	2.1	2.1	1.6	1.8
	20	4.8	4.2	4.2	3.2	3.7
	30	7.2	6.2	6.4	4.8	5.5
	40	9.6	8.3	8.5	6.4	7.3
	50	11.8	10.2	10.6	8.1	9.1
	60	13.6	11.7	12.3	9.6	10.9
	70	15.4	13.2	13.8	10.8	12.4
	80	17.1	14.7	15.3	11.9	13.7
	90	18.8	16.2	16.9	13.1	15.0
	100	20.5	17.7	18.4	14.3	16.3
>=50’, <75’	10	5.0	5.0	4.4	3.7	4.1
	20	10.0	10.0	8.9	7.4	8.2
	30	15.0	15.0	13.3	11.2	12.3
	40	20.0	20.0	17.7	14.9	16.4
	50	24.7	24.4	22.1	18.6	20.5
	60	28.4	28.0	25.6	22.1	24.6
	70	32.0	31.7	29.0	24.9	27.9
	80	35.6	35.3	32.1	27.5	30.7
	90	39.2	38.8	35.4	30.3	33.8
	100	42.8	42.4	38.5	33.0	36.6
>=75’	10	9.7	10.2	9.7	9.0	8.1
	20	19.5	20.3	19.4	18.0	16.2
	30	29.2	30.5	29.2	27.0	24.3
	40	38.9	40.7	38.9	36.0	32.4
	50	48.0	49.7	48.6	45.0	40.5
	60	55.2	57.2	56.3	53.4	48.5
	70	62.3	64.6	63.6	60.2	55.0
	80	69.2	71.9	70.5	66.7	60.6
	90	76.3	79.2	77.7	73.3	66.7
	100	83.2	86.5	84.6	79.8	72.2

Table 11. Mean estimated per-vessel costs for fishing years 13-17 at 91% ASM coverage ($2017, thousands)

Length class	2013	2014	2015	2016	2017
>=30’, <50’	19.0	16.4	17.1	13.2	15.2
>=50’, <75’	39.6	39.2	35.7	30.6	34.0
>=75’	77.0	79.9	78.3	73.9	67.2

Electronic Monitoring

Equipment
Total equipment cost estimates for the entire fleet range from a low end of \$1.5m to an upper bound of about \$2.4m[8]. Per vessel estimates range from \$6.2k to \$9.1k. These estimates do not follow a normal distribution, and median values are on the high end of these ranges (Fig 8, Table 12). Total costs by gear type length class and home state scale mainly by the number of vessels though, in general, per vessel costs are slightly lower for smaller vessels (Table 13).

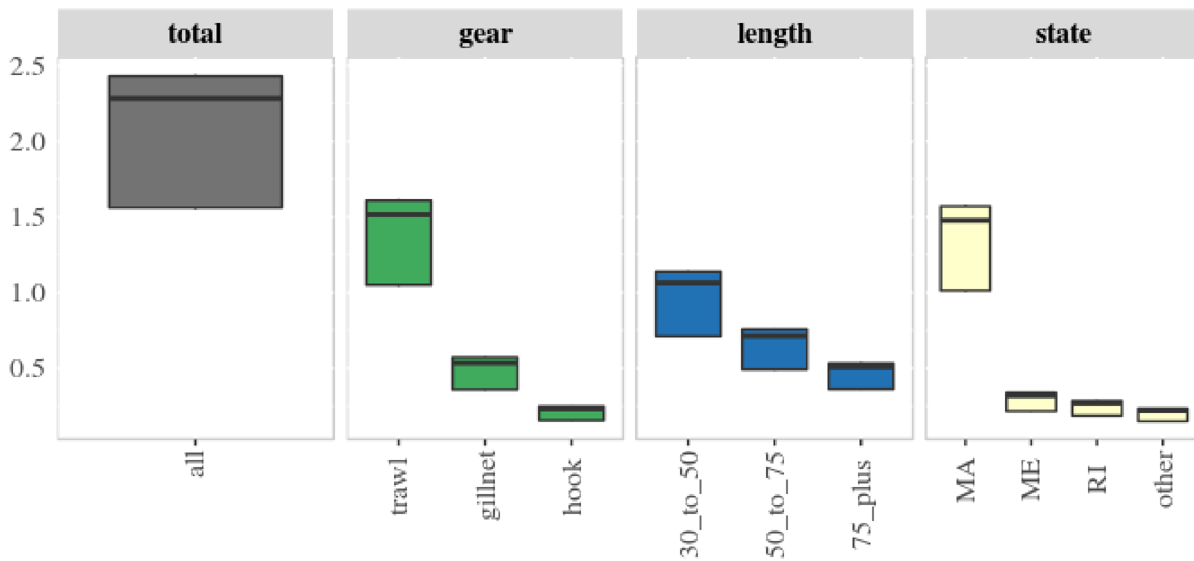

Figure 8. EM equipment cost estimates modeled using fishing year 17 data (\$2017, millions)

8 Based on the 198 vessels that made non-FW55 exempt groundfish trips in 2017.

Table 12. Mean estimated per-vessel equipment costs (estimates generated from fishing year 17 data, $2017, thousands)

Length class	State group	Gillnet	Hook	Trawl
>=30’, <50’	MA	7.6	7.3	7.6
	ME	7.6	7.3	7.6
	other	7.7	7.3	7.7
	RI	7.5	7.3	7.7
>=50’, <75’	MA	8.1	-	8.0
	ME	-	-	8.0
	other	8.0	-	8.0
	RI	-	-	8.0
>=75’	MA	-	-	8.4
	ME	-	-	8.4
	other	-	7.9	8.4
	RI	-	-	8.4
>30	MA	-	7.0	-
	other	7.0	7.0	-

Table 13. Descriptive statistics for estimated per-vessel equipment costs (estimates generated from fishing year17 data, $2017, thousands)

Length class	Minimum	Maximum	Median	5th Percentile	95th Percentile
>30	6.2	7.9	7.0	6.7	7.4
>=30’, <50’	6.5	8.6	7.6	7.0	8.1
>=50’, <75’	7.1	9.0	8.0	7.7	8.4
>=75’	7.3	9.1	8.4	7.9	8.8

Field Services Costs

Year one field cost estimates (includes install, maintenance, on-call response and data transfer) range from $1.5m to $1.8m with a median cost of $1.65m. A majority of these costs are related to equipment installation, which has a median cost of $810km (Fig 19). In subsequent years, composite costs no longer include the cost of installation, and maintenance visits decline, therefore median cost estimates drop to $600k in year 2, $550k in year 3 and $530k in year 4 (Fig 10).

These total estimates translate into roughly $8.3k per vessel for year one field service costs. Cumulative year 2 through 4 field service costs are estimated to average $2.8k per year per vessel (Table 14, dividing totals by 198 vessels).

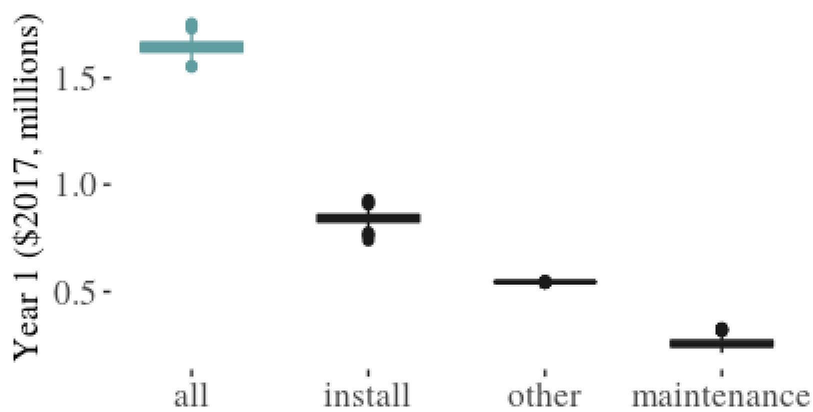

Figure 19. Year one field service cost estimates by component (estimates generated from fishing year 17 data, $2017, thousands)

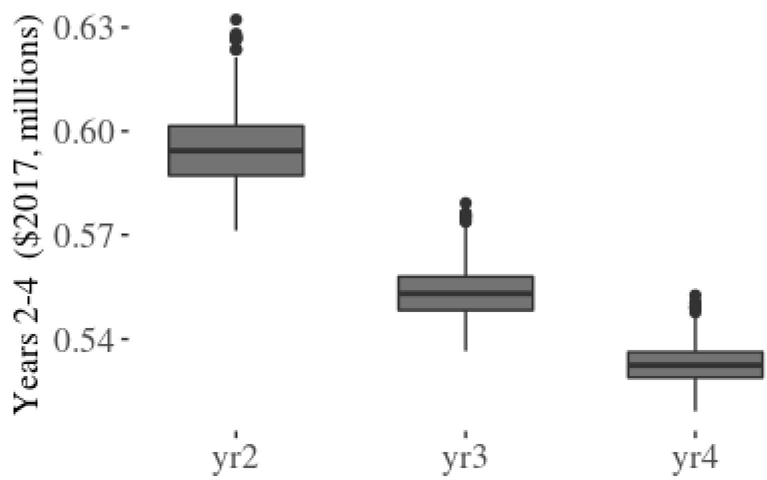

Figure 10. Field service cost estimates for subsequent years (estimates generated from fishing year 17 data, $2017, thousands)

Review Costs

Review costs are modeled for three review programs and summarized by gear type (Figures 11-12). Costs were generated for various randomly selected review rate (selected anywhere from 0 to 100%) and plotted. Each randomly selected review rate was replicated 10 times to account for random trip selection and, for the aggregated model,a total of 400 randomly generated review rates were modeled (Figure 11). For the disaggregated gear-based models, 10 replicates were generated for 200 random review rates (Figure 12). A regression line was fit to model review costs as a function of review rates for each gear type. Each of the nine gear-based linear models yields R squared values ranging from 0.79 to 0.98. From these models, total costs for each gear group are estimated across various review rates for each of the three programs (Census, Audit and Compliance).

As a direct comparison, at 100% video review under each model for full fleet-wide implementation in FY17yields a cost estimate of $3.9m for the compliance model. The census model costs just over $15m at 100% review. The audit model costs slightly more than$13.1m. At any given review rate, the costs of video review for the compliance model are substantially lower than those of the audit and census models (Figure 11).

For the census and audit models, 100% video review is not necessry to achieve precise and unbiased discard estimates. Other regions including British Columbia have settled on a 15% review rate for an audit model. At this rate, the audit model presents a total review cost of ~$2.1m (Figure 11, Table 14). More work would be required to estimate the review rate that would provide precise discard estimates under a census model, but at a 50% video review, the census model is more costly than either the compliance or audit models at ~$7.2m (Figure 11, Table 14).

Trawl gear vessels contribute the bulk of these costs, noting that trawl gear review costs increase at a higher rate than either hook or gillnet gillnet gears due to more variability footage review time, driven by greater diversity of species caught (which may add to review time) and, sometimes, more challenging camera locations and more frequent periods of deteriorated images. It is important to note that, of all the variables analyzed to predict video review times, the overwhelming driver was the vessel itself. Operational consideration of image quality can cut needed review times in half, whereas lack of understanding or consideration can add 3x or 4x to the review process.

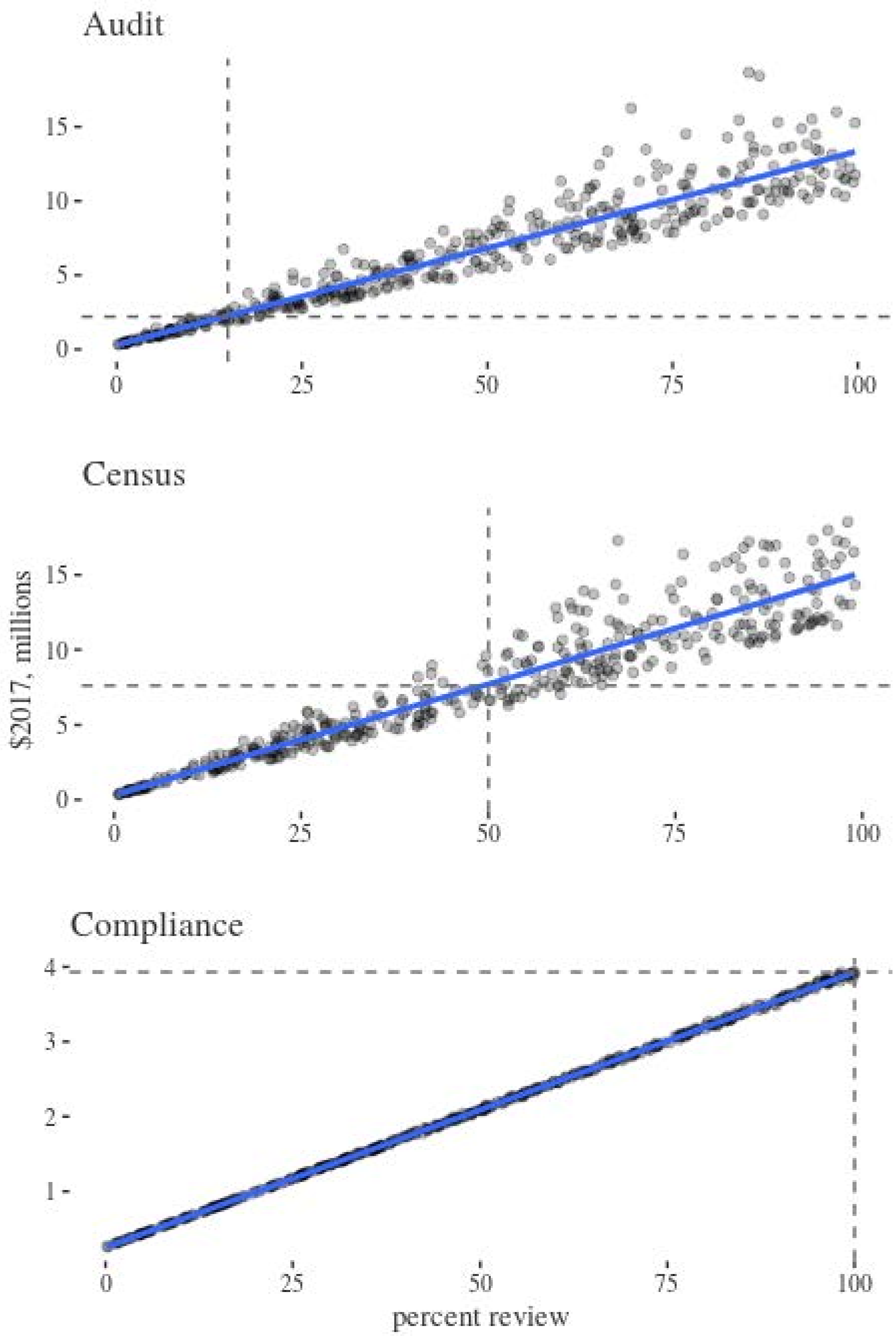

Figure 11. Total video review cost estimates for the three EM models, vertical and horizontal lines corresponding to the review rates selected for comparison. (Source: pilot project video review from 2015-16 and applied to fishing year 17 fishing effort data)

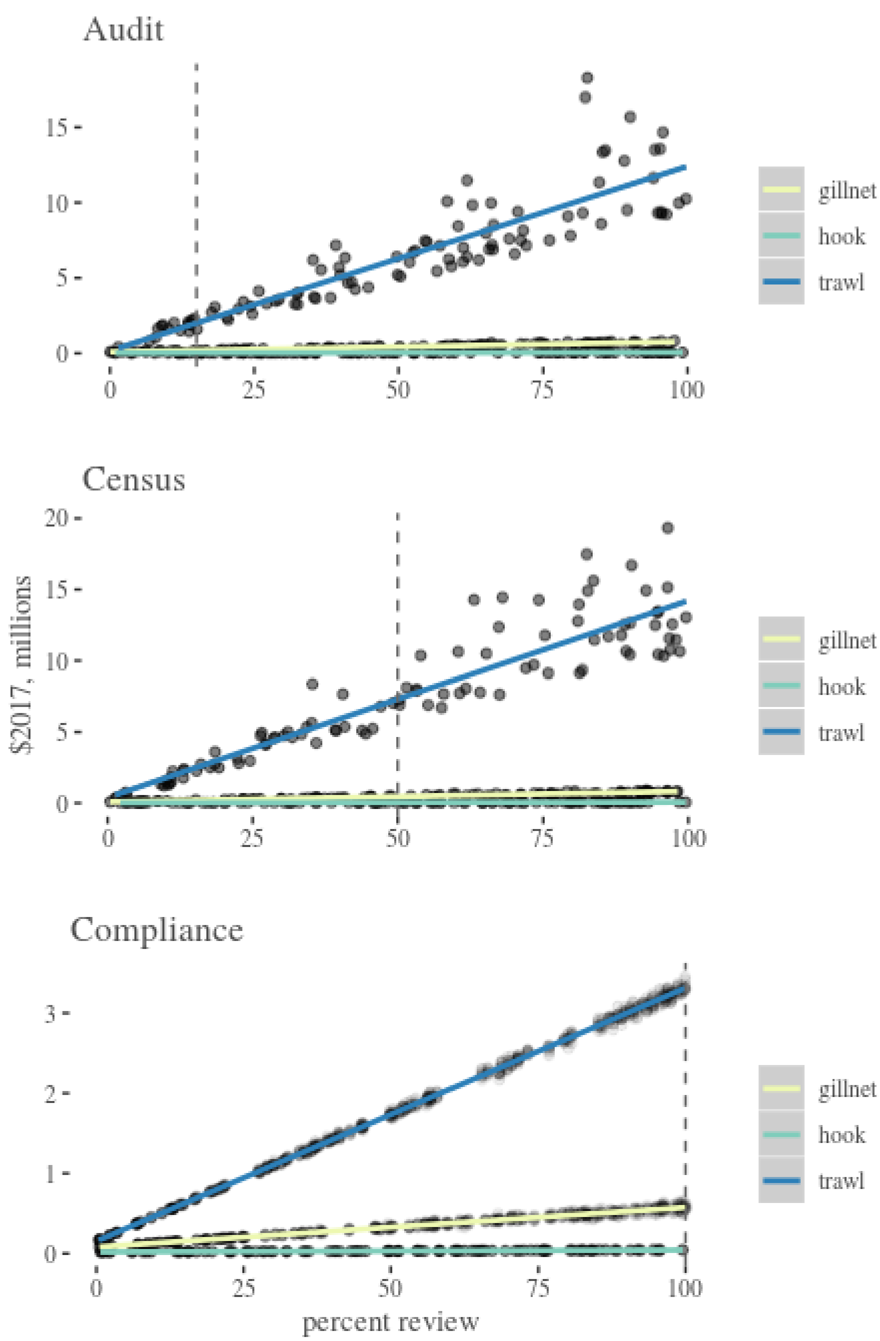

Figure 12. Video review cost estimates by gear type. (Source: pilot project video review from 2015-16 and applied to fishing year 17 fishing effort data)

Data storage

Median annual data storage costs for 100% of the footage accumulated for groundfish trips in FY17 is estimated at approximately $208k (Fig 13). Under this scenario we do not differentiate footage quality by program design. In reality, storage costs will likely differ by program model (audit, census, maximum retention) if these models require differing levels of footage quality and therefore have differing GBPH rates. Storage costs are distributed across the fleet in proportion to fishing effort. Higher data volumes cost more to store (Figure 14). We assume these storage costs accrue annually and data are stored for three years, based on the specifications for the west coast groundfish fishery (Fed Reg 2016).

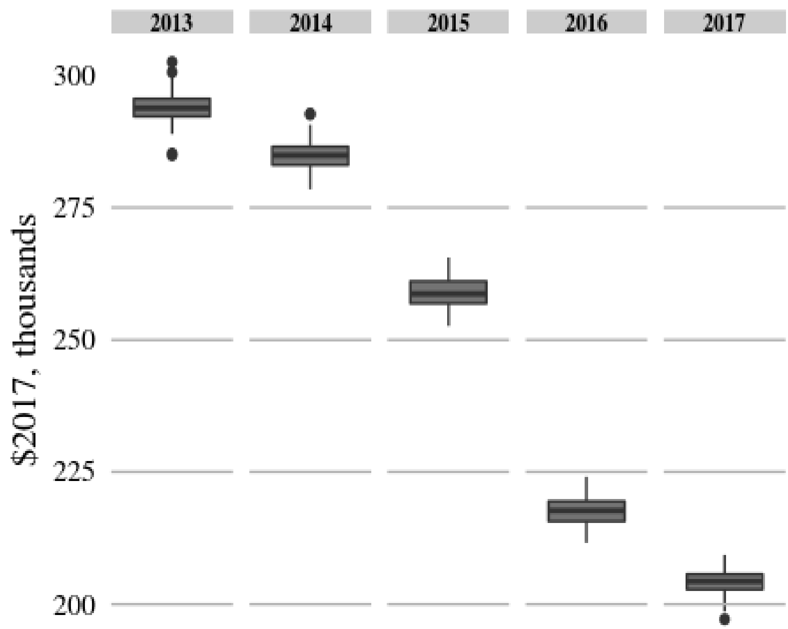

Figure 13. Aggregate data storage costs by year

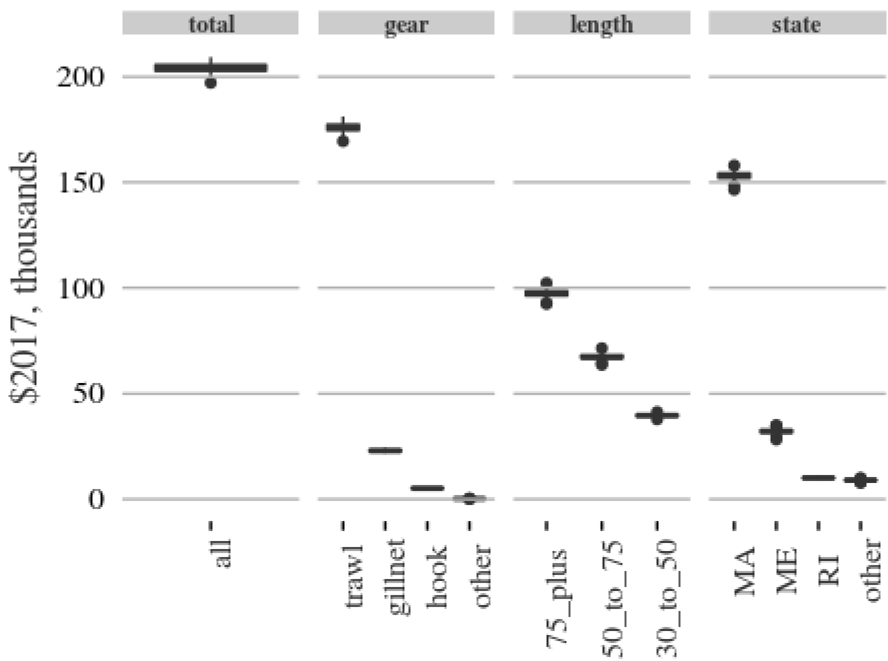

Figure 14. Data storage costs, total and disaggregated by gear, length and state group based on fishing year 17 fishing effort data.

Total costs

EM programs have high up-front costs due to the fixed costs associated with equipment and installation at the beginning of any EM program. Estimates of the average lifespan of EM equipment vary and depend upon the frequency and conditions of use. A commonly used estimate of EM system lifespan, is five years, and we accordingly estimate costs over this timespan.

To arrive at a total annual EM cost, mean values for equipment, field costs, and storage costs were averaged across five years. In year one, equipment costs and field costs represent substantial cost components. Once the equipment is installedwe assume no further installations will be needed over the five years. Field service costs remain after year one, but decrease sharply. In years 2-5 , the majority of EM costs are attributable to video review. This is true even at low review rates (such as the audit model at a 15% review rate). We assume review costs will decline over time, particularly if there exists some cost-based incentive for operators to continually optimize their operations in order to assure high-quality video, noting that vessel operations are the primary driver or review times. To model this, we simply costs from different locations in the overall cost estimates at the assumed model-specified review rates—higher in the distribution of modeled estimates in yearlier years, and lower in later years.

The average annual cost for the audit model at a video review rate of 15%, is $3.5m. Video review represents 60% of total EM costs under the audit model. Review costs represent about 35% of total costs in year one, but ~80% in subsequent years (Table 14).

Average annual cost for the census model at a video review rate of 50%, is $8.5m. Review costs are represent most of these costs, about 88% over the five-year period. During year one, review costs are 71% of total costs, increasing to ~95% in subsequent years.Average annualcost for the compliance model at a video review rate of 100%is $ 5.0m. Video review represents 68% of total EM costs under the compliance model. During year one, review costs are 41% of the total, and ~85% in subsequent years. Review costs under a 100% compliance model are slightly higher than those estimated under a 15% audit model, but well below those estimated for a census model at 50% video review.

We make no assumptions about the role of technology improvement over time in bringing review costs down below those modeled here—cost savings are assumed to come from improvements in operations alone. Technological advances will likely reduce these costs, in fact it's likely that costs have declined since these models were developed.

Table 14. EM Audit, Census and Compliance model costs, program implementation in fishing year 13. Costs in $2017, millions. Audit review rate = 15%, Census review rate = 50%, Compliance review rate = 100%.

	AUDIT MODEL				
Year	**Equipment Costs**	**Field Costs**	**Review Costs**	**Storage Costs**	**Total**
1	2.09	1.65	2.33	0.21	6.28
2	0	0.60	2.13	0.21	2.93
3	0	0.55	2.06	0.20	2.82
4	0	0.53	2.03	0.20	2.76
5	0	0.53	1.95	0.20	2.68
Mean	*0.42*	*0.77*	*2.10*	*0.20*	*3.49*

	CENSUS MODEL				
Year	**Equipment Costs**	**Field Costs**	**Review Costs**	**Storage Costs**	**Total**
1	2.09	1.65	8.04	0.21	11.99
2	0	0.60	7.25	0.21	8.05
3	0	0.55	7.01	0.20	7.76
4	0	0.53	6.87	0.20	7.61
5	0	0.53	6.70	0.20	7.43
Mean	*0.42*	*0.77*	*7.17*	*0.20*	*8.57*

	COMPLIANCE MODEL				
Year	**Equipment Costs**	**Field Costs**	**Review Costs**	**Storage Costs**	**Total**
1	2.09	1.65	3.92	0.21	7.87
2	0	0.60	3.69	0.21	4.49
3	0	0.55	3.60	0.20	4.36
4	0	0.53	3.54	0.20	4.28
5	0	0.53	3.48	0.20	4.21
Mean	*0.42*	*0.77*	*3.65*	*0.20*	*5.04*

Internal and External Data Validity of ASM and EM Technologies

Internal validity

Internal validity of ASM data refers to the sampling error that occurs when the monitor is sampling the catch. At sea monitors are charged with the difficult task of identifying and quantifying all discards before they are tossed over the rail, as well as all kept catch before it gets stored in the fish hold. All this information is collected while minimizing the impact on normal fishing operations. To collect these data efficiently, numerous methods are used to estimate the amount of catch or discards recorded by the observer. These estimation methods have differing levels of accuracy and precision ranging from highly accurate "actual" weights which are directly measured, to less accurate visual estimations and other subsampling methods. A complete discussion of the various estimation methods is provided in the Appendix. An increase in ASM coverage would not change the internal data validity. Monitoring protocol and estimation methods would not change, meaning the quality of the data collected would remain more-or-less consistent regardless of what percentage of trips are covered.

In census and audit model EM programs, discard weights are estimated using length-weight tables calculated from numerous years of NEFSC survey data (Wigley et al 2003). While there is some error associated with these calculations, they are relatively small. Weights calculated using these relationships have been used in numerous data collections in the northeast. Other errors that occur during review are associated with the length of the fish as estimated from the footage and the species identification. Pilot projects have reported minimal errors associated with length and these are reduced as crew becomes more familiar with the procedures and places more importance on proper catch handling. Error in species identification is dependent on the species. Hakes (red/white) and some flat fish have been especially problematic during pilot programs.

In an audit system, there is error associated with how the captains fill out their logbooks. This can be due to unintentional inaccuracies or strategic misreporting. This will be impacted by the percent of logbooks audited as well as the standards for an acceptable logbook report. There is a potential for bias depending on how the audit "pass/fail" criteria are determined. For example, if captains know that everything within 10% is considered a pass, they could systematically under-report within 10% and consistently "pass" the audit. Additionally, the review rate of an audit program must be such that it is unlikely that misreporting, rare events, or consistent biases go undetected. A description of EM projects in the Northeast groundfish can be found in Fitzgerald et al (2019).

Both census and audit models provide the benefit of consistent estimation methods across gear types, catch volumes, and catch compositions. conditional on well-trained operators, all discard data are collected using the same processes for a specific program design, so there is no variability in data quality based on estimation methods. In an audit model, one particular benefit is that the fishermen are actively participating in collecting and reporting data that are directly used in the catch accounting process. This keeps the process transparent, increasing the credibility of the estimates from the fishermen's perspective (Stanley et al 2011).

Different error structure is associated with compliance programs, as the compliance systems are not designed to collect discard data, rather to ensure discarding is not occurring. If discard events occur under a compliance EM system, identifying the quantity and composition of the discards will be challenging. In the west coast pacific whiting fishery, estimates of total volume discarded are made when reviewing video footage based on size and number of codend straps. Discard composition is then assumed to be identical in proportion to landed catch. In this case, data quality depends on the randomness of discard events and the randomness of which species are discarded.

External validity

The external validity of ASM data refers to the sampling error that is associated with applying the ASM data to unobserved trips. One aspect of external validity is the process of creating the discard ratios used to estimate total discards. The discard methodology was reviewed in November 2016 (Zhou 2016, Cook 2016). Analysis reported for this review show that for most species of groundfish the current observer coverage meets the CV 30 requirement but for others the discard estimates are less precise (the CV is higher than 0.3) (Caless 2016). Previous analysis has shown that increased monitoring coverage leads to more precise discard estimates (NEFMC 2016). The discard methodology review focused on the "application of (the discard methodology) and alternative stratification schemes" not the validity of applying ASM data to unobserved trips. However, reviewers noted the utility of addressing this: "This review is confined to the statistical methods used to estimate discards given the samples available. It assumes that observer coverage is, in general, adequate, representative and unbiased. The latter are extremely important issues that merit careful review in their own right to ensure that the overall performance of the monitoring system is sound, but they were not subjects for this review (Cook 2016:4). And if the statistical impacts if these assumptions are not met: "missing data (such as unobserved trips) will introduce additional uncertainty whereas erroneous data will bias the estimate" (Zhou 2016:9)."

The amount of uncertainty and bias introduced by applying ASM data to estimate discards on unobserved trips has not yet been quantified, however the potential existence of this bias has been illustrated (Demarest 2019). Analysis of Canadian groundfish fisheries showed non-random patterns in observer deployment which would bias discard estimates low (p.2033) as well as statistical differences in numerous variables by vessel between observed and unobserved trips such as lower overall landings and lower landings of non-target species on observed trips (Benoit and Allard 2009).

External data validity would greatly improve under increased ASM coverage rates. As coverage increases, a smaller portion of the data would rely on the assumption that fishing behavior is equivalent on observed and unobserved trips. At 100 percent coverage this assumption would not apply because observers would be onboard every trip. This would remove the biggest source of uncertainty and bias in the current ASM system that occurs when applying observer data to unobserved trips.

One of the biggest advantages of an EM system is that it can run on every trip. Unlike an ASM program where the captain knows from the start of the trip if it is monitored or not, depending on program design, a captain may not know if an EM trip has been selected for review until after the trip is completed. Therefore, regardless of the review rate, the footage that is reviewed is a random sample from a population that includes the whole universe of trips. This minimizes the potential for an observer effect and leads to a less biased sample of fishing effort. Depending on the review rate selected, fishermen may still feel incentivized to discard legal-sized fish, as they will have different levels of comfort with the probability that their trips will be reviewed.

MONITORING LANDINGS

Dockside Monitors (DSM): Methods, Models, and Data

Both at sea monitoring and electronic monitoring programs focus on collecting data on discarded catch. At sea monitors collect kept catch data but the primary purpose of this is to calculate discard to kept catch ratios to estimate discards on unobserved trips. Absent any additional monitoring, these systems rely on self-reporting to document landings, the vast majority of fish removals among allocated groundfish stocks. Many other quota based management systems implement dockside monitoring (DSM) programs to document kept or landed catch. The West Coast IFQ fishery requires that all landings are monitored by certified catch monitors who are present during the entire duration of the offload and ensure accurate sorting, weighting and reporting of landings (PSMFC 2017). The British Columbia Groundfish fishery also requires that a dockside monitor is present before an offload can begin. These monitors verify the weight and species of all landed fish (DFO 2013).

As originally implemented in 2010, Amendment 16 required dockside monitoring for 50% of each sector's trips, with the coverage rate decreasing to 20% in subsequent years (NEFMC 2009). These monitors observed offload activity and verified the accuracy of dealer reported weights. A proposal to require monitors to board the vessels and inspect fish holds to ensure all catch was offloaded was discussed but eventually removed due to safety concerns (FW45). The DSM program was eliminated in 2011 citing concerns of costs and duplicative data collection: FW48 to the groundfish FMP stated, "as long as unreported landings do not occur, the dealer reports can be used to monitor sector landings and there is little advantage to having dockside monitors verify these reports." (NEFMC 2013). Recent discoveries of unreported and misreported landings has renewed discussions regarding the value of a dockside monitoring program (Cramer 2017).

We estimate DSM costs based on actual cost data from the DSM program in 2010. We have information on the monthly costs billed by sector as well as the total groundfish pounds monitored, total number of trips monitored, and the number of trips in remote ports (as specified in provider contracts). Using these data we model monthly cost by sector (*C*) as a linear function of groundfish pounds monitored (*g*), trips monitored (*t*) and remote trips monitored (*r*), as

$$C = a + b_1 g + b_2 t + b_3 r + e \quad .$$

(Equation 5)

This model has an adjusted r-squared of 0.8398 and all variables are statistically significant at $p<0.001$. Using data from FY17 trips we predicted DSM costs using this model. We then adjusted these predicted costs to $2017 using the GDP Implicit Price Deflator[9]. We estimated costs under two scenarios, first, assuming all live groundfish pounds that are landed are monitored, and second, assuming all live groundfish pounds landed and live groundfish discarded are monitored. This second scenario is similar to landings under compliance management. The linear model estimates costs on a monthly basis per sector. We randomly resample these 100 times to display the potential cumulative monitoring sums if monthly costs occurred in any order.

[9] GDP Implicit Price Deflator from the Federal Reserve Bank of St. Louis, available at: https://fred.stlouisfed.org/

Costs and cost incidence

The median for DSM cost for all trips that landed groundfish in FY17 is $376K (Figure 13, A, B). Including both discards and landings increases total DSM costs to $383K (Figure 13, C, and D).

The cumulative total cost for all trips that landed groundfish in FY17 at 100% DSM is equal to $747,874 (Figure 13, A, B). Including both discards and landings (under a compliance EM model, for example) increases total DSM costs to $ 759,420 (Figure 13, C, and D).

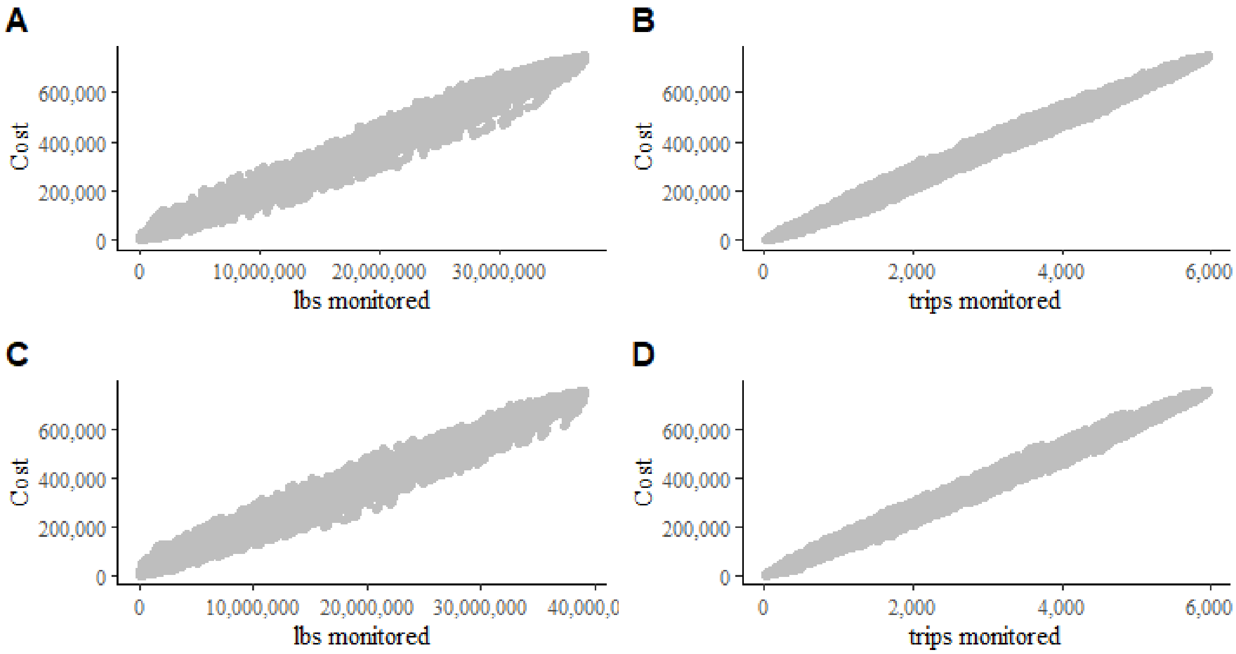

Figure 13. Estimated DSM costs for live groundfish pounds offloaded in FY17 by live groundfish pounds (A) and trips monitored (B). Estimated DSM costs for groundfish pounds offloaded including discards in FY17 by live groundfish pounds (C) and trips monitored (D). Note x axis of A and C are not aligned.

Contracts were negotiated under the assumption that at minimum, 50% of each sector's trips would be monitored. In 2010, this would have been approximately 4,678 trips (half of all sector trips landing groundfish). However when the contracts were negotiated, the amount of trips estimated to be covered was much greater based on fishing effort in previous years. Because rates were negotiated under the expectation of relatively high fishing effort, the model may underestimate costs for lower coverage levels, assuming there would be diminishing marginal costs for dockside monitoring providers.

The costs presented here represent our best estimation for a dockside monitoring program in the groundfish fishery. A reintroduced program may result in higher costs, given how limited the data collection efforts were in the initial program. A more rigorous program include higher hourly rates for monitors and more time monitoring each vessel offload.

Internal and external data validity

Data produced by DSM programs are generally of high quality. The conditions are such that a dockside monitor should be able to accurately monitor and record all landings as they are offloaded. The dockside monitoring program in place for FY10 was of a very limited nature and a reintroduced program may have to be adjusted to allow for accurate catch accounting.

DISCUSSION

Designing a proper comparison of catch monitoring technologies is not without challenges. We have generally focused on two aspects of monitoring technologies, cost and data quality.

Cost

An ASM program at 91% coverage is estimated to cost roughly $6.4m annually based on FY17 fishery datat. These costs exceed that of fleet-wide EM under both the the audit and compliance models. The audit model is estimated to have a fleet-wide aggregate cost of $3.5m annually, roughly equal to the estimated cost of 45% ASM coverage. The compliance model is estimated to cost roughly $5m annually, roughly equal to 65% ASM coverage. The compliance model uses 100% video review, but the nature of the review activities is much less labor and time intensive and thus is less expensive. A census model, which requires significantly higher video review than an audit model, is the most expensive of the technologies investigated here, costing roughly $1m more than 91% ASM coverage and more than twice as much as a comprehensively applied audit model (Tables 8 and 14).

In comparing ASM and EM costs, it is important to recognize the difference in cost drivers between the two monitoring options. While ASM costs are driven largely by trip length, EM costs, especially review costs, may differ by gear type or species composition. The monitors themselves change the way they collect the data which may impact the data quality, but the costs do not differ. Furthermore, the burden of costs can incentivize better/worse compliance, and who will opt in. If ASM and EM are both viable monitoring options, cost structure is of primary importance. If ASMs were required to collect data the same way on every trip and every haul (i.e. remove the volume extrapolations) it would change the cost structure of the ASM program considerably. Part of this is because EM places that additional burden of the catch handling time on the vessel. For ASM programs we try to limit the impact on normal fishing operations while audit and census style EM programs significantly impact the flow of fish on a boat. Another component of an EM program, that is beyond the scope of this paper, is the design of proper incentives for captains to record accurately, and for crew to handle catch appropriately, under an EM audit or compliance model. If EM review rates are low, fishermen may be incentivized to misreport without proper repercussions in place. The possible repercussions are wide-ranging, but may include increased monitoring for the vessel, a reduction in quota, or monetary fine.

How marginal ASM and EM costs increase is an important consideration. We presented ASM costs that increase both linearly and at a diminishing rate. What the appropriate rate should be set at is a difficult question. For our EM program analysis, we presented review costs only as a linear function of effort. In reality, these costs may not scale linearly if there are certain review thresholds which require hiring additional staff.

The cost estimates we present for electronic monitoring are based off current technology and market conditions. EM costs may decrease with technological changes, such as automated review and wireless data transfer. Furthermore, an expansion of EM technology may drive down costs. For these reasons, future costs for electronic monitoring are likely more uncertain than with human at-sea monitors.

Data Quality

- Internal validity-
    - ASM: high variability based on catch estimation method.
    - EM: consistent methodology (regardless of gear type/catch volume/composition).
- External validity-

    - ASM: biased, degree of bias based on coverage rates, observer effect, deployment effect
    - EM: representative sample
- Quantifying the impacts of the data quality of our current monitoring system on the catch accounting and stock assessment process is outside the scope of this report. However, other research has shown that when the level of misreporting and subsequent bias in data is inconsistent year to year it can impact the assessment process (Rudd, et al.).

ACKNOWLEDGEMENTS

We are very grateful to all electronic monitoring providers who participated in our survey. Our analysis would not be possible without their participation. We would like to thank Brett Alger and Mark Grant at NOAA Fisheries Greater Atlantic Fisheries Office. We would also like to thank Mark Hager at Gulf of Maine Research Institute. A debt of gratitude is owed to Howard McElderry, Amanda Bailey, Eric Torgerson, Luke Curci, and Nancy Munro, all of whom were instrumental in the preparation of this report.

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APPENDIX A: Estimation methods of at-sea monitors

Table 1 includes a description of each method at-sea monitors utilize to estimate groundfish catch. The accuracy of high volume subsampling methods depends in large part on the size of the subsample with increasing accuracy corresponding to larger subsamples (Heales et al 2003). Monitors are instructed that their target subsample should be at least 20% of the overall catch, however, there is no data field to document the size or number of subsamples taken.

Figure 1 shows the percentage of observed pounds of catch (discards and kept) in FY2015 that were estimated using the different estimation methods and how this varies across components of the fleet based on length classes and gear groups[10]. Observers work very hard in difficult conditions to collect a large amount of data so it would be unfeasible to expect actual measurements on a substantially larger portion of the catch, but it is important to note that there are considerable differences in data quality within observer data as a whole.

Table 1. Descriptions of ASM catch estimation methods. Adapted from NOAA NEFSC FSB Observer Operations Manual 2016.

Method	**Description**
Preferred methods	
Actual weights	Actual weight taken using spring or electronic scale
Tally counts	Obtain actual weights of representative sample, determine an average weight per individual and multiply by number of individuals
Basket/tote counts	Obtain actual weight of subsample of full container, determine average weight per container and multiply by number of full containers
Visual methods	
Captain's estimates	Provided by the vessel captain
Visual estimates	Made without weighing , counting or subsampling
Subsampling methods	
Count-to count	Count the total number of individuals, extrapolate the weight of the subsample based on the ratio of individual animals
Weight-to-weight	Obtain a total weight, extrapolate the weight of the subsample based on the ratio of the weights
Volume-to-volume	Weigh subsamples of a container with known volume (i.e. baskets, totes), extrapolate based on total volume of catch
Cumulative sum	Distribute an actual weight for the total catch amongst several hauls
Combination	Two or more estimation methods are used for a single species and disposition

10 Note that vessel length and gear are related with hook gear and gillnet gear more commonly used on smaller vessels and trawl gear associated with larger vessels (see figure 2A for gear/length relationship).

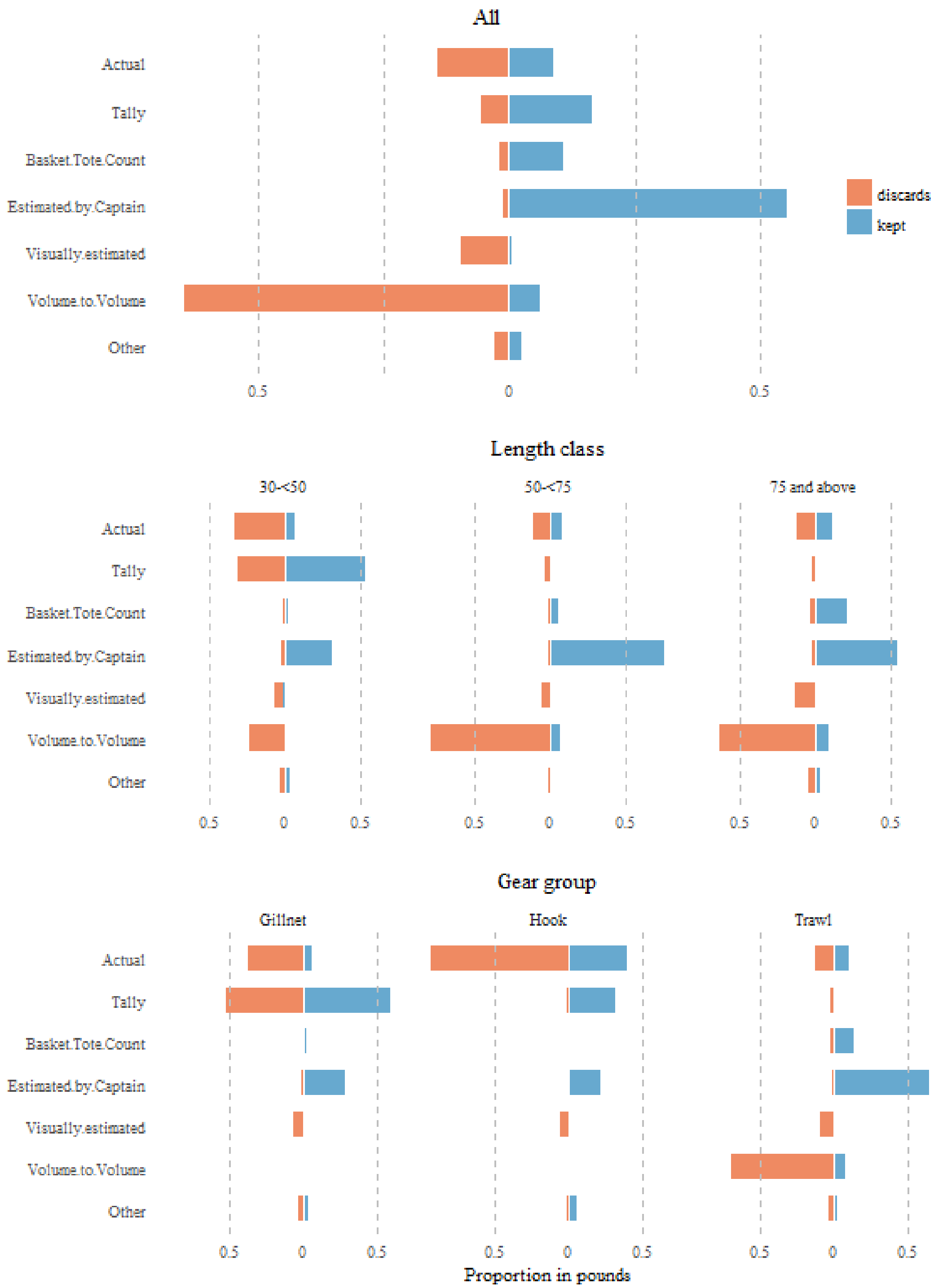

Figure 1. Proportion (in pounds) of kept and discarded catch, observed by ASMs on groundfish trips using each estimation method for Fishing Year 2015. Estimation methods are listed in order of preference according to the Observer manual with Actual measurements being the most preferred method and volume to volume the least preferred.

Additionally, ASMs have varying priorities for data collection, so it should be expected that higher priority data will be collected using more accurate methods than lower priority data. The sampling priorities on ASM trips are listed in the Observer On-Deck Reference Guide (2016) as follows:

1. Actual weight of discarded groundfish. If actual weights are not possible, tally or basket count are next preferred method.
2. Weights of all other discarded catch, using most accurate method possible.
3. Weights of all kept catch, using basket/tote counts (preferred) or captain's estimate (less preferred).

Despite these differences in data quality associated with catch estimation methods, kept catch and discard data of all estimation methods are treated comparably when used to estimate discards for catch accounting (NOAA 2010). GARFO D/K ratio estimates use all observer data pooled by strata with no accounting for the differences in quality within each data type.

APPENDIX B: Electronic monitoring data storage

Figure 2 shows data volume generated (in gigabytes per hour, GBPH) for EM video showing a sorting table in the pacific cod fishery during three scenarios: 1) at daytime, 2) at nighttime and 3) a changing image (whitewater footage). The whitewater footage is used as a "worst case scenario" as the subject matter is constantly changing so it would result in large data volumes. Using the same data from Figure 2, but setting the frame rate constant at 15FPS[11], still generates a range of data volume depending upon the values of the other variables (resolution, bit rate and subject matter) (Figure 3). We use a distribution of the nine highest GBH scenarios from Figure 2 (rnorm mean 2.03, sd 0.373) for fishing footage and the nine lowest GBH scenarios from Figure 8 (rnorm mean 1.03, sd 0.285) for the transit footage.

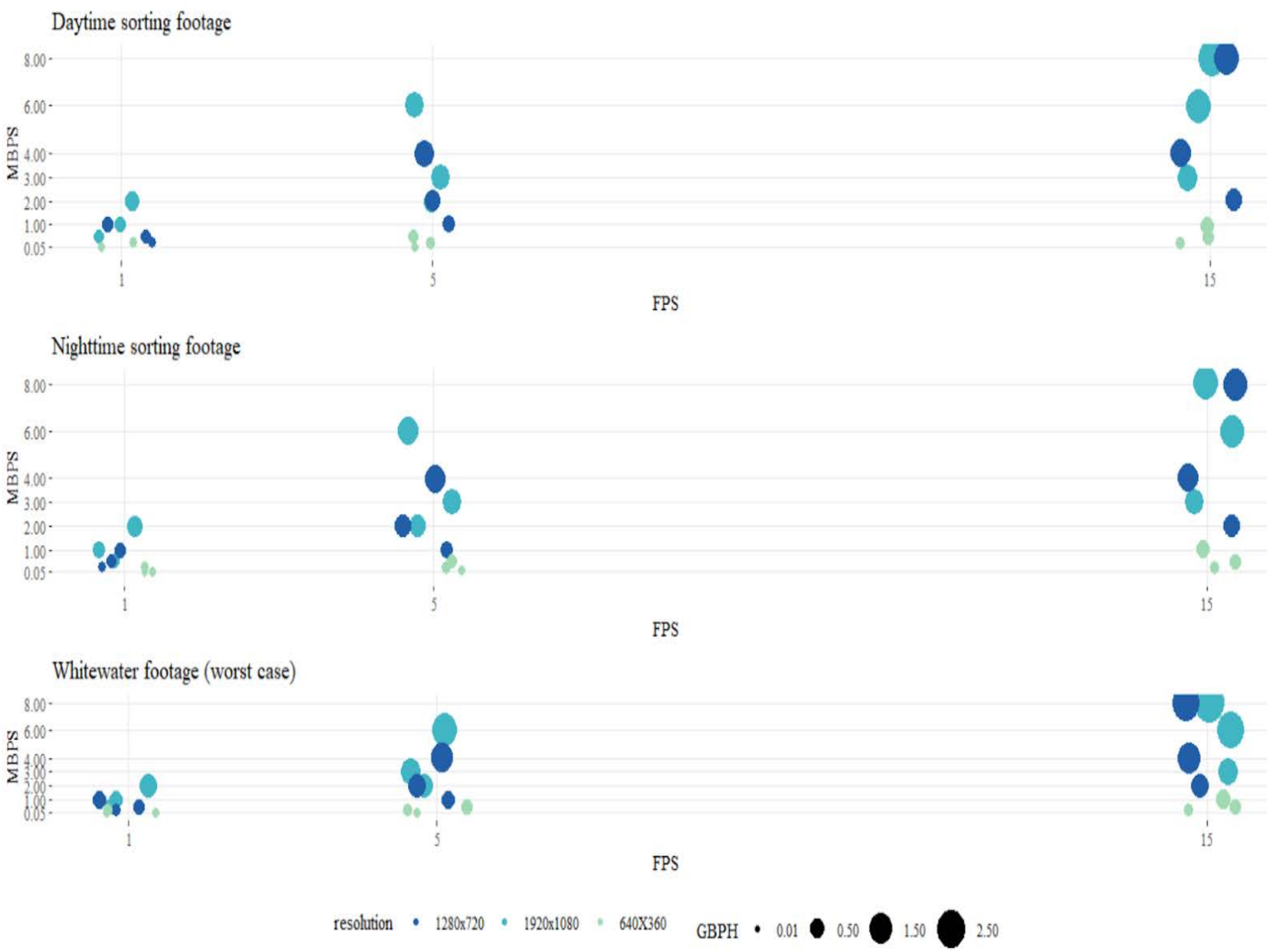

Figure 2. Relationship between compression-Megabits per Second (MBPS), Frame Rate Frames per Second (FPS), resolution and data volume, Gigabytes per hour of video footage (GBPH) (personal communication Eric

11

We do not hold the resolution constant at 1080 x 720 because a current pilot EM project in New England is using 1920 x 1080 resolution cameras (Integrated Monitoring).

Torgerson). Note that MBPS and FPS are at constant intervals, slight randomness is added to figure so that the data points aren't overlapping.

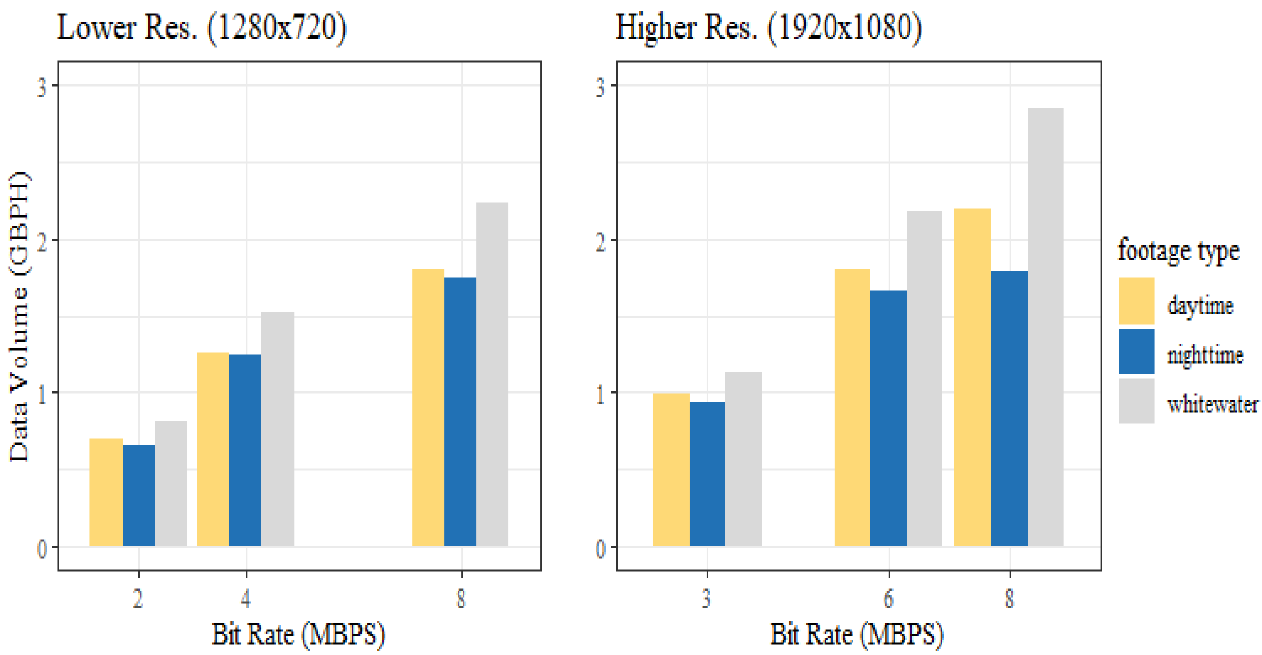

Figure 3. Data quality variables impact on data volume with frame rate set at 15 FPS (Torgerson 2017).

APPENDIX C: Field services cost sub-components of electronic monitoring

Under an electronic monitoring program, field services represents one component of total costs. Field services include all of the technical support for vessels and the activity that occurs in the field. Within this cost category, there are sub-components: maintenance costs, labor costs, and travel costs for the technician. All three of these sub-components have costs estimated for fishing years 2013-2017 (Figures 4-6). These cost estimates are assumed to be equal across all three EM programs (Census, Audit, and Compliance).

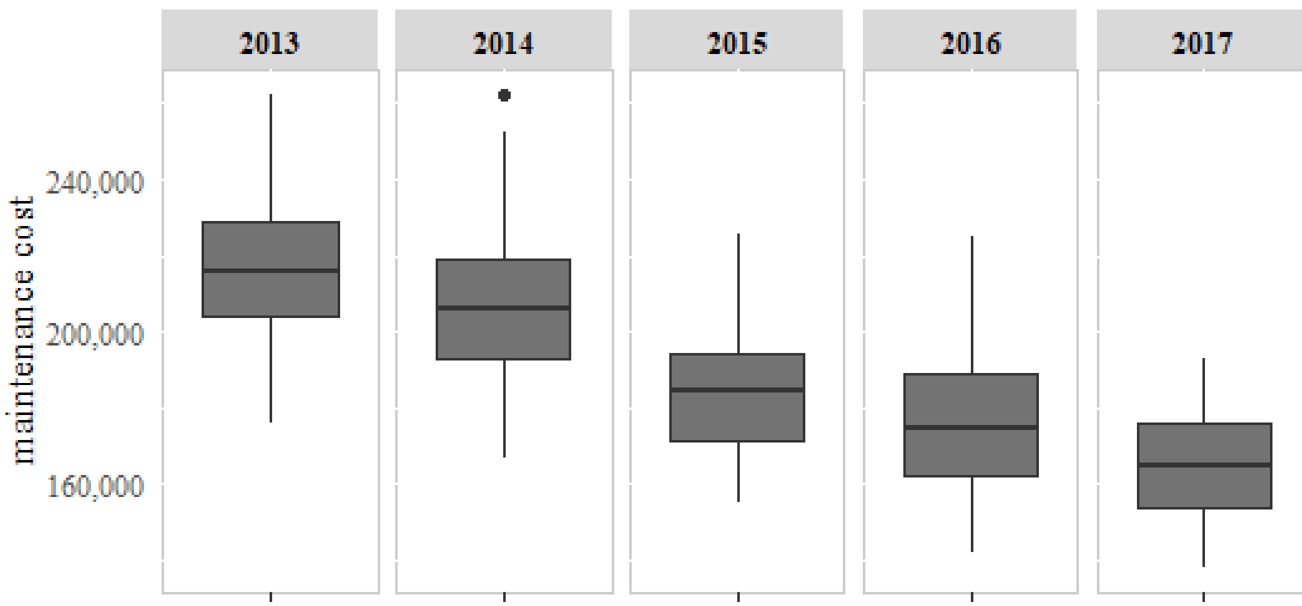

Figure 4. Technician maintenance costs (2017 USD) under electronic monitoring programs, FY13-17

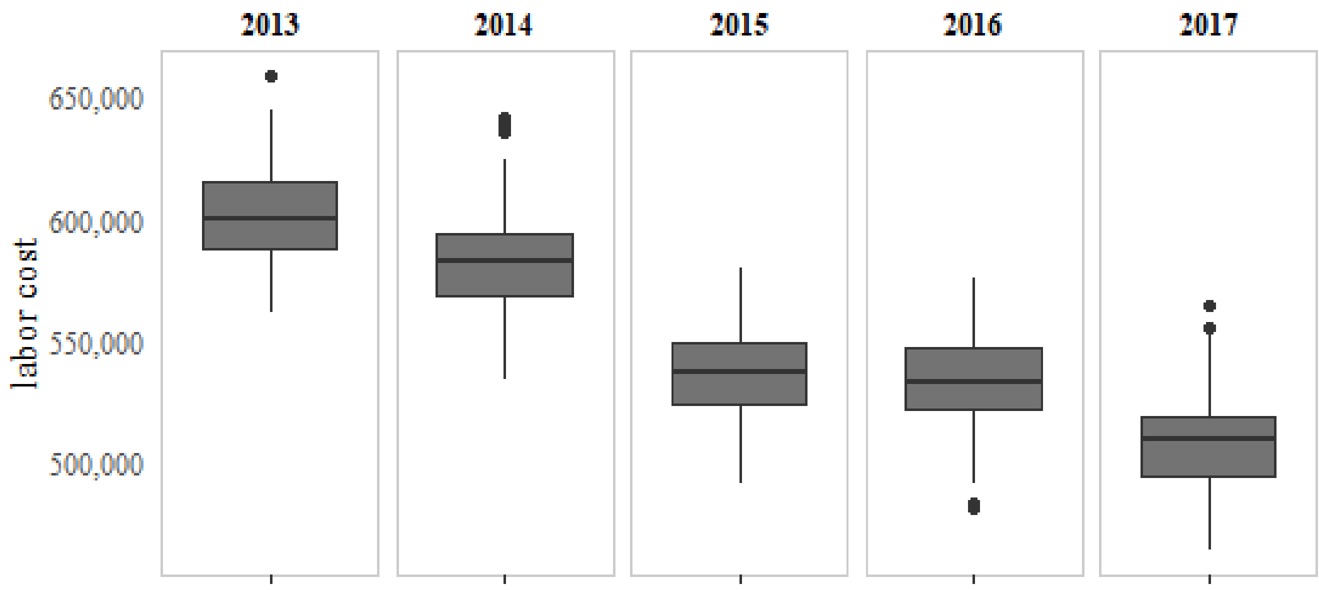

Figure 5. Technician labor costs (2017 USD) under electronic monitoring programs, FY13-17

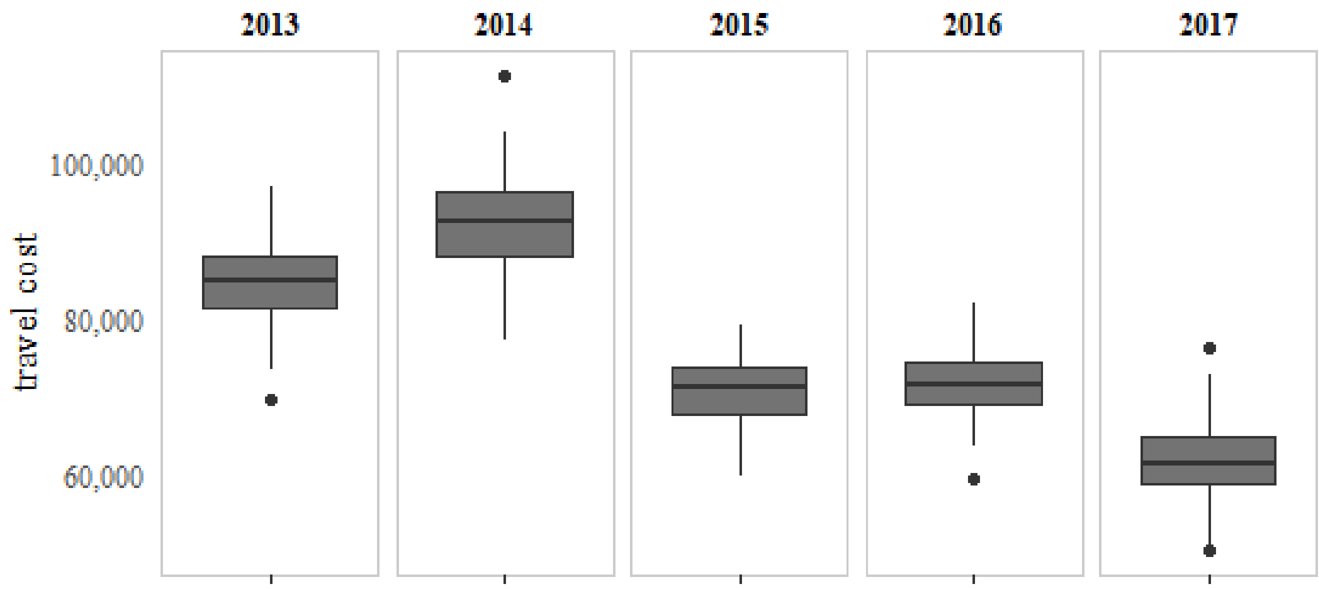

Figure 6. Technician travel costs (2017 USD) under electronic monitoring programs, FY13-17

APPENDIX D: Survey of Electronic Monitoring costs for New England Groundfish Fishery

The purpose of this survey is to understand the costs of an electronic monitoring program for multiple gear types, program designs and coverage levels in the New England Groundfish Fishery. All responses are completely confidential and are strictly for the purposes of this assessment.

This survey includes 3 parts and 36 questions with a potential additional 18 sub questions. **Estimated completion time is 20 minutes.**

Please refer to the following definitions when filling out this survey:

EM system- One EM system (including a control box, user interface, a GPS receiver, a hydraulic pressure transducer, and a drum rotation sensor) with two cameras. In general, EM units shall be configured to provide GPS location and date at all times while the vessel is at sea, CCTV imagery of all fishing operations with adequate resolution for species and estimate of fish size and CCTV imagery of transit operations with adequate coverage and resolution to determine if discarding is occurring. Some vessels will need up to 4 total cameras but the baseline system for this survey includes only two cameras.

Audit Model- Discards are estimated from electronic vessel trip reports (eVTRs) or other approved logbook systems submitted by vessel operators. Data from EM video is used to verify and validate the reporting accuracy of discards.

Census Model- EM video is used to directly identify and quantify discards of groundfish species.

Compliance Model- EM video is used to document compliance and facilitate enforcement of prohibitions on discarding of specific species to facilitate documentation of catch at the dock. Also sometimes called maximum retention model.

Background information-This survey is collecting data for application to the New England Groundfish fishery. The fishery is prosecuted year round with relatively stable effort comprising a total of 1000-1500 sea days per month. The fishery is dominated by trawl gear with gillnet and hook gear comprising smaller components of the fishery. Vessels have home ports from New York to Maine however a majority of the fishery is landed in a handful of ports in Maine, Massachusetts and Rhode Island. In 2015 there were approximately 325 vessels that made at least one groundfish trip. Groundfish is a mixed fishery of both round and flat fish. In 2015 almost all trips had 10 or fewer discarded species.

The survey is not designed to collect cost information for coverage of the entire fishery. Rather, the questions and units of measurement are designed to identify costs in fixed and marginal units to create a cost curve. This allows us to scale to different coverage levels with varying assumptions regarding program design and fishery characteristics.

Please fill out the survey according to the level of specificity (unit) designated in each question. If costs vary based on vessel or gear characteristics, indicate in the appropriate cell or add information in the notes. All costs should be listed in 2016 USD or otherwise labeled. If you have any questions regarding this survey, please contact Anna Henry (anna.henry@noaa.gov).

Your contact information:

Name		**Email**	
Title		**Phone**	
Company/Org.			

Please provide a brief description of your experience with EM systems:

Part I. Equipment

A. Purchase

Please enter the costs to purchase the following equipment.

Component	Description	Unit	Amount	Notes
EM system with 2 cameras	Including a control box, user interface, a GPS receiver, a hydraulic pressure transducer, and a drum rotation sensor.	$/system		
Camera	Each additional camera	$/camera		
Software	Costs of any software associated with these components that is required to run the system at an additional cost (such as control box software). Do not include software necessary for data processing/review.	$/system or $/month (circle unit or add info in notes)		
Spare parts/ hardware	cost to have general parts on hand for minor repairs	$/system		
Hard drive	cost of additional hard drive	$/hard drive		
	storage capacity of additional hard drive	GB/hard drive		
	Lifespan of hard drive	Hrs running		

If there are software costs listed above is this software proprietary☐ or open source☐

Other equipment costs or variables impacting equipment costs not listed above:

B. Installation

Please enter the costs of the following related to EM installation. If it is something not generally covered indicate with "n/a".

Component	Description	Unit	Amount	Notes
Install technician	Hourly rate for an installation technician	$/hour		
Travel costs for install tech	mileage	$/mile		
	meals	$		
	lodging	$		
	time	$		
Average installation time	2 camera EM system	hours		
	3 camera EM system	hours		
	4 camera EM system	hours		
Impact of gear type or vessel size on installation time. If no impact enter "n/a"	Longline	+/- %		
	Gillnet	+/- %		
	Trawl	+/- %		
	30 - 50 ft	+/- %		
	50 - <75 ft	+/- %		
	75 ft and above	+/- %		

Please describe the influence of general gear characteristics, program design or other variables on the number of cameras necessary for an adequate EM system:

Other installation costs or variables impacting installation costs not listed above:

C. Maintenance

Please enter the costs of the following related to EM maintenance. If there is a difference between maintenance to the software and the hardware of the system indicate accordingly. If something is not generally covered indicate with "n/a".

Component	Description	Unit	Hardware Amount	Software Amount	Notes
Maintenance technician	Hourly rate for an installation technician	$/hour			
Travel costs for maintenance tech (if same as install indicate with "same")	mileage	$/mile			
	meals	$			
	lodging	$			
	time	$			
Frequency of maintenance events requiring a trained technician - number of system running hours per maintenance event?	2 camera EM system	hours			
	3 camera EM system	hours			
	4 camera EM system	hours			
If maintenance frequency changes based on gear type indicate %change of running hours	Longline	+/- %			
	Gillnet	+/- %			
	Trawl	+/- %			
Duration of average repair		hours			
Average "lifespan" of EM system		hours running			

Other maintenance costs or impacts on frequency of maintenance not listed above:

Part II. Data

Component	Description	Unit	Amount	Notes

Data transfer	Hard drive submission by vessel operator using a method requiring signature on delivery and providing return receipt or delivery notification to sender	$/trip		
Logbook preparation	Any preparation, data entry, or QA/QC that needs to be done for comparison to EM footage if using an audit model	$/trip		
Review cost: hourly rate paid to reviewers of footage	Hourly rate to review EM footage for discard identification and quantification	$/hr		
	Hourly rate to review EM footage for presence of discard events	$/hr		
	Hourly rate to review EM footage to annotate when/where fishing is occurring	$/hr		
Fishery review: time required per hour of EM footage of fishing activity. If review ratio changes based on gear type or EM design indicate appropriately.	audit model	review hrs/1 hr footage		
	compliance model			
	census model			
	Longline	+/- %		
	Gillnet			
	Trawl			
Transit review	Review time required per hour of transit footage	review hrs/1 hr footage		
Fishing event identification	Review to annotate when/where fishing is occurring			
Storage	Secure cloud storage- with data access	$/100TB of data for 3 yrs		
	Secure cloud storage- no data access			
Software	If there is additional software associated with any of these components that is required to prepare, review or store the data at an additional cost	per system		

Other data costs or variables impacting data costs not listed above:

Part III. Program management

Please list the estimated administrative costs as a percent of overall program costs.

Component	Description		Unit	Amount	Notes
Administrative costs	To provide the services listed elsewhere in this survey including hiring and training personnel, reporting results to agency, communication and feedback to vessels, operations and overhead expenses	audit	% overall program cost		
		compliance			
		census			

Other comments:

Please send your responses to Anna Henry (anna.henry@noaa.gov).

Thank you very much for your time!