Fishery Data for Stock Assessment Working Group Report

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Working Group: Steve Cadrin (Chair, SMAST), Robin Frede (NEFMC), Emily Keiley (GARFO), Brian Linton (NEFSC), Jean-Jacques Maguire (SSC), Paul Rago (NEFSC retired), Rich Bell (TNC), Vito Giacalone (NESC), Chad Demarest (NEFSC), Chris Brown (FV Proud Mary) and Mark Gibson (RIDEM retired)

Other Contributors: Cate O'Keefe (MADMF), Greg DeCelles (MADMF), Brooke Wright (SMAST), Alex Hansell (SMAST), Chris McGuire (TNC), Dan Hennen (NEFSC)

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Glossary

Catch per unit effort (CPUE) - The quantity of fish caught (in number or in weight) by a defined unit of fishing effort, e.g. number of fish taken per 1,000 hooks per day; or weight of fish (in tons) taken per hour of trawling. Also referred to as fishery catch rates, CPUE can be considered as an index for long-term monitoring of a fishery. CPUE can be used as an index of stock abundance, where some relationship is assumed between that index and the stock size.

Landings per unit effort (LPUE) - The landings of fish taken (in number or in weight) by a defined unit of fishing effort. LPUE can be used as an index of abundance, where some relationship is assumed between that index and the stock size.

Effort - A measure of the amount of fishing. Typically expressed as the amount of fishing gear of a specific type used on the fishing grounds over a given unit of time, e.g. hours trawled, number of hooks set per day.

Footprint - An expected area of species distribution and targeted fishing for that species based on historical knowledge of the stock and fishery distribution. A comprehensive summary of expected seasonal footprints for abundance can be used to develop a set of stock specific inclusion probabilities that could be used as weighting factors for fishery-dependent data (see below).

Inclusion Probability - The probability of observations from a fishery that fish at a given location will be sampled. In statistically designed surveys, inclusion probabilities are ideally equal for all locations. By contrast, inclusion probabilities are unequal for fishery data, but standardization of CPUE can help to account for unequal probabilities.

Fishery-Dependent Data - Fishery data collected directly from fishery operations, including commercial and recreational fishermen and seafood dealers, e.g. self-reported data (logbooks, trip tickets), fisheries observers, port sampling

Fishery-Independent Data - Fishery data collected independently of fishery operations, e.g. fishery surveys for stock abundance information, research vessel surveys

Index of Abundance - A measure of population abundance, used to track changes in the population.

Target Species - The intended species sought by the fishermen in a particular fishery on a fishing trip. The subject of directed fishing effort in a fishery.

Catchability - The relationship between an index of abundance and the true population size for a given stock. Also referred to as fishing power. In general, it is the extent to which a stock is susceptible to fishing.

Selectivity – "the probability that a fish of a certain age or size will be captured by a given gear."

Standardize - To adjust a quantity to be directly comparable to a unit that is defined as the "standard" one. For example, CPUE and LPUE, standardizing means to account for or remove the effects of factors that may influence catch rates, e.g. vessel size, targeting behavior, spatial availability, by adjusting all observations to the standard. Standardization is also the procedure of maintaining methods and equipment as constant as possible. Without standardization one cannot determine whether measurements of yearly differences in relative abundance are caused by actual fluctuations in stock abundance or by differences in the measurement procedure used.

Fishing Mortality - A measurement of the rate of removal from a population by fishing activity, including in cases both when the fish is captured and kept and when it is released and has a discard mortality associated (an estimate of some percentage of the released fish that will not survive). Fishing mortality is the resultant of fishing effort and catchability.

Abundance - A measure of how many fish are in a population

Biomass - The total weight of fish species in a given population or area

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 gear), 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 year class 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 and occasionally 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 composition 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, but statistical methods have been developed to account for common factors of catch rates to derive standardized CPUE.

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 under certain conditions. 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 was previously used in many groundfish assessments before 2008 and is currently used in other northeast U.S. stock assessments. 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, particularly during periods with changes to survey operations. Even if it is not used as an index of abundance in the stock assessment model, including CPUE in a stock assessment can 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 unequal inclusion probabilities of fishery observations (i.e., the chance of each time/location observation being sampled) should be accounted for so that a CPUE is 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 commercial fishery discard estimates. However, the precision estimate does not account for 'observer bias' (i.e., observed trips do not represent unobserved trips because of differences in fishing behavior between observed and unobserved trips). Observer coverage should provide confidence that the estimate of discard rate is accurate. Vessel Trip Reports (VTRs) do not record fine-scale effort data. Many VTRs report aggregate effort by statistical fishing areas. Most of the data in VTRs is self-reported but is not usually verified (e.g., location, discarded catch). Vessel Monitoring System (VMS) information could be used to routinely verify VTR location information, but such evaluations are rare and not used for compliance or enforcement.

Federally permitted seafood dealers submit weekly electronic purchase reports. Although total landings derived from dealer reports are assumed to be a census of commercial fishery landings, recent violations document substantial mis-reporting. Although case violations

document some misreporting, the magnitude of misreporting and resulting bias in commercial landings are unknown. Recreational landings, discards and fishing effort are estimated by a telephone angler survey, angler intercept surveys, for-hire vessel trip reports and observer samples, and estimates of total fishing effort are much more uncertain than those for the commercial fishery.

Study fleets and Electronic Monitoring (EM) projects have the potential to provide greater spatial and temporal resolution of catch and effort in the commercial fishery. 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. Evaluation of CPUE should be considered as a research track for all groundfish assessments. CPUE should also be considered as a new index when level 3, management track assessments, are conducted. Consideration of CPUE as an index of abundance in assessments is recommended, but we recognize it may not necessarily be 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, unequal inclusion probabilities, spatial aggregation of fish, and hyperstability (the tendency for CPUE to be stable as a stock decreases). 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 a standard fleet for 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. The report was reviewed by a panel of the New England Council's Scientific and Statistical Committee (SSC) on November 30 2018. The report and the SSC's review were presented to the Council on January 30 3019. The SSC panel's recommendations and comments from the Council were addressed in this final report.

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 the 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 (maximized 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 year class 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 (MRIP). 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 year classes 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. Most assessments include multiple indices of abundance, and agreement in trends among indices strengthens the perception of a relatively high or low stock. By contrast divergent trends among indices add uncertainty to stock estimates.

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 to maintain the same fishing efficiency over the entire time series. 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 were 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

Recreational discards at age	Angler intercept survey Coastal household survey NEFSC surveys Port biological samples	Discards Angler effort Borrowed age-length keys Borrowed age-length keys
Catch weights at age	Port biological samples NEFSC surveys	Lengths and ages 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 an 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 for the Southern New England/Mid-Atlantic yellowtail flounder stock, 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 (VTRs) 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 the 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. 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.

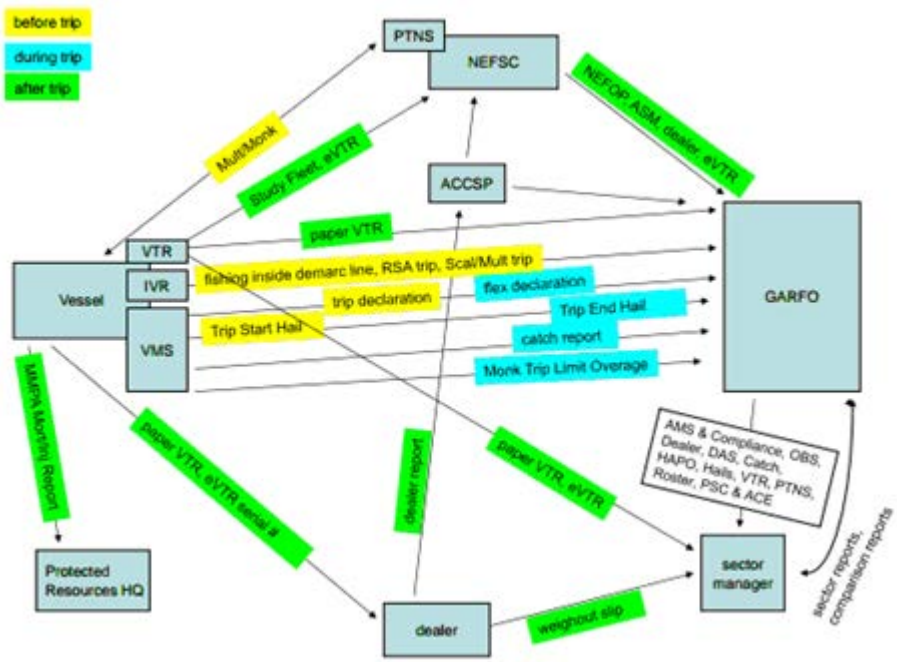

Figure 1 - Fishery-dependent data flow chart for northeast multispecies Sector vessels, developed for the Northeast fishery-dependent Data Visioning Workshop (Figure credit: Daniel Salerno, fishery-dependent Data Mapping Exercise).

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 Northeast Fisheries Science Center (NEFSC) Fisheries Sampling Branch (FSB) 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 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 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 percent 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 differences in fishing behavior).

Table 6 - Target and realized coverage rates for groundfish sectors, fishing years 2010-2019.

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 %	14.8%
FY 2017	8 %	8 %	16 %	17.3%
FY 2018	5 %	10 %	15 %	14.6%
FY 2019	N/A†	N/A†	31 %	N/A*

† NEFOP rates are stratum-specific starting in FY 2019.
*Realized coverage not available; fishing year still underway.

For more information on these programs:

https://www.greateratlantic.fisheries.noaa.gov/ro/fso/reports/Sectors/ASM/FY2019_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 limited and are not done routinely or for compliance and enforcement. An example of an approach to validate self-reported data with VMS data is published in the NEFSC Center Reference Document: "Validating the Stock Apportionment of Commercial Fisheries Landings Using Positional Data from Vessel Monitoring Systems (VMS)" (Palmer and Wigley, 2007). 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. Landings by market category offer information on size distribution of removals, and port samples stratified by market category can precisely estimate size composition with relatively few samples. If no fish are purchased or received during a reporting week, a report stating so 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/ASM 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 complement 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 undersampled.

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 Fishery 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 2019; 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, trip revenue and opportunity costs of quota. Observer presence has the smallest effect on the number of groundfish market categories and non-groundfish average prices, but, particularly in the former, 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, legally and perhaps illegally, and fish 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.

Use of CPUE indices for Atlantic Halibut

An assessment of Atlantic halibut for the Atlantic halibut in the US stock area included several metrics of relative abundance based on observations of commercial landings and discards (Rago 2018). Estimates of commercial discard rates from the NEFSC Observer Program, expressed as the ratio of discarded halibut in weight to weight of total species kept (i.e., landed) was used as indices of halibut abundance for 2002 to 2016. Estimates were obtained for both otter trawl and gill net fisheries. Neither of these gear types are well suited for catching Atlantic halibut, but each showed comparable trends in both discard rates and in total catch per unit effort. In this analyses, total catch of all species was used as a measure of fishing effort, thus integrating differences in vessel size and power, and trip duration. Estimates of trends in discard rates compared favorably with trends observed in trawl survey indices both for the NEFSC bottom trawl survey and the ME-NH inshore fall survey. Resulting measures of aggregate trend were used to adjust halibut catches limits upward using a model that relied on the first and second derivatives of the rate of change. By using dimensionless ratios as measures of trend it was possible to derive changes in catches commensurate with observed changes in a suites of fishery-independent and fishery-dependent indices of relative abundance. Comparisons of this methodology for catch forecasting for Atlantic halibut in Canada and Pacific halibut in US-Canada, each with age-based stock assessment models suggested potential broader utility of the method.

The 2018 halibut assessment also considered fishery CPUE. Although there are several fishery-independent surveys available in the region, few halibut are typically encountered, and a reliable index of abundance is not available. In the absence of reliable fishery-independent surveys, standardized catch per unit effort (CPUE) time series from the fishery can be used as an index of abundance to inform stock assessment. Incorporating fishermen's knowledge into the CPUE standardization process can be beneficial, because fishermen are knowledgeable about their fishery and target species, and can provide valuable information on factors affecting catch rates and patterns in catch rates. Atlantic halibut fishermen from Maine were interviewed to determine which covariates influence catch rates, and incorporated those covariates as predictor variables in the CPUE

standardization of logbook data (2002-2017) from Maine's Atlantic halibut fishery. Fishermen identified significant factors of their catch rates (fishing license, location and an interaction of depth and month) that accounted for 91% of the total variability in catch rates. The standardized time series showed a stable or increasing trend in Atlantic halibut catch rates, which is consistent with most fishermen's perspectives and the results of the most recent assessment. The results from this study highlight the value of collaborative research and provide information for management as a relatively empirical indicator or input to analytical stock assessment models.

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-reported 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 a 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 percent 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 (Hosken et al. 2016, Monteaguido et al. 2015). 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, though 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 Standardization of CPUE

One of the main goals of CPUE is to develop an index of abundance in which the CPUE is proportional to the abundance of the species. Fishery dependent data include a range of factors that impact the relationship between CPUE and species abundance (e.g. gear, vessel, area, targeting behavior, dock price) causing the relationship to vary over time and space. The CPUE must therefore be standardized to account for factors influencing the relationship. A number of methods exist to standardize CPUE (Maunder and Punt 2004). While vessel, captain, gear and area are commonly included in the standardization, additional factors such as socio-economic information and environmental data should also be considered.

Socio-Economic Information

There are a number of social and economic consequences of risk and decision making relative to fishing behavior and responses to management actions. Understanding these is of interest because fishermen are guided by economic incentives. For commercial fisheries incentives are primarily related to the expected profit, and for recreational fisheries incentives involve a combination of the number of fish kept or caught plus the value in spending time on the water. Fishermen behavior models take into account how choices in response to factors such as regulations, technology, weather, and expectations about prices, costs, and abundance influence catch rates. For example, Branch et al. (2006) review fleet dynamics and fishermen behavior from an economic and sociological basis in several fisheries under different exploitation levels, and discuss the need to create individual incentives that align fleet dynamics and fishermen behavior with the intended societal goals. Ono et al. (2018) introduce a framework for a realistic multispecies fishery management strategy evaluation (MSE) by accounting for fleet dynamics, multispecies fishery quota allocation, and the temporal dynamics of technical interactions, and note the importance of understanding human behavior as well as its uncertainty and refining approaches to incorporate this information into a multispecies fishery management strategy analysis. Lee et al. (2017) integrate a utility-theory consistent model of demand for recreational fishing trips with an age-structured stock dynamics model to provide policy relevant advice to managers of the groundfish fishery in the Northeast United States. The economic component of the model is a recreational demand model that is parameterized with a choice experiment (CE) survey, where angler effort is a function of trip costs, trip length, and expectations about landings and discards.

Understanding social and economic incentives and developing the behavioral models could reduce the biases of fishery dependent data and hence enhance the usefulness of CPUE data. In the groundfish fishery, quota and lease price also influences fishermen's choices on when and where to fish as well as targeting behavior or avoidance behavior, in order to avoid stocks with high leases prices relative to ex-vessel prices. Such targeting and anti-targeting information is important to include when developing CPUE, because this defines targeted effort and reduces bias in the indices. Socio-economic factors related to fishermen behavior and choice influence the magnitude and location of fishing effort and should be incorporated where possible when standardizing CPUE.

Environmental Data

Oceanographic features can impact the dynamic habitat of marine organisms altering the availability of species to fishing operations (Manderson 2016). The physical environment

can, therefore, impact the catchability, the relationship between CPUE and abundance of fishery dependent data. Lynch et al (2012, 2018) found that including a dynamic habitat factor (e.g. the temperature at different water depths) could account for substantial changes in catchability. In the studies, the pelagic thermal habitat variable was included within a two-part generalized linear model (delta GLM) to account for changes in catchability with temperature. The first part of the GLM modeled the presence/absence of the species to account for high numbers of tows with zero catches of the species of interest and the second part of the GLM modeled the catch when the species was present (Stefansson 1996). While habitat can impact abundance, seasonal changes in dynamic habitat such as temperature can have a larger impact on species distribution. Shifts in distribution can impact catchability and create the perception in CPUE data that abundance has changed when in reality, the species has simply shifted its spatial footprint in response to available habitat. When standardizing CPUE it is important to account for all factors that influence the catchability in order to ensure that the relationship between CPUE and total abundance is consistent over time. The physical environment can have major impacts on the distribution of fished species and should be considered when standardizing CPUE, particularly across broad areas.

As the dynamic habitat changes over seasonal and annual scales it can also cause shifts in species distribution that alter the overlap among different species. Because different species have different life histories and niche requirements the overlap in species ranges can vary among years. The spatial overlap between target species and discard/choke stocks and how it varies over time can be an important consideration, particularly if the amount of discards is the main value used to calculate CPUE. If the spatial overlap changes, it could cause large changes in the discard per unit effort, that is unrelated to the abundance of the discard species. Including spatial components as well as dynamic habitat variables in CPUE standardization can account for some of the variability in spatial overlap.

4.3.7 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. 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.

The International Council for the Exploration of the Sea (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, status of key fish species, and 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 total allowable catches (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, there is 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.

4.3.8 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;

3. Interpretation of signals derived from CPUE estimates where abundance in unobserved areas must be imputed. (e.g. What would catch rates in closed areas have been?)
4. Examine the impacts of regulations and/or misreporting on an index of CPUE; and
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.

4.3.9 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.

Changes to the stock assessment framework were recently adopted by the NRCC. The new framework may provide more opportunities to consider, and include CPUE indices into routine “management track” assessments, and may provide an opportunity to more holistically evaluate the use of CPUE for groundfish stock assessments within the “research track”. In the previous model exploration, and incorporation of new CPUE indices were generally limited to benchmark assessments, which occurred infrequently relative to the routine update assessments.

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 et al. 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.

4.3.10 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 (SASI) 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).

References

Bell, R. J., B. Gervelis, G. Chamberlain, and J. J. Hoey. 2017. Discard Estimates from Self-Reported Catch Data: an Example from the U.S. Northeast Shelf. North American Journal of Fisheries Management 37:1130-1144.

Beverton, R. J. H. and S. J. Holt. 1957. On the dynamics of exploited fish populations. HMSO, London.

Branch, T. A., R. Hilborn, A. C. Haynie, G. Fay, L. Flynn, J. Griffiths, K. N. Marshall, J. K. Randall, J. M. Scheuerell, E. J. Ward, and M. Young. 2006. Fleet dynamics and fishermen behavior: lessons for fisheries managers. Canadian Journal of Fisheries and Aquatic Sciences 63(7): 1647-1668.

Cadrin, S. X. and B. L. Wright 2016. Considering Fishery Catch Rates for New England Groundfish Assessments: A Case Study in Witch Flounder. In Mercaldo-Allen et al. eds, 15th Flatfish Biology Conference 2016 Program and Abstracts. NEFSC Ref Doc 16-14: 17.

Dobby, H., L. Allan, M. Harding, C. H. Laurenson, and H. A. McLay. 2008. Improving the quality of information on Scottish anglerfish fisheries: making use of fishers' data. ICES Journal of Marine Science:1334-1345.

Field, J. C., A. E. Punt, R. D. Methot, and C. J. Thomson. 2006. Does MPA mean 'Major Problem for Assessments'? Considering the consequences of place-based management systems. FISH and FISHERIES 7:284–302

GMA. 2001. Study fleet and industry based survey meeting summary November/December, 2000. Gulf of Maine Aquarium. On-line document: http://www.nero.noaa.gov/ro/doc/sfibsfr.pdf.

Hansell, A. C., G. DeCelles, and S. Cadrin. 2018. Incorporating fisher knowledge into an index of abundance for Atlantic halibut (*Hippoglossus hippoglossus*) in the Gulf of Maine. ICES C.M. 2018/ R:281.

Hoare, D., N. Graham, and P.-J. Schon. 2011. The Irish Sea data-enhancement project: comparison of self-sampling and national data-collection programmes—results and experiences. ICES Journal of Marine Science 68:1778-1784.

Hosken, M., H. Vilia, and J. Ago. 2016. Report on the 2014 Solomon Islands Longline E-Monitoring Project. Pacific Community, Noumea, New Caledonia.

Lee, M-Y., S. Steinback, and K. Wallmo. 2017. Applying a Bioeconomic Model to Recreational Fisheries Management: Groundfish in the Northeast United States. Marine Resource Economics 32(2): 191-216.

Lynch, P. D., K. W. Shertzer, and R. J. Latour. 2012. Performance of methods used to estimate indices of abundance for highly migratory species. Fisheries Research 125-126: 27-39.

Lynch, P. D., K.W. Shertzer, E. Cortés, and R. J. Latour. 2018. Abundance trends of highly migratory species in the Atlantic Ocean: accounting for water temperature profiles. ICES Journal of Marine Science 75(4): 1427-1438.

Manderson, J. P. Seascapes are not landscapes: an analysis performed using Bernhard Riemann's rules. ICES Journal of Marine Science 73: 1831–1838.

Maunder M. N., and A. E. Punt. 2004. Standardizing catch and effort data: A review of recent approaches. Fisheries Research 70(2): 141-159.

Maunder M. N., J. R. Sibert, A. Fonteneau, J. Hampton, P. Kleiber, and S. J. Harley. 2006. Interpreting catch per unit effort data to assess the status of individual stocks and communities, ICES Journal of Marine Science 63: 1373–1385.

Miona, M., C. Piras, T. Fortibuoni, I. Celić, G. Franceschini, A. Giovanardi, A. Belardinelli, M. Martinelli, and S. Raicevich. 2015. Collection and validation of self-sampled e-logbook data in a Mediterranean demersal trawl fishery Regional Studies in Marine Science 2:76-86.

Monteaguido, J., G. Legorburu, A. Justel-Rubio, and V. Restrepo. 2015. Preliminary study about the suitability of an electronic monitoring system to record scientific and other information from the tropical tuna purse seine fishery. SCRS/2014/132. Collect. Vol. Sci. Pap. ICCAT 71: 440-459.

Murphy T., G. Ardini, M. Vasta, A. Kitts, C. Demarest, J. Walden, and D. Caless. 2018. 2015 Final Report on the Performance of the Northeast Multispecies (Groundfish) Fishery (May 2007 – April 2016). US Dept Commer, Northeast Fish Sci Cent Ref Doc. 18-13; 128p.

Northeast Fisheries Science Center, Fisheries Sampling Branch, Observer Operations Manual, 2016, https://www.nefsc.noaa.gov/fsb/manuals/2016/Operations_Manual.pdf

Northeast Fisheries Science Center. 2017. Operational Assessment of 19 Northeast Groundfish Stocks, Updated Through 2016. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 17-17; 259 p. doi: 10.7289/V5/RD-NEFSC-17-17.

Ono, K., A. C. Haynie, A. B. Hallowed, J. N. Ianelli, C. R. McGillard, and A. E. Punt. 2018. Management strategy analysis for multispecies fisheries, including technical interactions and human behavior in modelling management decisions and fishing. Canadian Journal of Fisheries and Aquatic Sciences 75(8): 1185-1202.

Palmer, M. C., S. E. Wigley, J. J. Hoey, and J. E. Palmer. 2007. An Evaluation of the Northeast Region's Study Fleet pilot program and Electronic Logbook System: Phases I and II. NOAA Technical Memorandum NMFS-NE-204. National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Sarndal, C.-E., B. Swensson, and J. Wretman. 1992. Model Assisted Survey Sampling. Springer-Verlag, New York, pp. 30-33

Smith, S. J., J. Black, B. J. Todd, V. E. Kostylev, and M. J. Lundy. 2009. The impact of commercial fishing on the determination of habitat associations for sea scallops (*Placopecten magellanicus*, Gmelin). ICES Journal of Marine Science 66: 2043-2051.

Smith, S. J., J. A. Sameoto, and C. J. Brown. 2017. Setting biological reference points for sea scallops (*Placopecten magellanicus*) allowing for the spatial distribution of productivity and fishing effort. Canadian Journal of Fisheries and Aquatic Sciences 74: 650-667.

Starr, P. 2010. Fisher-Collected Sampling Data: Lessons from the New Zealand Experience. Marine and Coastal Fisheries, 2, 47-59. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 2:47-59.

Starr, P. J., and M. Vignaux. 1997. Comparison of data from voluntary logbook and research catch-sampling programmes in the New Zealand lobster fishery. Marine and Freshwater Research 48:1075-1080.

Stefánsson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES J. Mar. Sci. 53: 577–588.

Walters, C. 2003. Folly and fantasy in the analysis of spatial catch rate data. Can. J. Fish. Aquat. Sci. 60:1433-1436.

Wigley, S. E., P. J. Rago, K. A. Sosebee, and D. L. Palka. 2006. The analytic component to the standardized bycatch reporting methodology omnibus amendment: sampling design, and estimation of precision and accuracy. National Marine Fisheries Service, Northeast Fisheries Science Center Reference Document 06–22, Woods Hole, Massachusetts.

Appendices

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

Appendix 2: Hennen 2018, CPUE as an Index of Abundance in Stock Assessments

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

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.

Literature Cited

Lo, N.C., L.D. Jackson, J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Canadian Journal of Fisheries and Aquatic Sciences 49: 2515-2526.

McCarthy, K. 2010. United States commercial longline vessel standardized catch rates of golden and blueline tilefish in the Gulf of Mexico, 1992-2009: Revised. SEDAR22-AW-01. 18 pp. Available online at: http://sedarweb.org/sedar-22-assessment-workshop.

SEDAR. 2011a. SEDAR 22 Stock Assessment Report: Gulf of Mexico Tilefish. SEDAR, North Charleston, SC. 467 pp. Available online at: http://sedarweb.org/sedar-22.

SEDAR. 2011b. SEDAR 22 Stock Assessment Report: Gulf of Mexico Yellowedge Grouper. SEDAR, North Charleston, SC. 423 pp. Available online at: http://sedarweb.org/sedar-22.

Stephens, A. and A. MacCall. 2004. A multispecies approach to subsetting logbook data for purpose of estimating CPUE. Fisheries Research 70: 299-310.

Appendix 1

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

	Not Applicable	Absent	Incomplete	Complete
DESCRIPTION OF THE DATA SOURCE				
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?				

Working Group Comments:

	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
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.				
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.				

Working Group Comments:

The feasibility of this diagnostic is still under review.

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

Catherine E. O'Keefe and Steven X. Cadrin
School for Marine Science and Technology (SMAST)
University of Massachusetts Dartmouth
Joshua Wiersma
Environmental Defense Fund

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

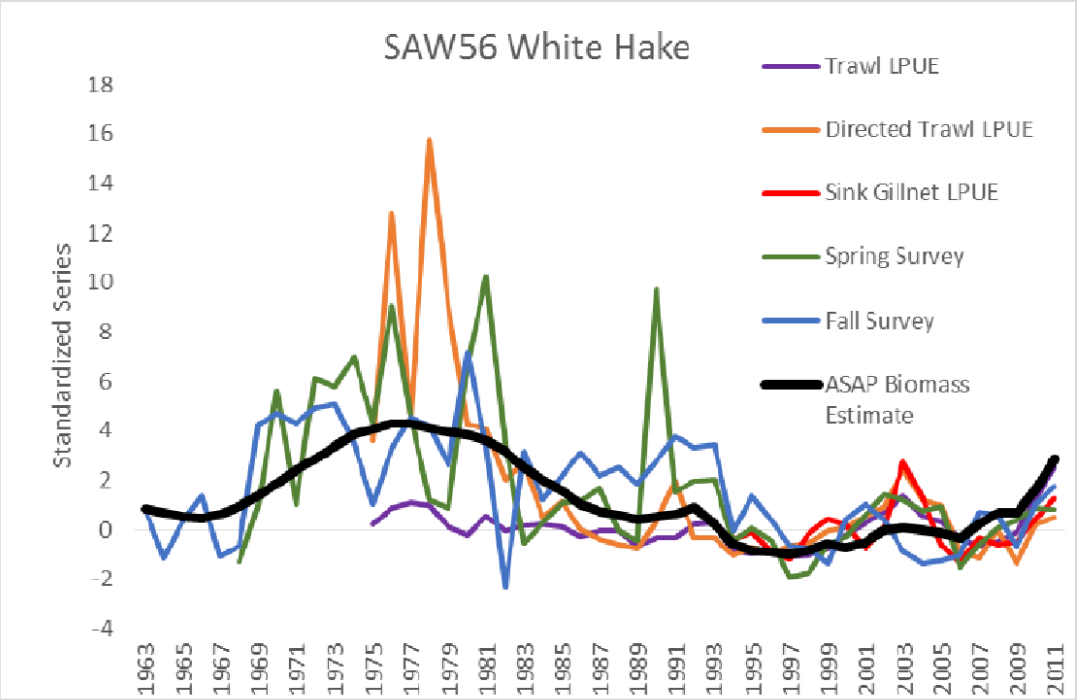
and which trips were engaged in other fisheries (e.g., fluke) with virtually no probability of encountering haddock. For that reason, only trips that landed ≥ 1 lb haddock were included in the model. Results for nominal Gulf of Maine haddock commercial trawl LPUE (landings per days fished) showed very 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.

REFERENCES

Bethoney ND, Schondelmeier BP, Stokesbury KDE, Hoffman WS. 2013.Developing a fine scale system to address river herring (*Alosa pseudoharengus, A. aestivalis*) and American shad (*A. sapidissima*) bycatch in the US Northwest Atlantic mid-water trawl fishery. Fisheries Research 141: 79-87.

Dunn DC, Boustany AM, Roberts JJ, Brazer E, Sanderson M, Gardner B, Halpin B. 2013. Empirical move-on rules to inform fishing strategies: a New England case study. Fish and Fisheries 15: 359–375.

Gauvin JR, Haflinger K, Nerini M. 1995. Implementation of a voluntary bycatch avoidance program in the flatfish fisheries of the Eastern Bering Sea. University of Alaska, Alaska Sea Grant Program, Sea Grant Program Report 96-03, Fairbanks.

Gulf of Maine Research Institute (GMRI). 2014. Northeast Federal fishery-dependent Data Visioning Project Workshop Report. September 2014. 41 p.

Harley SJ, Myers RA, Dunn A. 2001. Is catch-per-unit-effort proportional to abundance? Canadian Journal of Fisheries and Aquatic Sciences 58: 1760-1772.

Hilborn R, Walters CJ. 2013. Eds. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Springer Science & Business Media.

Holland DS, Jannot JE. 2012. Bycatch risk pools for the US west coast groundfish fishery. Ecological Economics 78: 132-147.

International Commission for the Conservation of Atlantic Tunas (ICCAT). 2014. Report of the 2014 Atlantic Bluefin Tuna Stock Assessment Session. 22-27 September 2014, Madrid, Spain.

International Council on the Exploration of the Sea (ICES). 2015. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). 28 April – 7 May 2015, Copenhagen, Denmark.

_____. 2014. Report of the Working Group for the Bay of Biscay and Iberian Waters Ecoregion (WGBIE). 7-13 May 2014, Lisbon, Portugal.

Maunder MN, Punt AE. 2004. Standardizing catch and effort data: A review of recent approaches. Fisheries Research 70(2): 141-159.

Maunder MN, Sibert JR, Fonteneau A, Hampton J, Kleiber P, Harley SJ. 2006. Interpreting catch per unit effort data to assess the status of individual stocks and communities. ICES Journal of Marine Science 63(8): 1373-1385.

Murawski SA. 2002. Statement to the US Commission on Ocean Policy: Scientific challenges in supporting living marine resource management. July 2002, Boston, Massachusetts.

Murawski SA, Wigley SE, Fogarty MJ, Rago PJ, Mountain DG. 2005. Effort distribution and catch patterns adjacent to temperate MPAs. ICES Journal of Marine Science 62: 1150-1167.

New England Fisheries Management Council (NEFMC). 1993. Final Amendment 5 to the Northeast Multispecies Fishery Management Plan incorporating the Supplemental Environmental Impact Statement. Volume I. September 1993, Newburyport, MA.

_____. 2015. Framework Adjustment 53 to the Northeast Multispecies Fishery Management Plan. March 2015, Newburyport, MA.

Northeast Fishery Science Center (NEFSC). 1993. 15th Northeast Regional Stock Assessment Workshop (15th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 93-05; 66 p.

_____. 1996. 22nd Northeast Regional Stock Assessment Workshop (22nd SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 96-13; 248 p.

_____. 1998. 27th Northeast Regional Stock Assessment Workshop (27th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 98-14; 80 p.

_____. 2007. An Evaluation of the Northeast Region's Study Fleet Pilot Program and Electronic Logbook System: Phases I and II. NOAA Technical Memorandum NMFS-NE-204; 90 p.

_____. 2009. 48th Northeast Regional Stock Assessment Workshop (48th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 09-15; 834 p.

_____. 2010. 50th Northeast Regional Stock Assessment Workshop (50th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 10-17; 844 p.

_____. 2011. 52nd Northeast Regional Stock Assessment Workshop (52nd SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 11-17; 968 p.

_____. 2012a. Assessment or Data Updates of 13 Northeast Groundfish Stocks through 2010. US Department of Commerce, Northeast Fisheries Science Center Reference Document 12-06; 789 p.

_____. 2012b. 53rd Northeast Regional Stock Assessment Workshop (53rd SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 12-05; 559 p.

_____. 2012c. Utility of Catch and Landings Per Unit of Fishing Effort (CPUE and LPUE) in Gulf of Maine and Georges Banks Cod Stock Assessments. Draft Report of the Cod Catch Per Unit Effort (CPUE) Working Group. 21 August 2012; 14 p.

_____. 2012d. 54th Northeast Regional Stock Assessment Workshop (54th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 12-18; 604 p.

_____. 2013a. 55th Northeast Regional Stock Assessment Workshop (55th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 13-11; 845 p.

_____. 2013b. 56th Northeast Regional Stock Assessment Workshop (56th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 13-10; 868 p.

_____. 2014a. 58th Northeast Regional Stock Assessment Workshop (58th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 14-04; 784 p.

_____. 2014b. 59th Northeast Regional Stock Assessment Workshop (59th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 14-09; 782 p.

_____. 2015a. 60th Northeast Regional Stock Assessment Workshop (60th SAW) Assessment Report. US Department of Commerce, Northeast Fisheries Science Center Reference Document 15-08; 881 p.

_____. 2015b. Draft Gulf of Maine Atlantic Cod 2015 Assessment Update Report. September 2015. 9 p.

_____. 2015c. A synoptic view of the stock status of the twenty Northeast groundfish stocks in 2015. 16 September 2015.

_____. 2015d. Draft Stock Assessment Update of 20 Northeast Groundfish Stocks Through 2014. US Department of Commerce, Northeast Fisheries Science Center Reference Document 15-XX; 238 p.

_____. 2017. Operational Assessment of 19 Northeast Groundfish Stocks, Updated Through 2016. US Dept Commerce, Northeast Fisheries Science Center Reference Document 17-17.

Ocean Studies Board (OSB). Review of Northeast Fishery Stock Assessments. National Academies Press, 1998.

O'Keefe CE, DeCelles GR. 2013. Forming a partnership to reduce bycatch. Fisheries 38(10): 434-444.

Palmer MC. 2012. Commercial catch-per-unit-effort (CPUE) indices for Gulf of Maine Atlantic cod (*Gadus morhua*). SAW 55 Data Meeting. 27-31 August 2012. Working Paper 9. 89 p.

Palmer MC. 2014. 2014. Assessment update report of the Gulf of Maine Atlantic cod stock. US Department of Commerce, Northeast Fisheries Science Center Reference Document 14-14; 119 p.

Palmer MC, Wigley SE. 2011. Validating the stock apportionment of commercial fisheries landings using positional data from Vessel Monitoring Systems (VMS): Impacts on the winter flounder stock allocations. SAW 52 Working Paper 9a. May 2011, Woods Hole, MA.

Richardson DE, Palmer MC, Smith B. 2012. The relationship of forage fish abundance to aggregations of Gulf of Maine Atlantic cod (*Gadus morhua*) and possible implications for catch-per-unit-effort indices. SAW 55 Data Meeting. 27-31 August 2012. Working Paper 4. 41 p.

The Nature Conservancy (TNC). 2012. The Nature Conservancy in California, 2012 Annual Report. 17 p.

United States Department of Commerce (USDOC). 1976. Magnuson-Stevens Fishery Conservation and Management Act. Public Law 94-265.

Wood A. 2012. Standardized LPUE for Gulf of Maine and George's Bank cod. SAW 55 Data Meeting. 27-31 August 2012. Working Paper 11. 11 p.

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

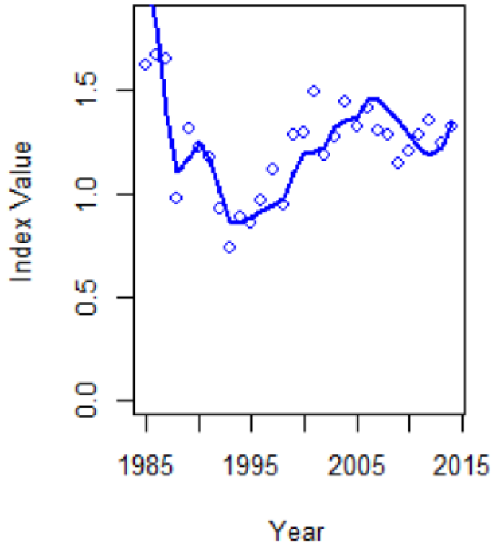


Figure 1. Bluefish model (solid line) fit to the MRIP CPUE index (open circles; from NEFSC, 2015a).

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

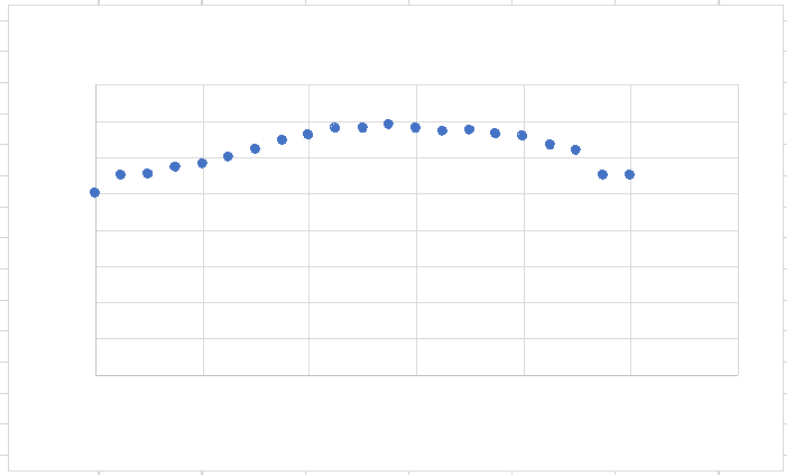
Table 5. Product of Catch value * probability of occurrence for filtered observations.

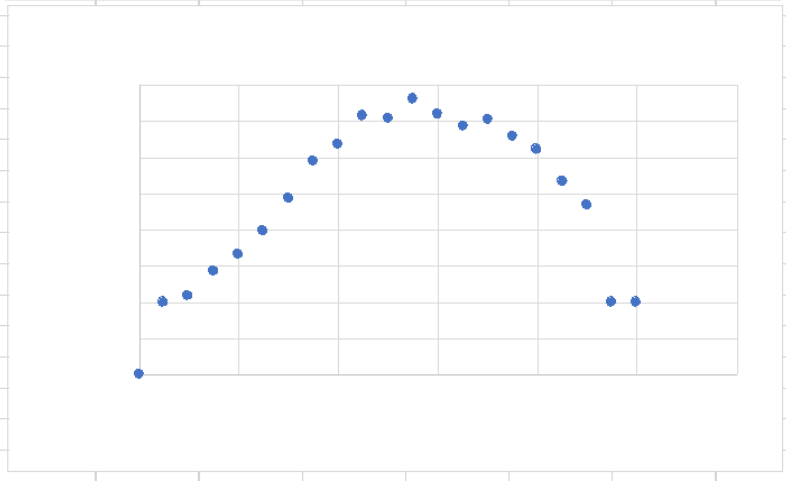
			Catch of Target species											
			0	1	2	3	4	5	6	7	8	9	10	Value
	value	Prob	0.09091	0.09091	0.09091	0.09091	0.09091	0.09091	0.09091	0.09091	0.09091	0.09091	0.09091	Probability
Species non-target	0	0.09091	0	0.008264	0.016529	0.024793	0.033058	0.041322	0.049587	0.057851	0.066116	0.07438	0.082645	
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

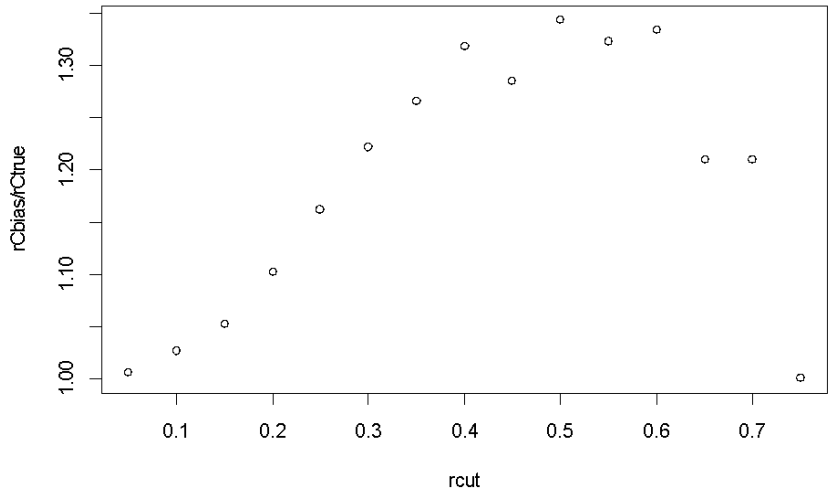
The above “toy” example assumes a uniform distribution of catches in both the species 1 and 2. More realistic simulations can be used to show the effects of alternative distributions of catch and the magnitude of bias induced when the abundance of the target species declines between sampling periods:

R code

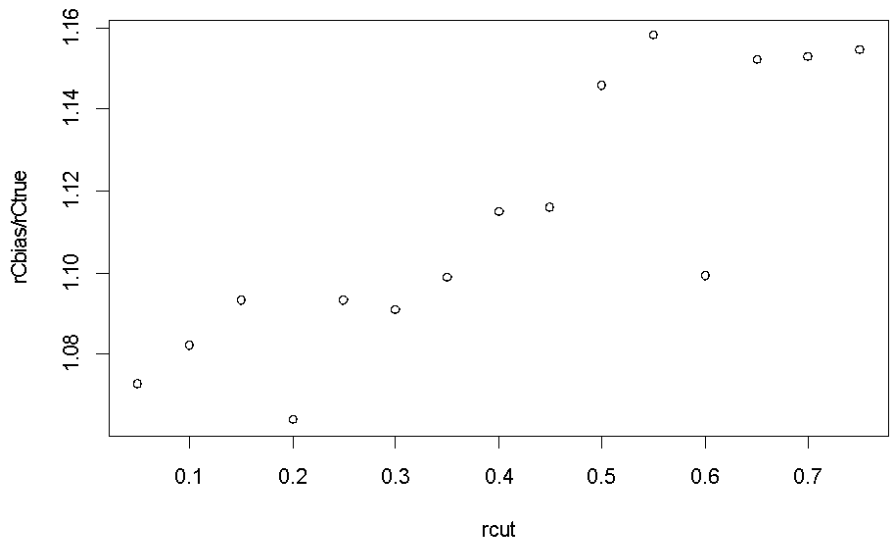
```
# Quick simulation model to demonstrate the bias of defining cpue based on % composition of target species
require(graphics)

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

updated April 18, 2019

Groundfish Plan Development Team

– 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

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

(Equation 1)

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

(Equation 2)

where y is a fishing year, f is fishing vessel and v is any one of the metrics evaluated. 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'.

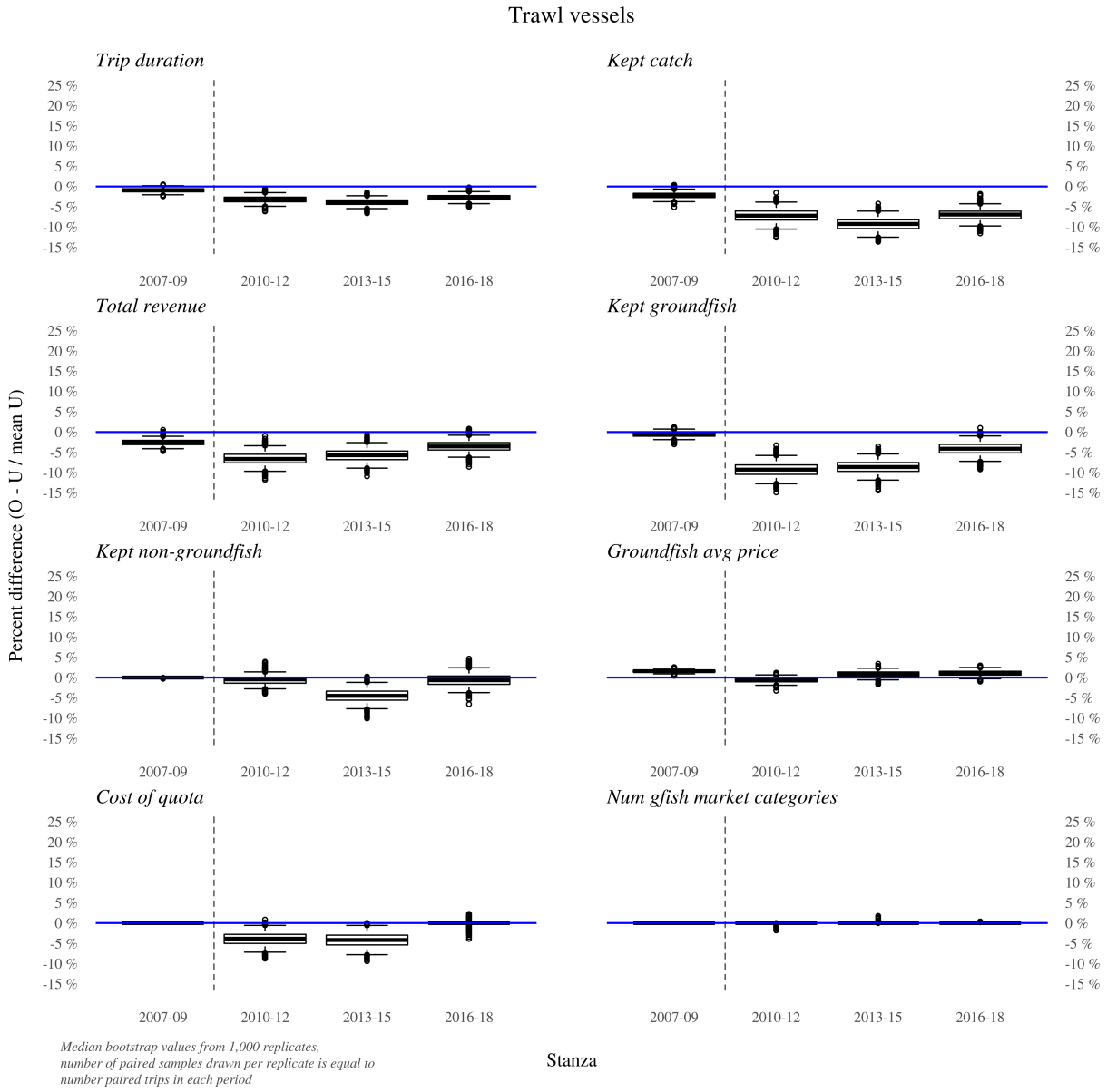


Figure 1: Results of bootstrap analysis, observed and unobserved same-vessel paired trips by stanza

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.

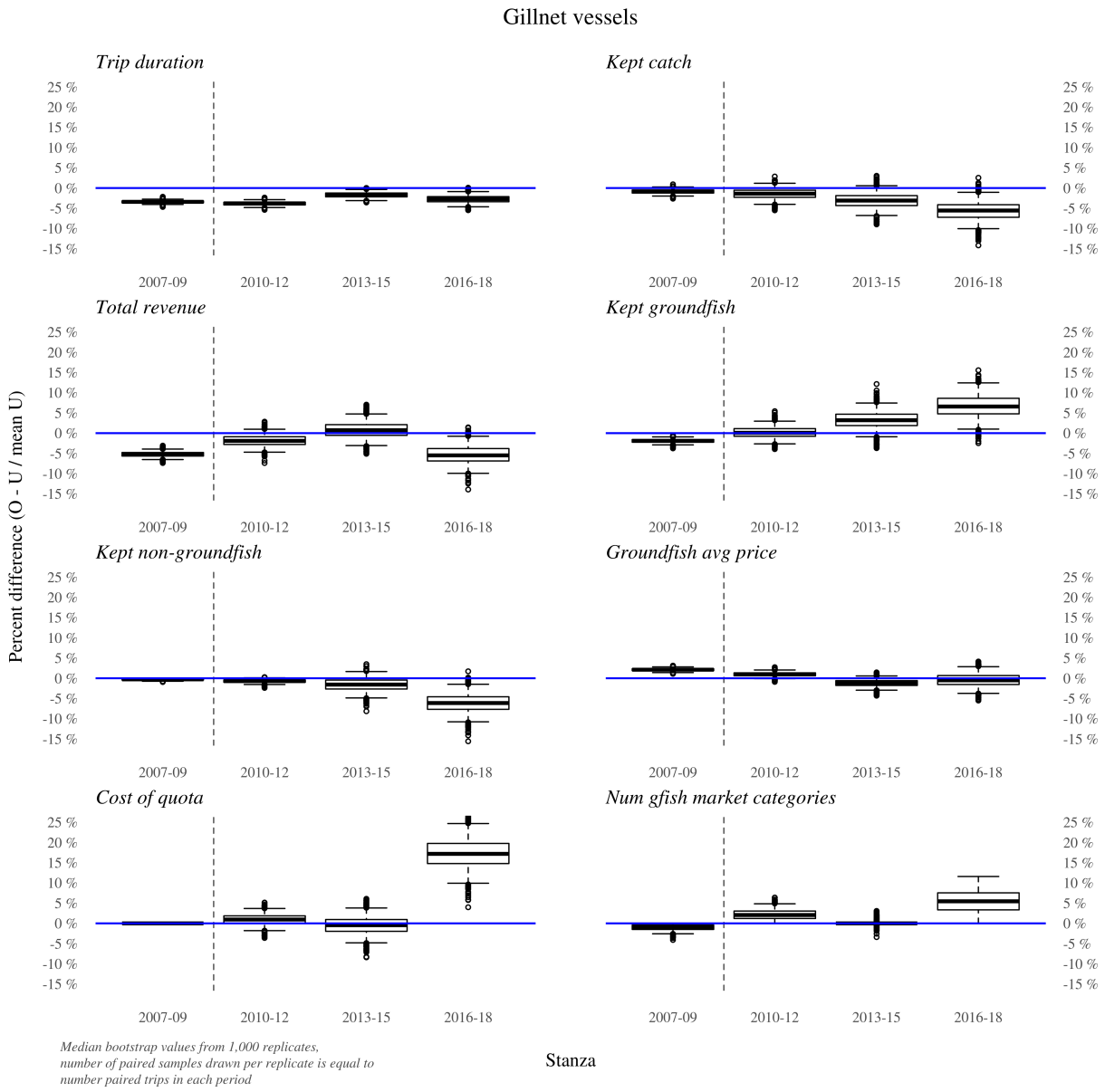


Figure 2: Results of bootstrap analysis, observed and unobserved same-vessel paired trips by stanza

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

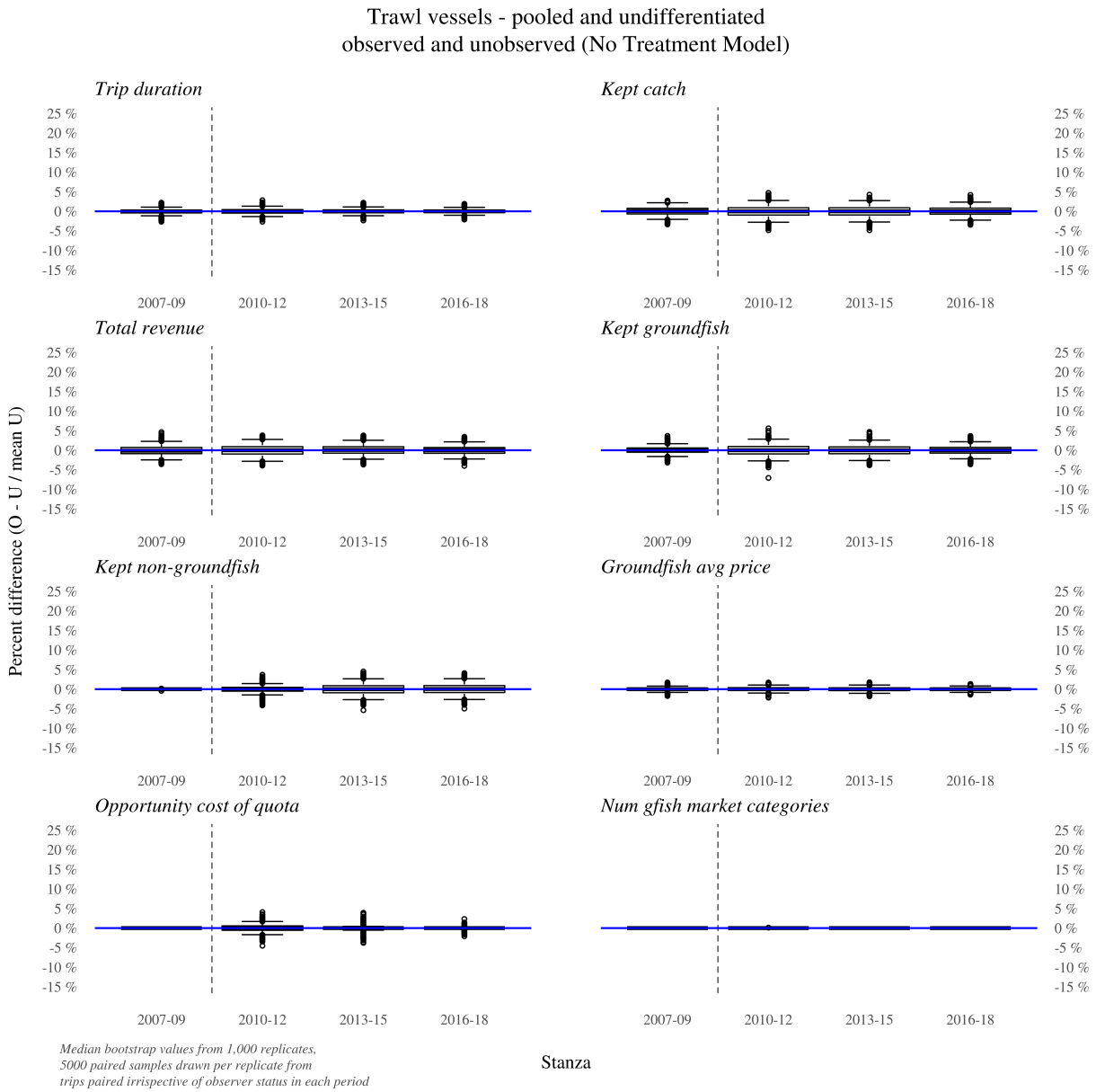
Gear	Variable	KS <= 0.005	p(KS)	K <= 0.005	p(K)	n Unobserved	n Observed
Gillnet	Kept groundfish		0.144		0.101	833	277
Gillnet	Number groundfish market categories		0.077	*	0.000	833	277
Gillnet	Groundfish avg price		0.702		0.486	833	277
Gillnet	Kept catch		0.040		0.033	833	277
Gillnet	Kept non-groundfish		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

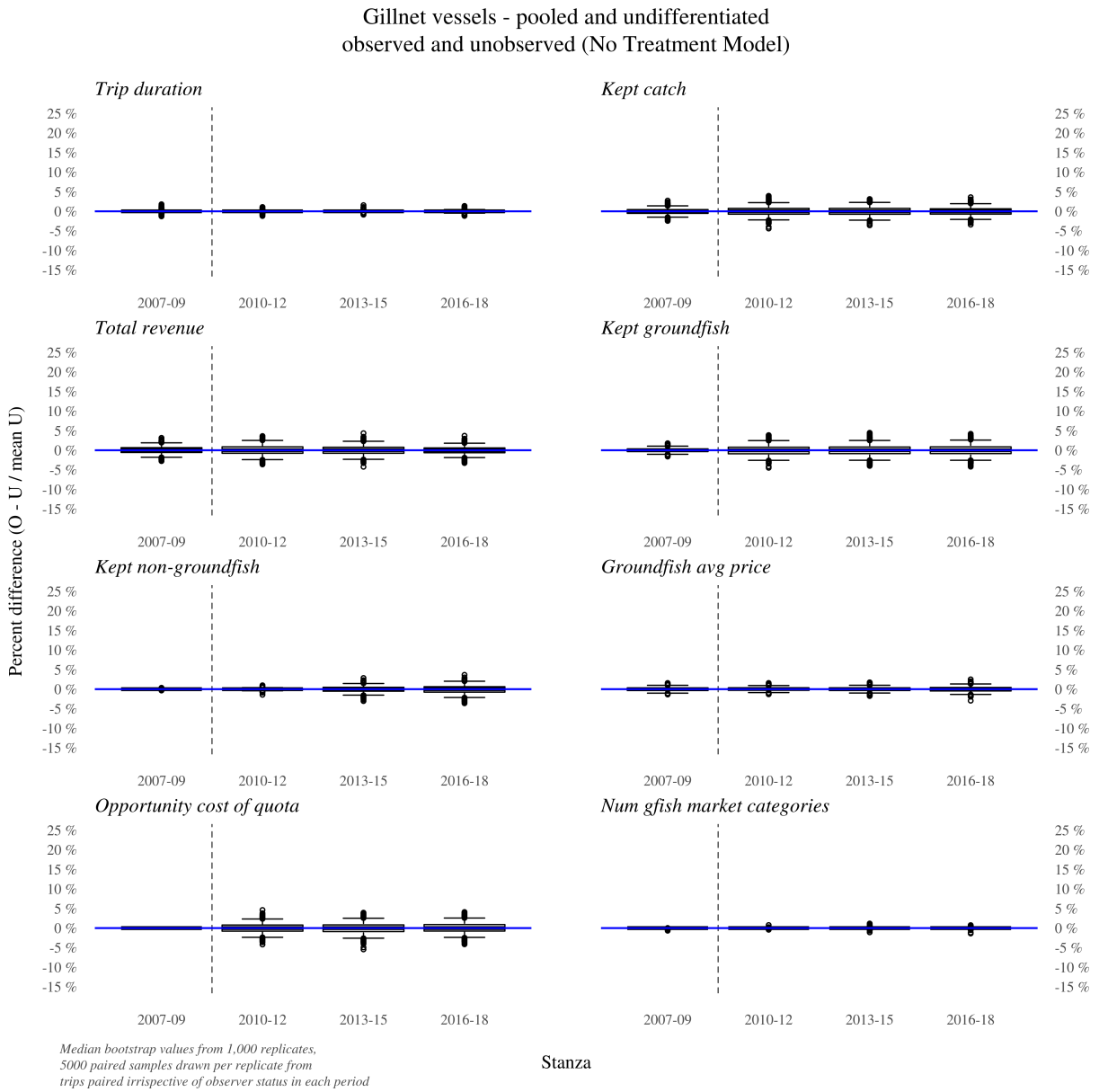
Discussion

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
Percent difference (O - U / mean U)
25 %
20 %
15 %
10 %
5 %
0 %
-5 %
-10 %
-15 %
2007-09
2010-12
2013-15
2016-18
Median bootstrap values from 1,000 replicates,
5000 paired samples drawn per replicate from
trips paired irrispective of observer status in each period
Stanza



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.

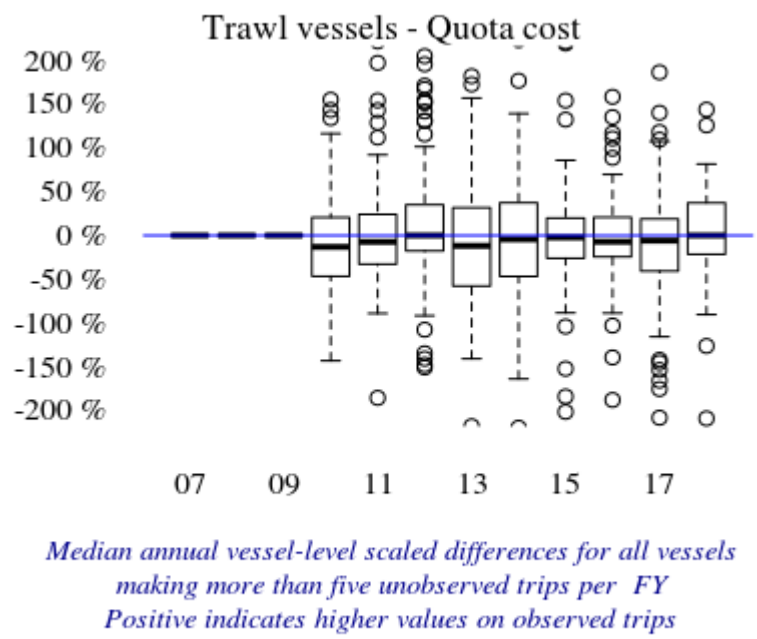


Figure 3: Distribution of vessel-level median annual observer effects, trawl)

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

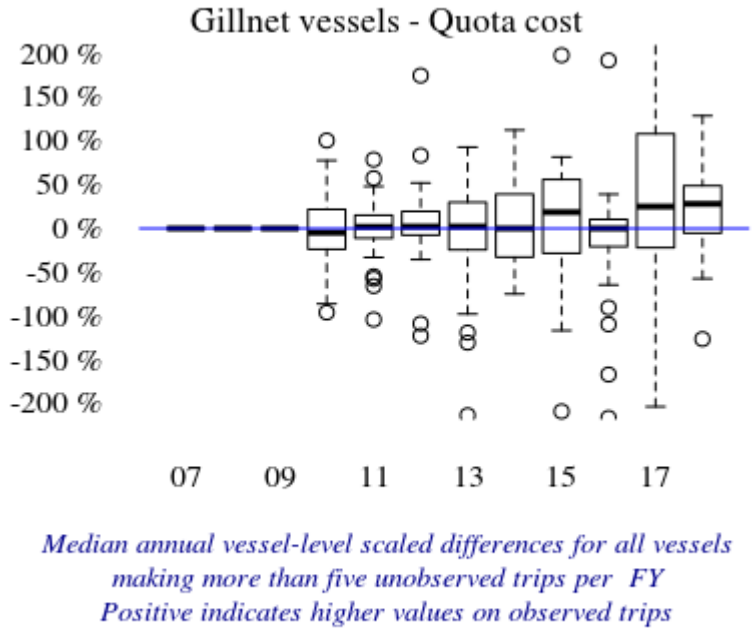


Figure 4: Distribution of vessel-level median annual observer effects, gillnet)

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}

References

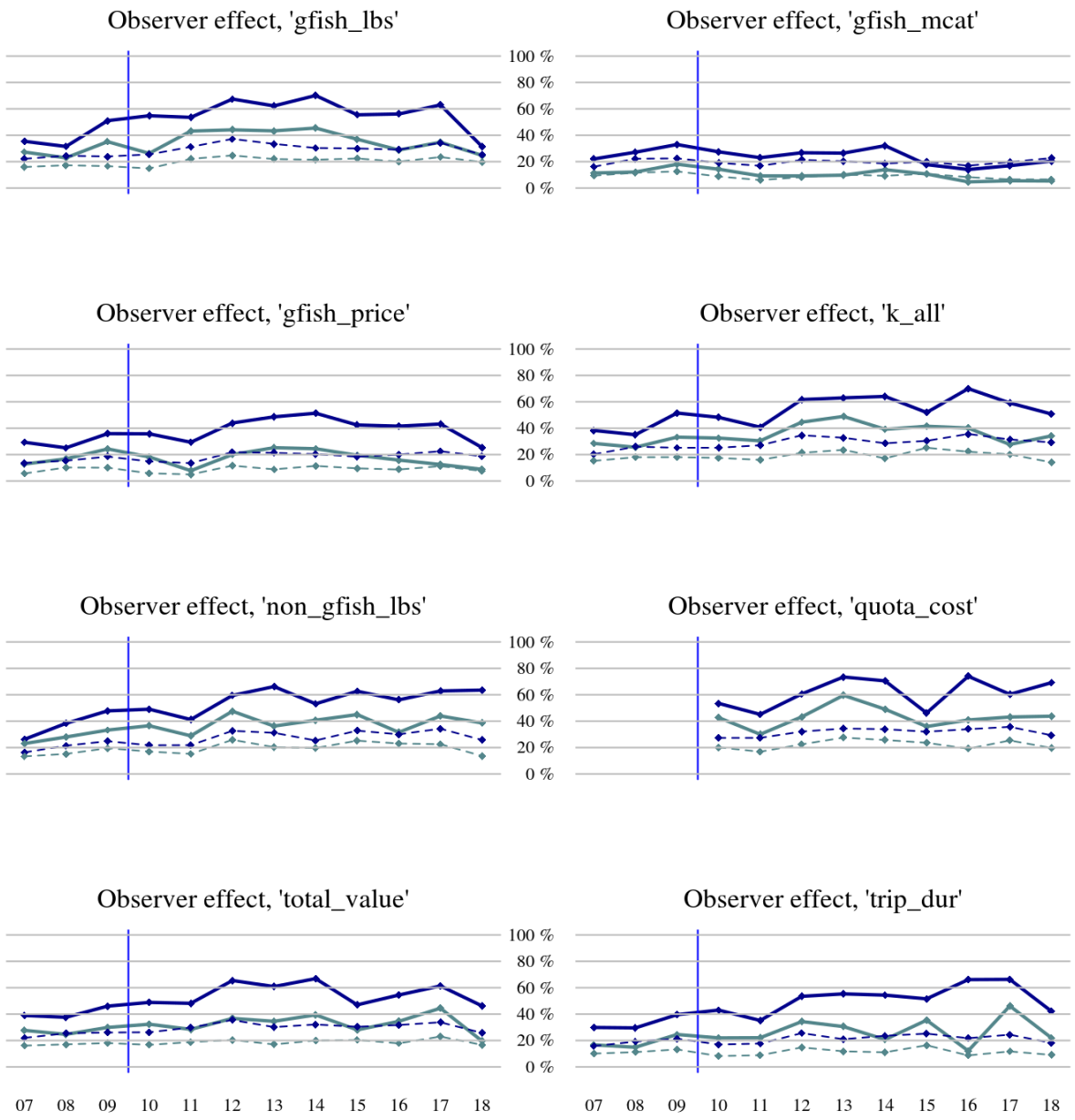
Benoît H. P., Allard J. Can the data from at-sea observer surveys be used to make general inferences about catch composition and discards? Canadian Journal of Aquatic Sciences 2009; 66:2025-2039.

Conover, W.J. 1980. Practical non-parametric statistics. 2nd ed. John Wiley and Sons, Inc, New York.

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.

New England Fishery Management Council (NEFMC). Framework Adjustment 46 to the Northeast Multispecies Fishery Management Plan. New England Fishery Management Council, Newburyport, MA. 2012. 299 pp.



solid line

Proportion of all groundfish caught by vessels exhibiting +/- 15% median annual effect

... +/- 30% median annual effect

dotted line

Proportion of all vessels exhibiting +/- 15% median annual effect

... +/- 30% median annual effect

Figure 5: Proportion of vessels and catch accounted for by vessels with median annual observer effect greater than +/- 15 and 30%

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.

Appendix 6

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				

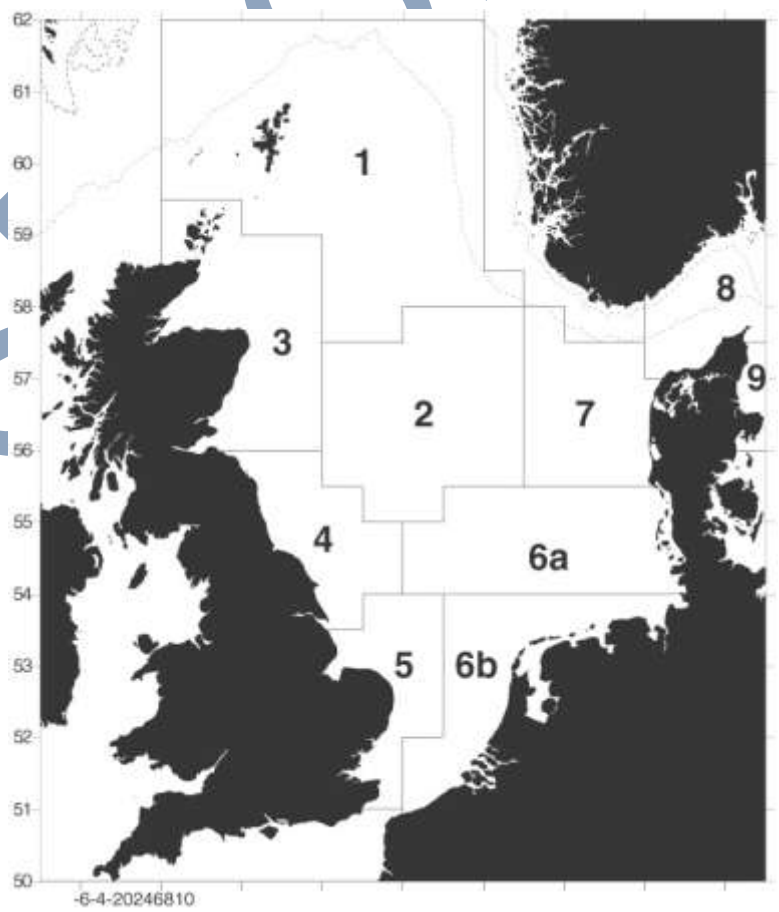
*Main fishing method **last year***	Trawl		*Nephrops* Trawl		Beam Trawl		Gill Net		Seine*	
	*Seine = Scottish Seine, Pair Seine, or Danish Seine (please indicate which)									
	Other (please specify)									

*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**

(ian.napier@uhi.ac.uk)

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

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

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%	27%	**60%**	13%	**82%**	4%
	-14%	-4%	**+19%**	**+2%**	+1%	-3%
Haddock	14%	**44%**	42%	13%	**87%**	0%
	-13%	**+12%**	+1%	+1%	**+6%**	-8%
Whiting	21%	**57%**	22%	21%	**78%**	1%
	-7%	**+26%**	-19%	**+9%**	-3%	-7%
Saithe	12%	**52%**	37%	21%	**71%**	7%
	-16%	**+21%**	-5%	**+10%**	-10%	-0%
Monkfish	9%	**54%**	38%	16%	**79%**	5%
	-19%	**+22%**	-3%	**+4%**	-2%	-2%
Nephrops	13%	17%	**70%**	16%	**69%**	15%
	-15%	-14%	**+29%**	+5%	-12%	**+7%**
Sole	24%	29%	**47%**	31%	**65%**	3%
	-4%	-2%	**+6%**	**+20%**	-16%	-4%
Plaice	14%	27%	**59%**	27%	**65%**	7%
	-13%	-4%	**+17%**	**+15%**	-15%	-0%

cont./

Table 4 cont.

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

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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

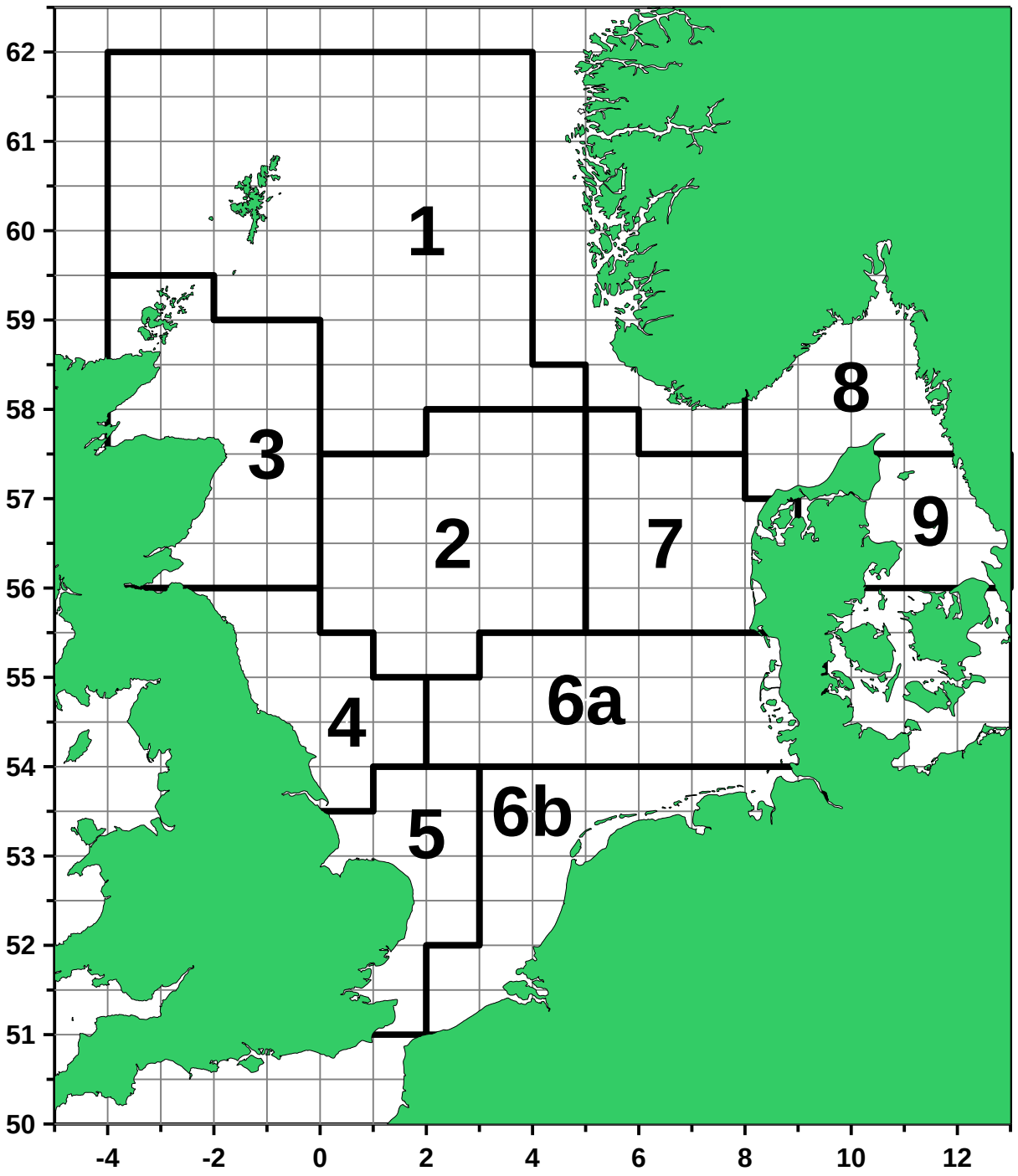

Figure 1 The areas of the North Sea used in the survey. Based on the ICES standard roundfish sampling areas with area 6 divided into two parts.

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

[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.

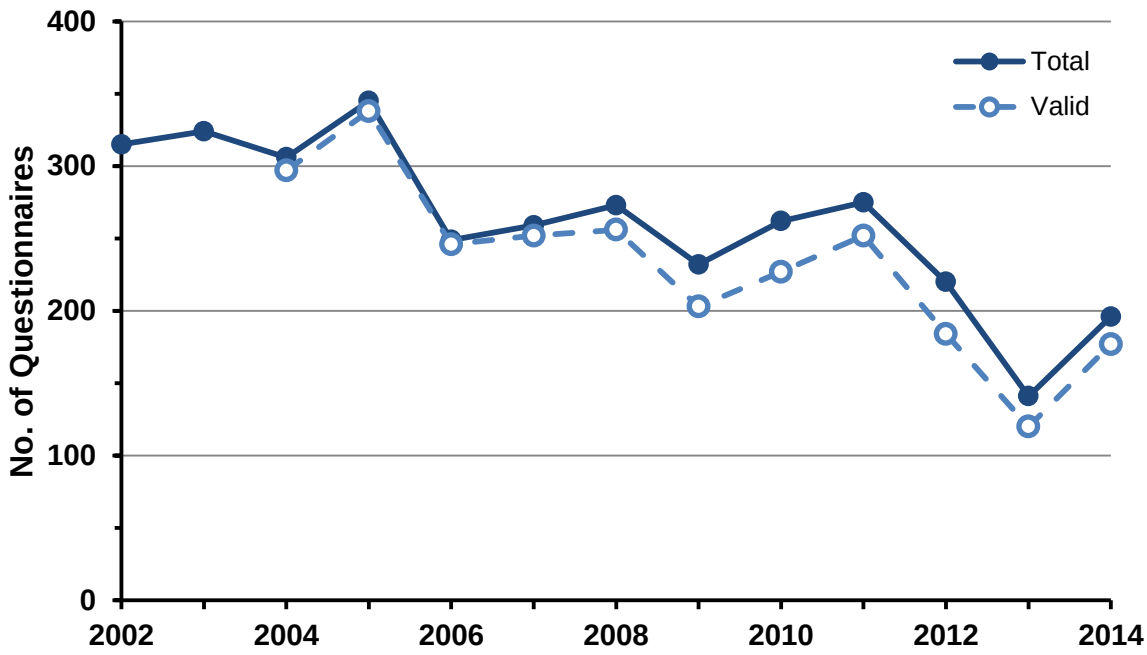

Figure 2 The total number of questionnaires returned each year, and the number of valid questionnaires included in the analysis.

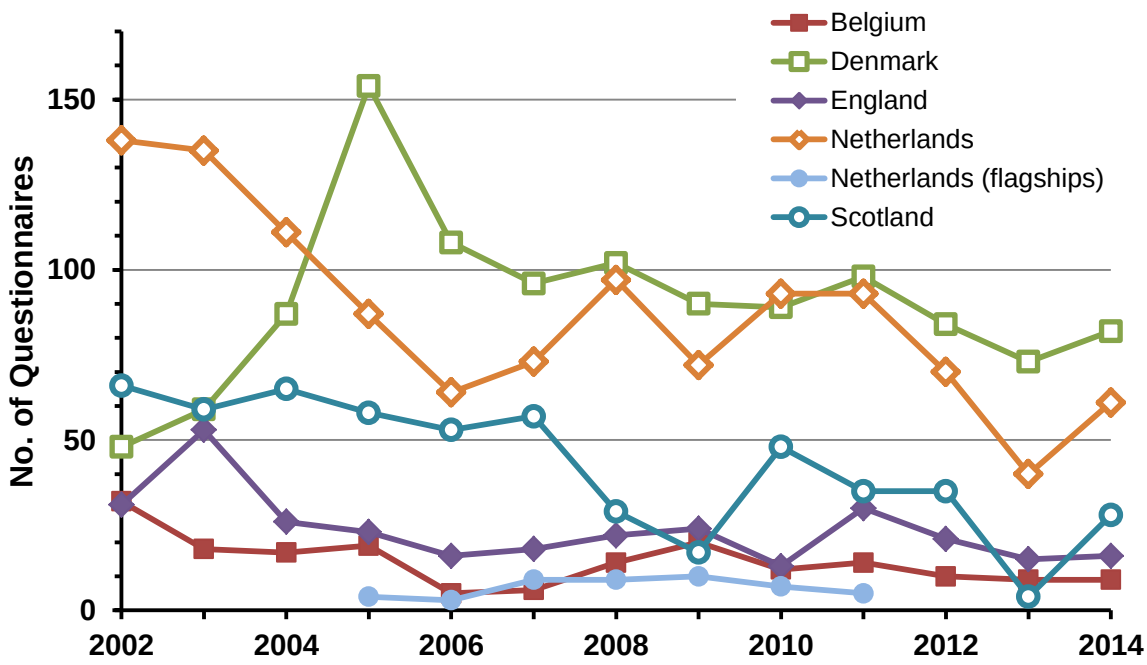

Figure 3 The total number of questionnaires returned each year, by country (all responses).

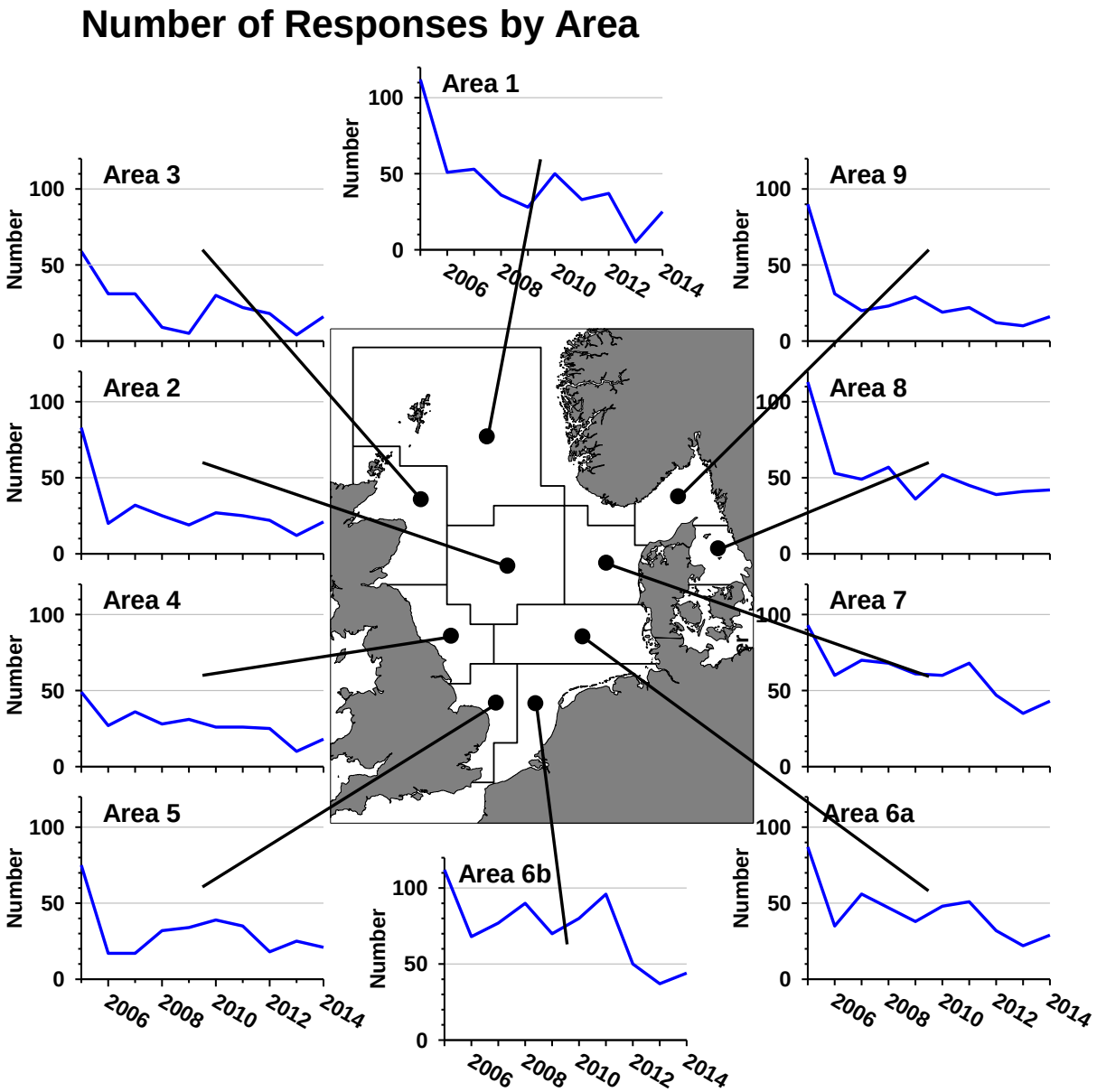

Figure 4 The number of valid questionnaires returned each year, by area. Number of responses providing information on at least one species in each area.

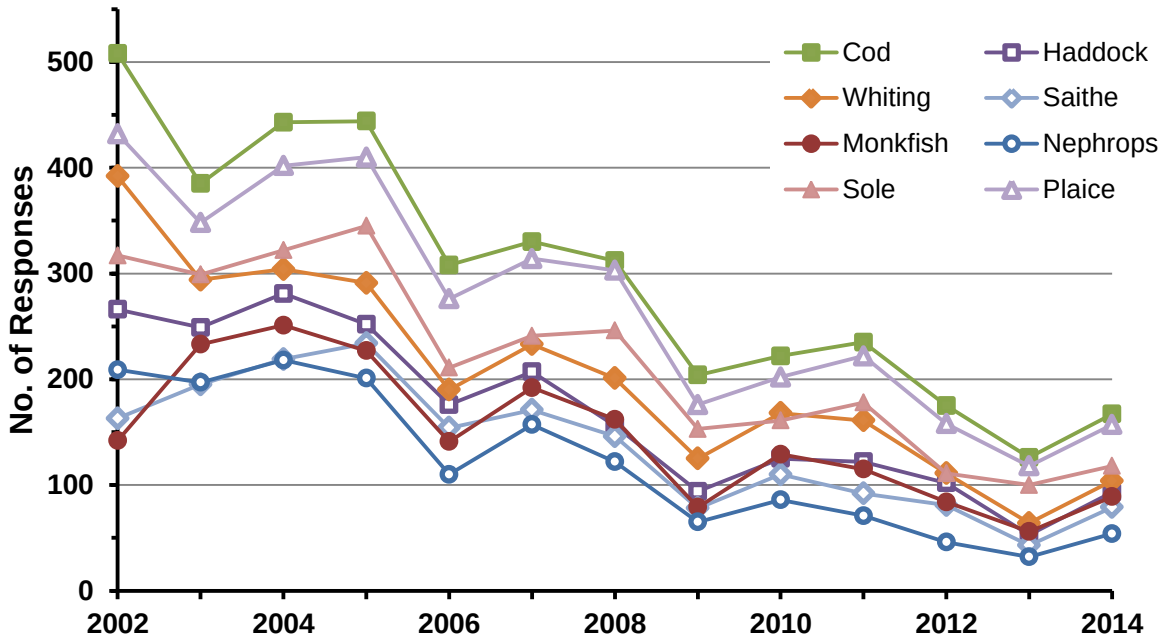

Figure 5 The number of valid questionnaires returned each year giving information for each species (most responses give information for more than one species).

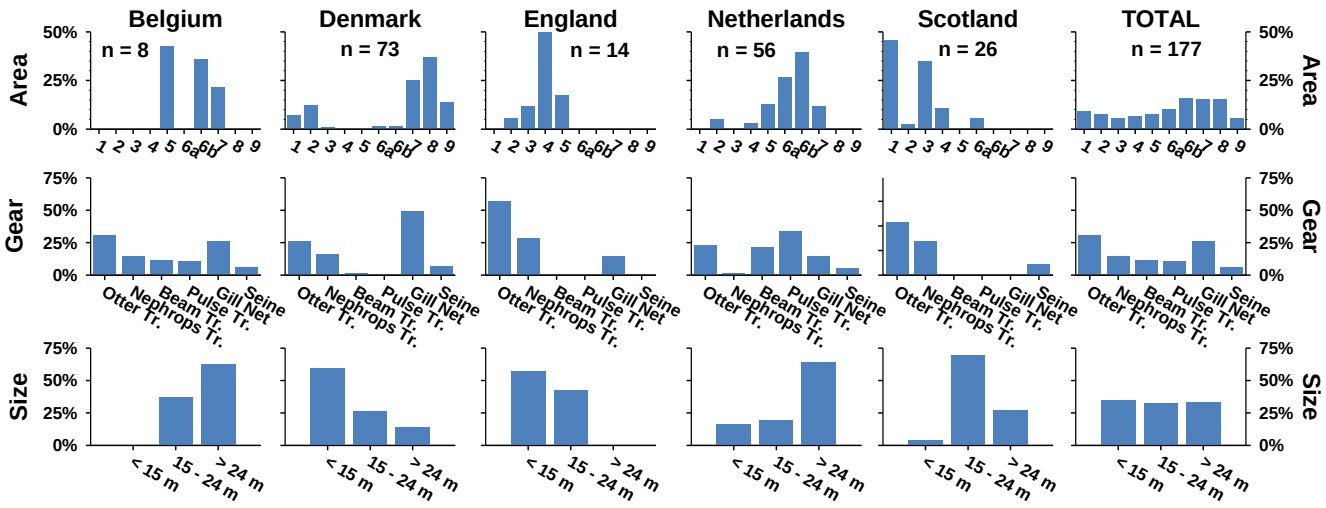

Figure 6 Breakdown of valid questionnaires received in 2014 by country, area fished, fishing gear, and vessel size. Numbers displayed on top row of charts ('n = X') are total numbers of valid questionnaires for that country.

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).

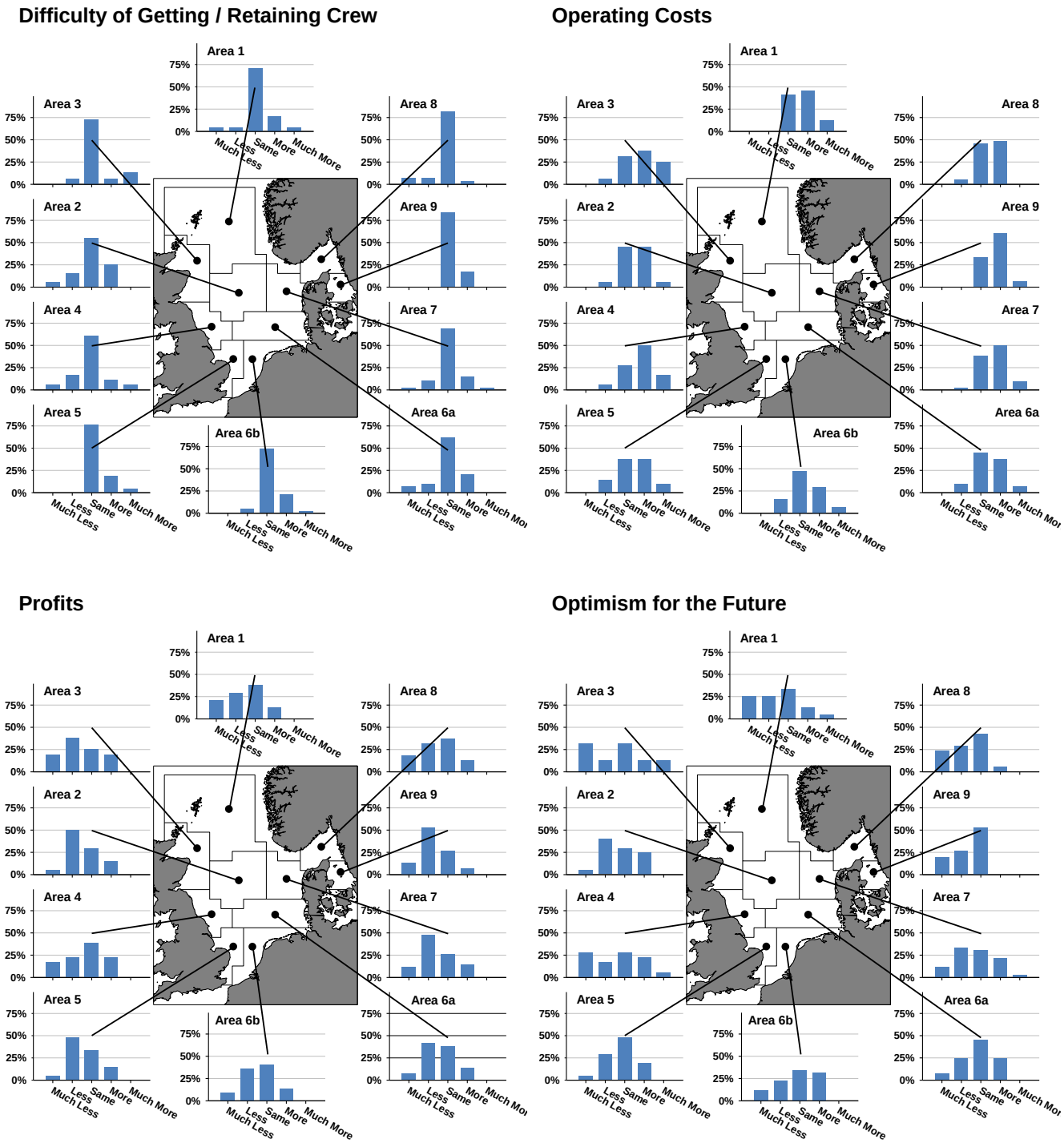

Figure 7 Breakdown by area of perceptions of changes in the difficulty of getting or retaining crew; of operating costs; of profit levels; and of optimism for the future. Percentage of responses from each area in each category.

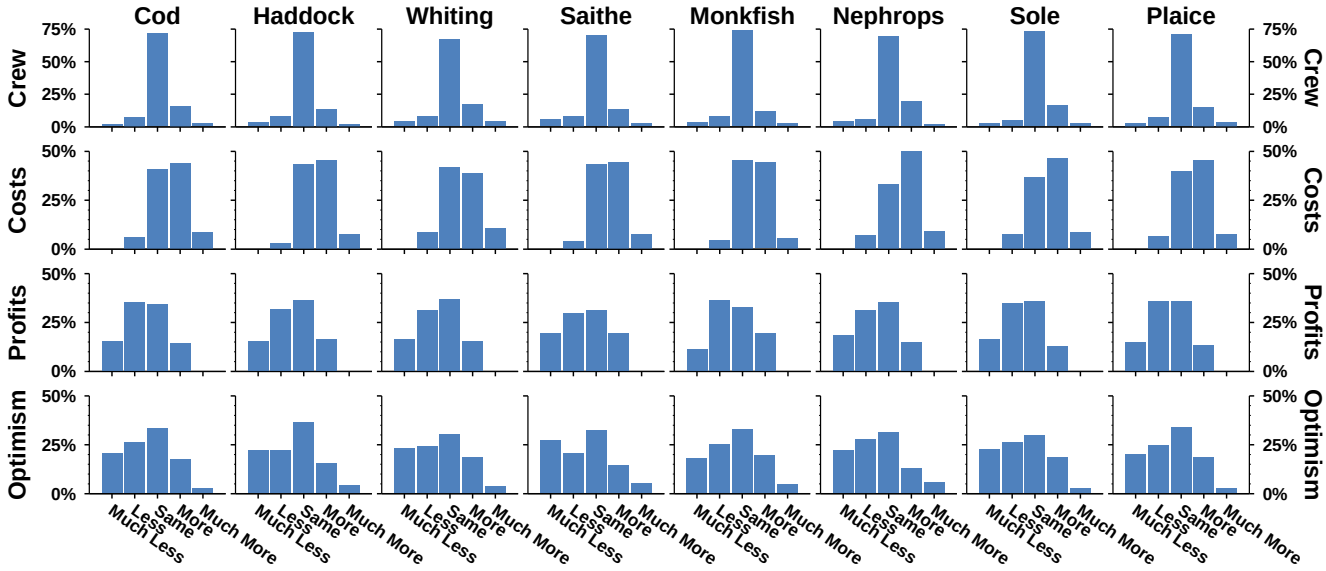

Figure 8 Breakdown of economic perceptions by species: difficulty of obtaining/retaining crew, operating costs, profits, and optimism about the future. Percentage of responses for each species in each category.

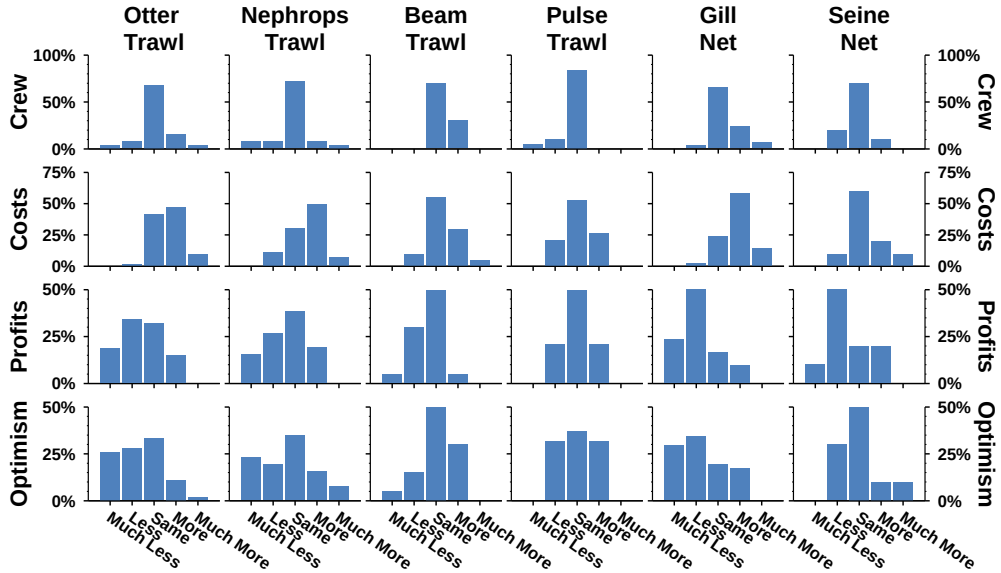

Figure 9 Breakdown of economic perceptions by fishing gear type: difficulty of obtaining/retaining crew, operating costs, profits, and optimism about the future. Percentage of responses in each category for all responses for each gear type.

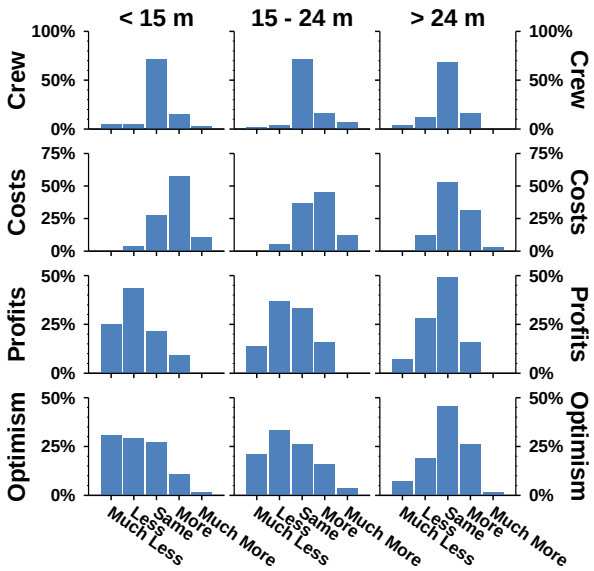

Figure 10 Breakdown of economic perceptions by fishing vessel size: difficulty of obtaining/retaining crew, operating costs, profits, and optimism about the future. Percentage of responses in each category for all responses for each vessel size.

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).

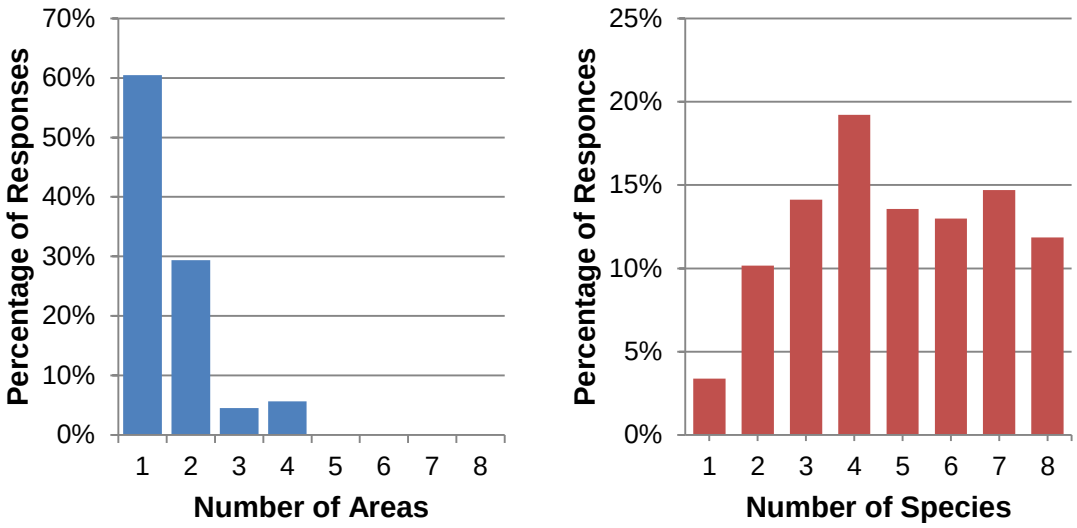

Figure 11 The proportions of responses providing information on different numbers of areas (left) and species (right).

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).

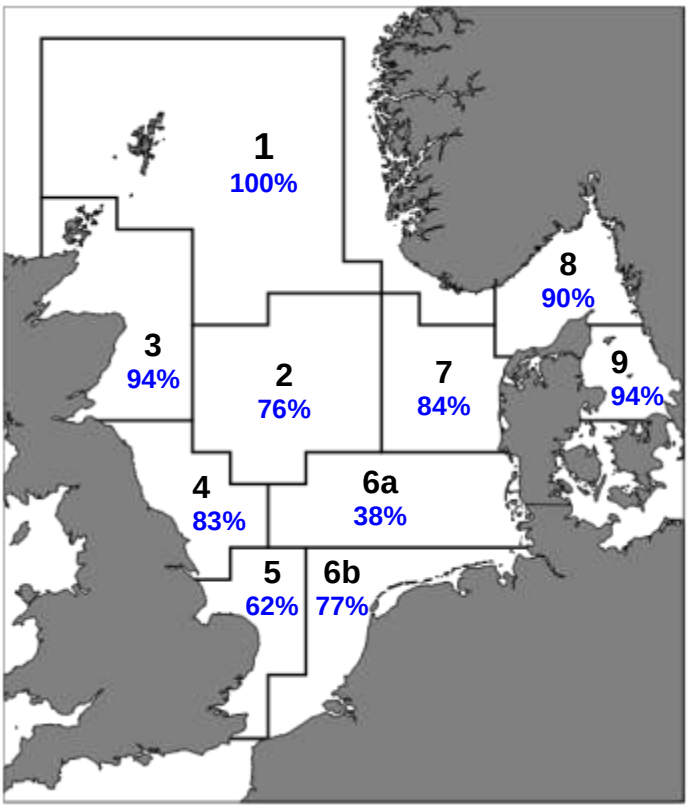

Figure 12 The proportions of responses from each area that provided information on cod.

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.)

		VESSEL SIZE CLASS							
		Numbers				% by Gear Type			
		<15m	15-24m	>24m	ALL	<15m	15-24m	>24m	ALL
FISHING GEAR – 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%
FISHING GEAR – % 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.

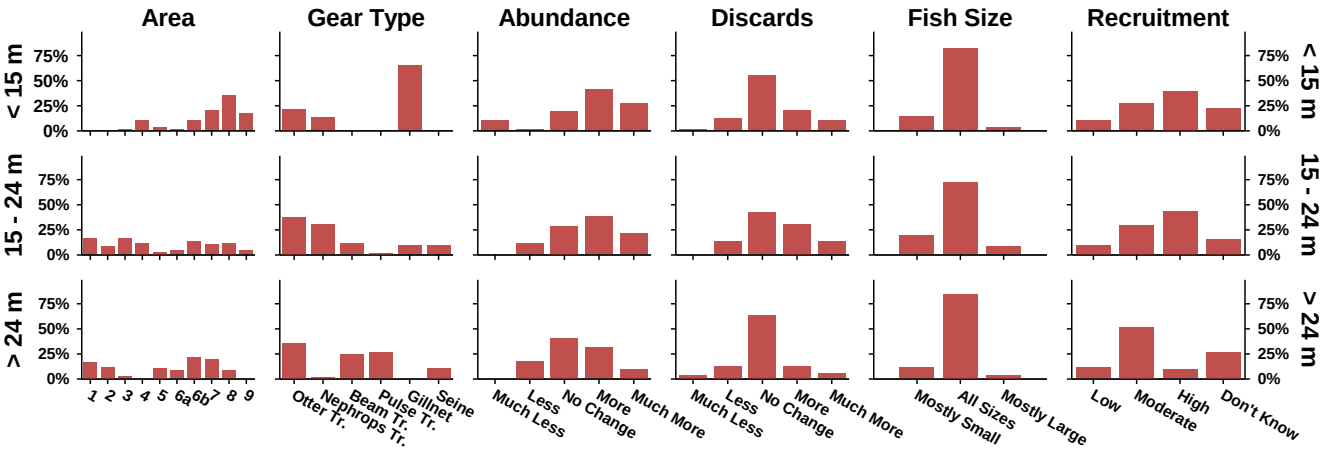

Figure 13 Breakdown of responses for cod by fishing vessel size class. Percentage of responses for each size class in each category.

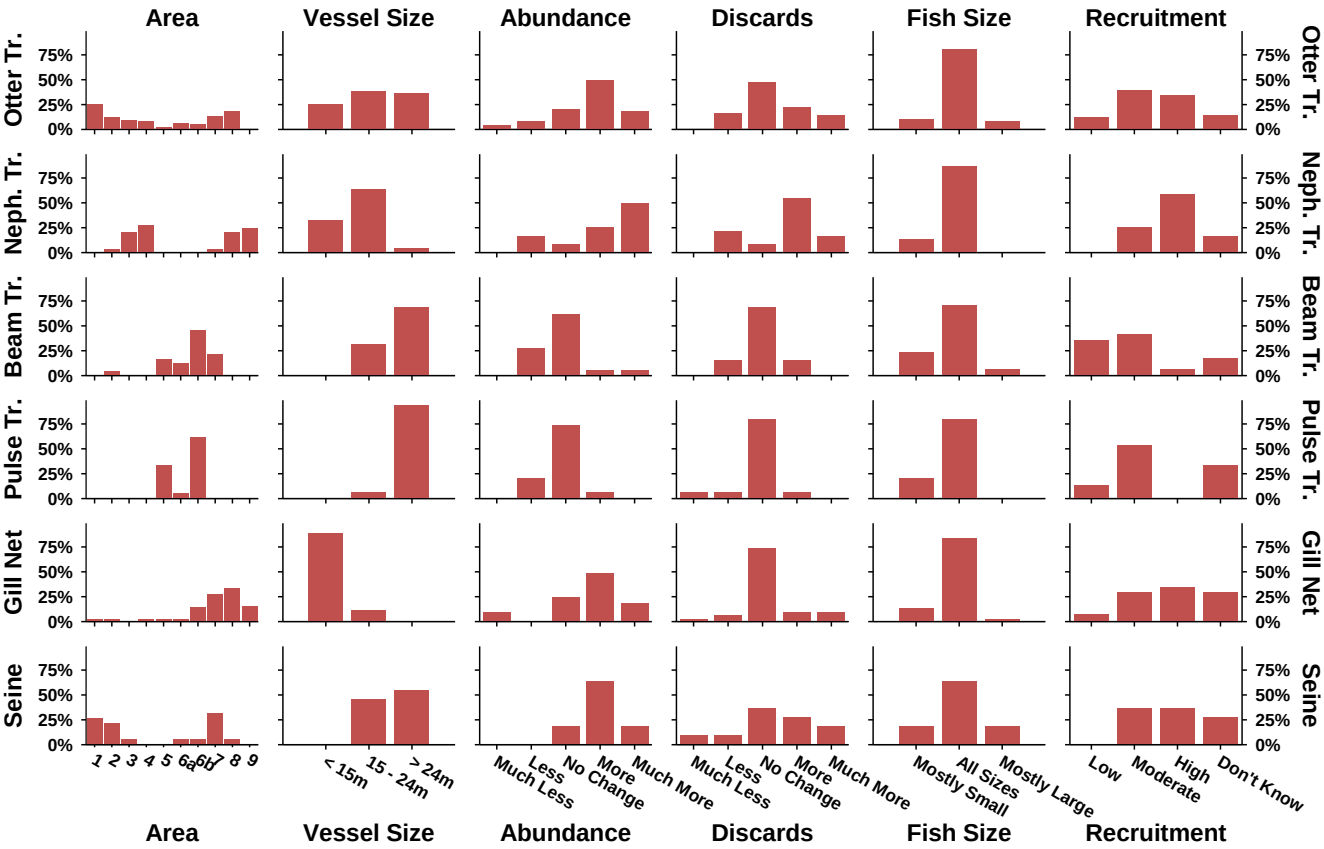

Figure 14 Breakdown of responses for cod by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

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).

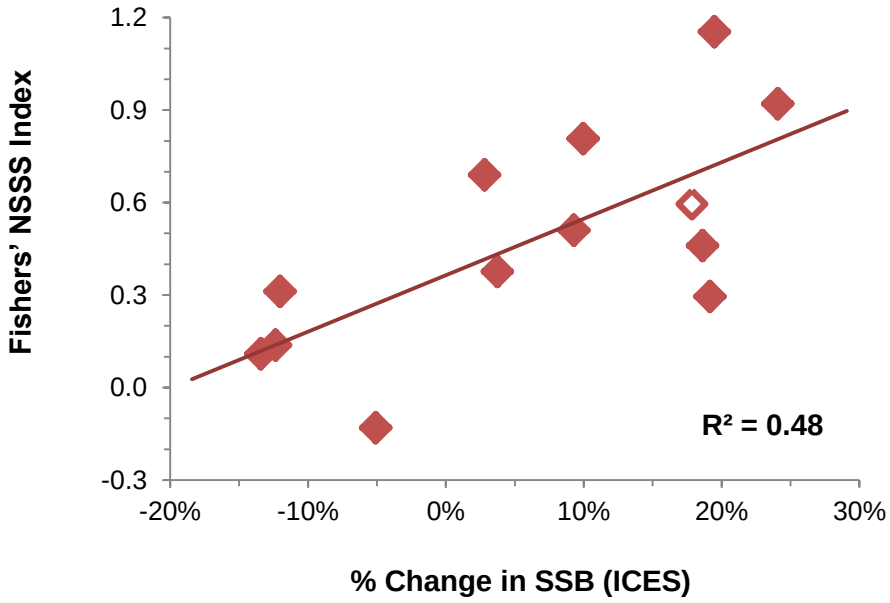

Figure 15 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea cod spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination (R^2; values closer to 1 indicate a better agreement.) The unshaded point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

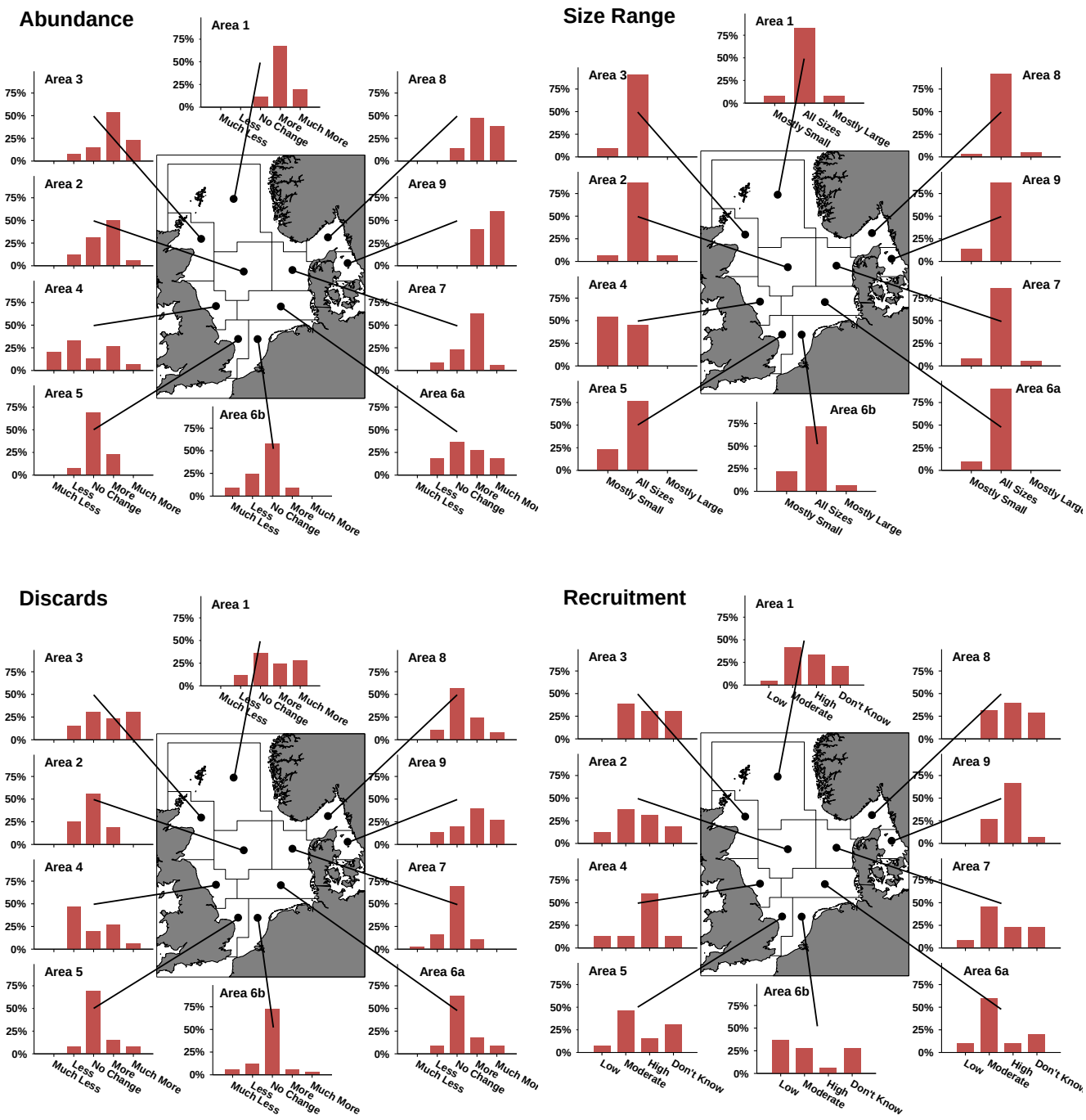

Figure 16 Perceptions of the abundance and size range of cod, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category.

Abundance Index

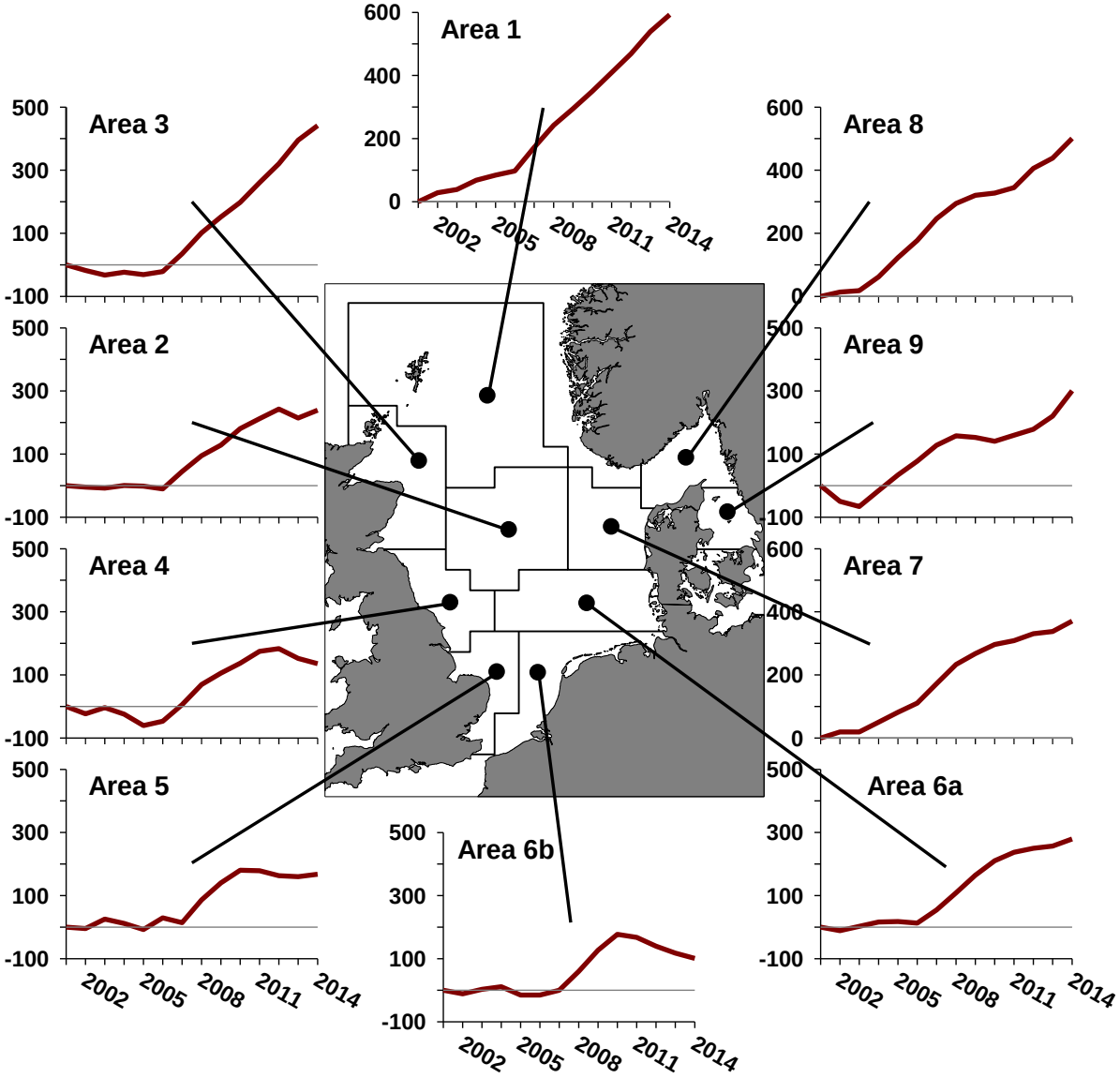

Figure 17 Cumulative time series of index of perceptions of abundance of cod, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

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).

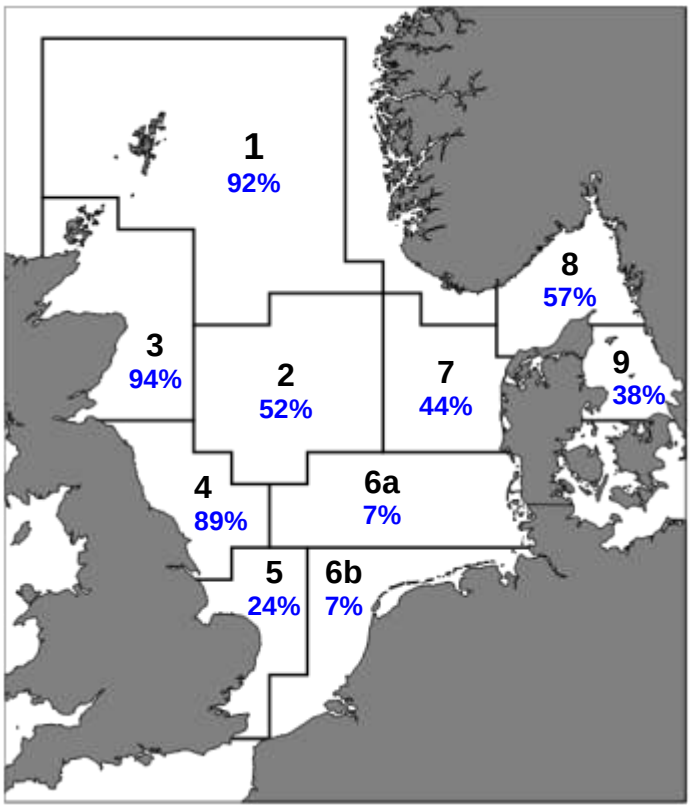

Figure 18 The proportions of responses from each area that provided information on haddock.

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.)

		VESSEL SIZE CLASS							
		Numbers				% by Gear Type			
		<15m	15-24m	>24m	ALL	<15m	15-24m	>24m	ALL
FISHING GEAR – 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%
FISHING GEAR – % 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.

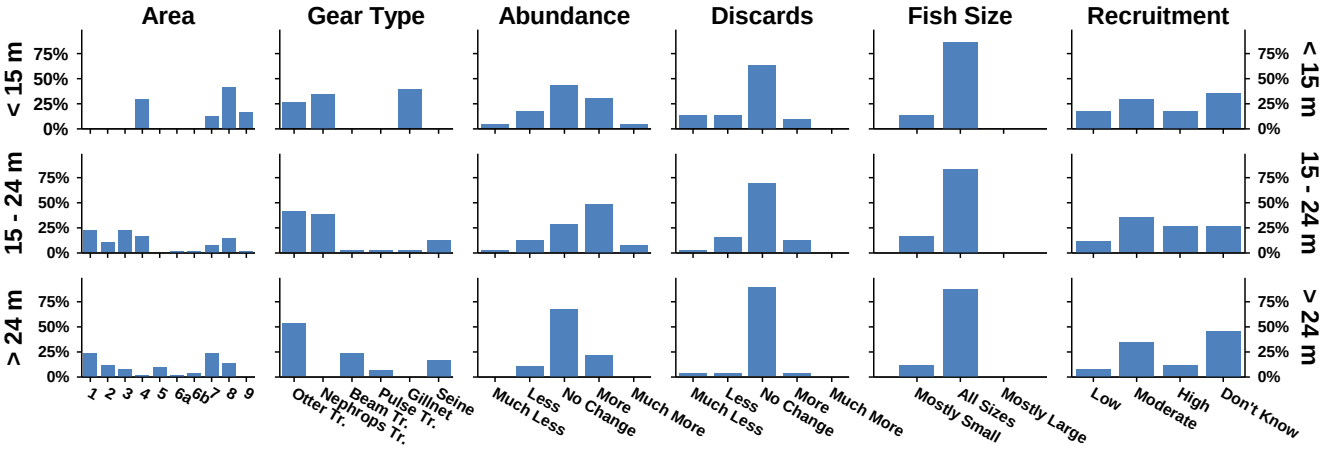

Figure 19 Breakdown of responses for haddock by fishing vessel size class. Percentage of responses for each size class in each category.

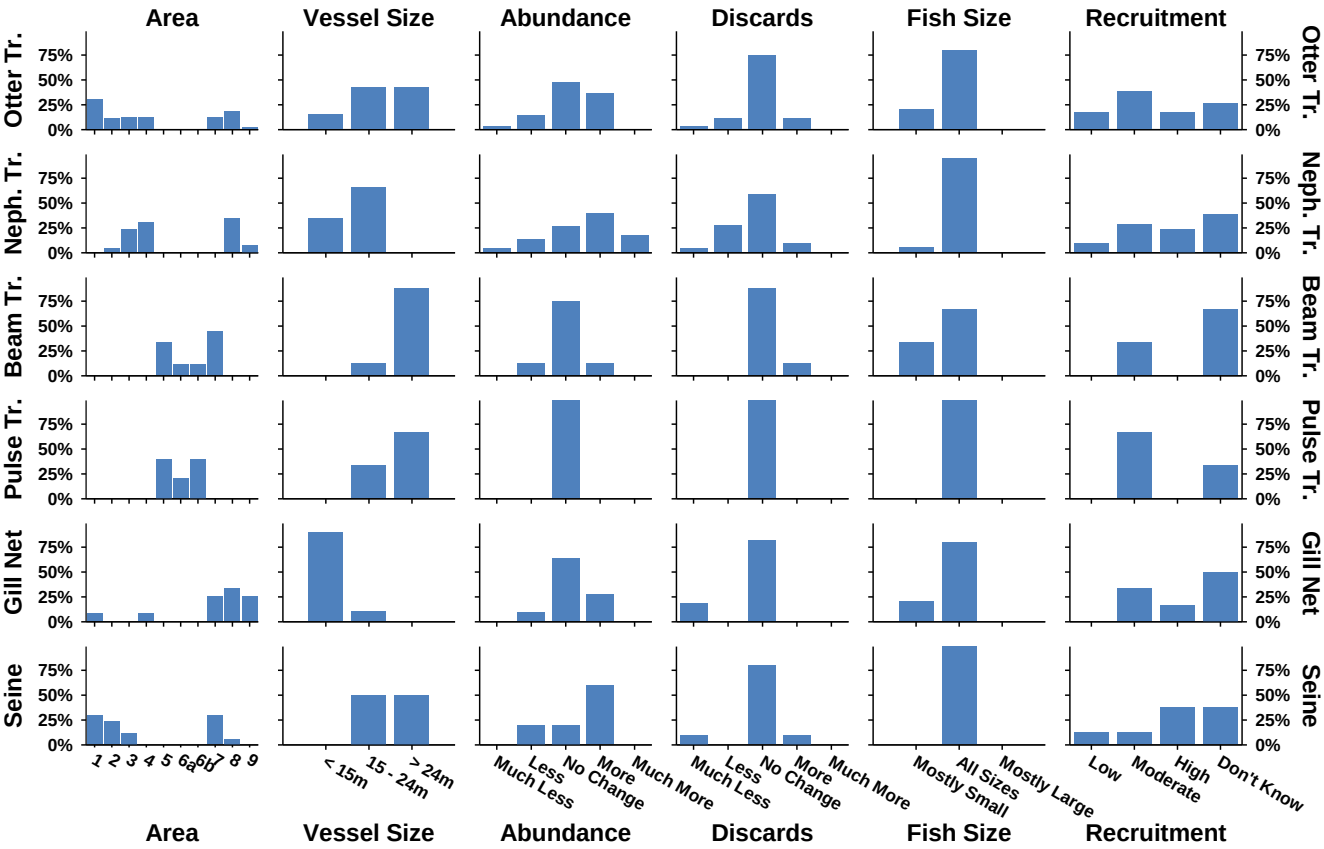

Figure 20 Breakdown of responses for haddock by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

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).

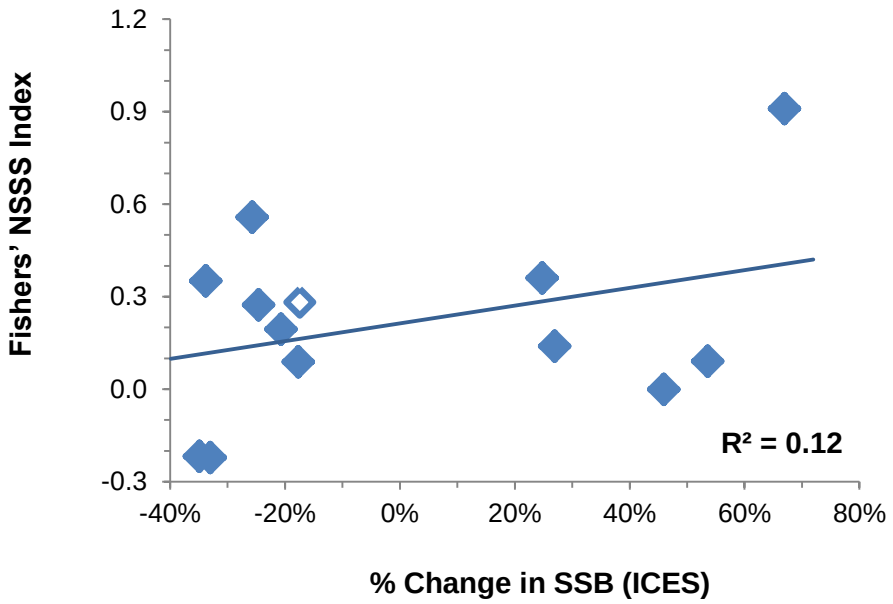

Figure 21 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea haddock spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination (R^2; values closer to 1 indicate a better agreement). The unshaded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

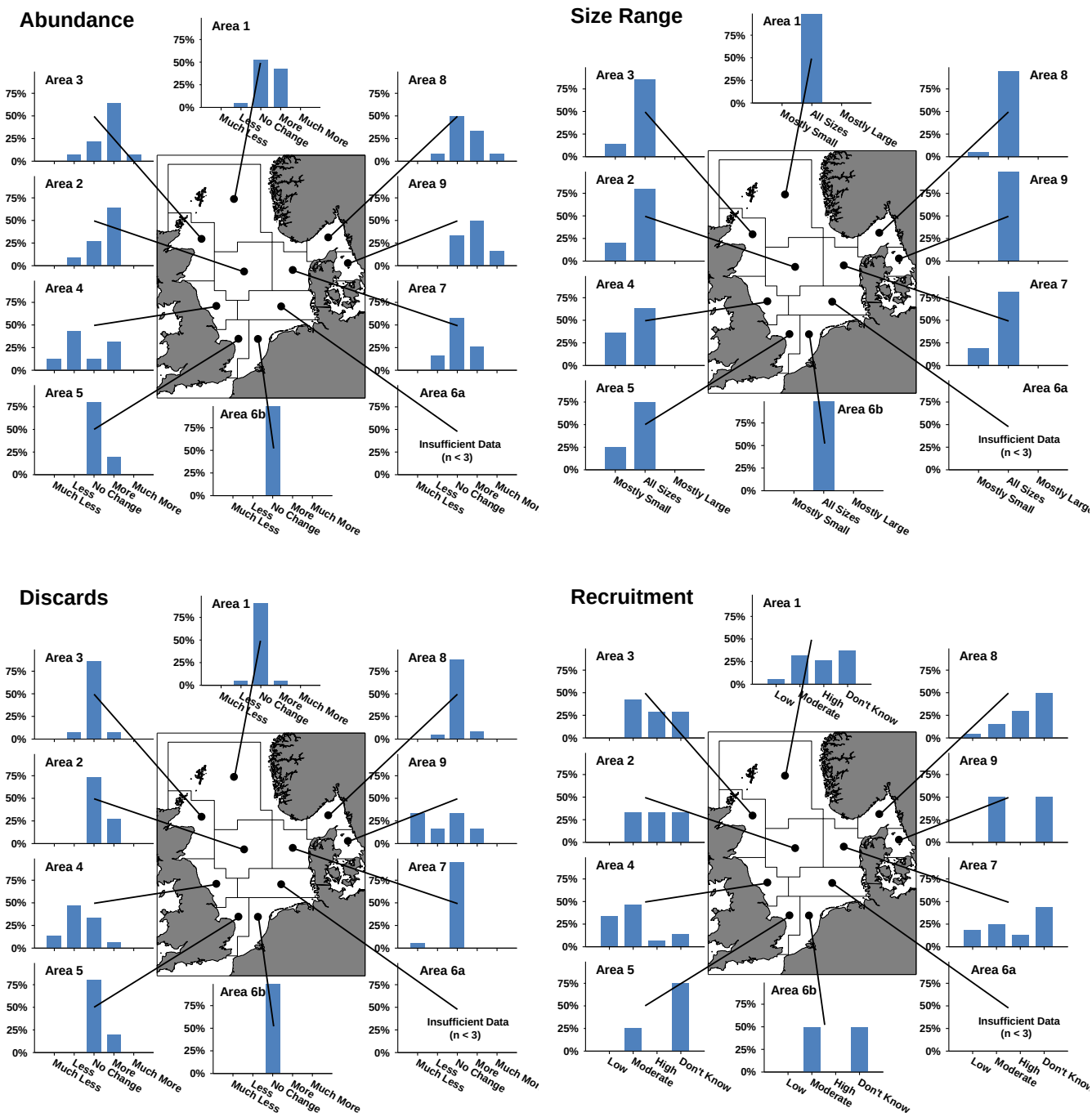

Figure 22 Perceptions of the abundance and size range of haddock, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category. No results are shown for Area 6a due to the small number of responses from that area (see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

Abundance Index

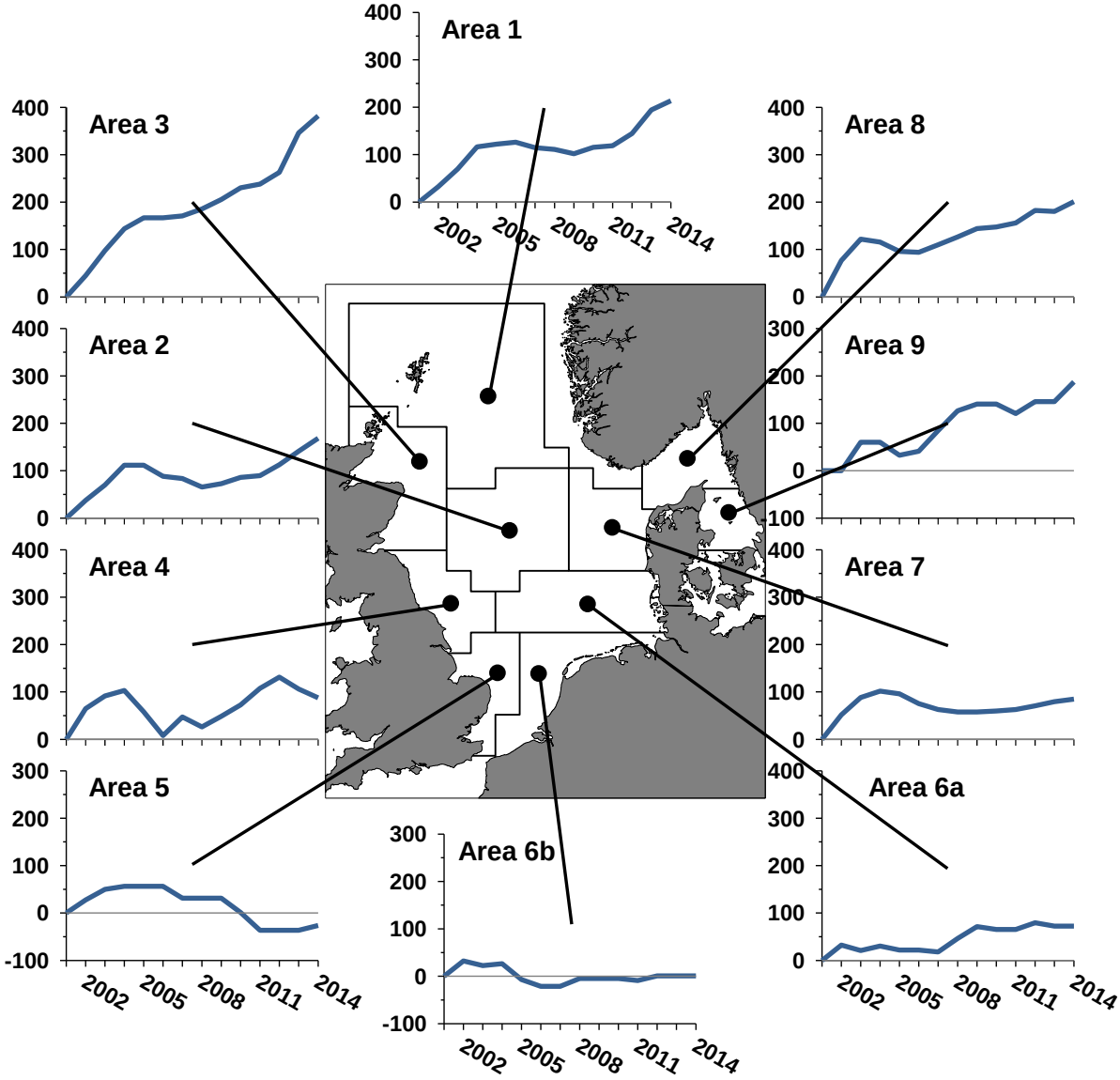

Figure 23 Cumulative time series of index of perceptions of abundance of haddock, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

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).

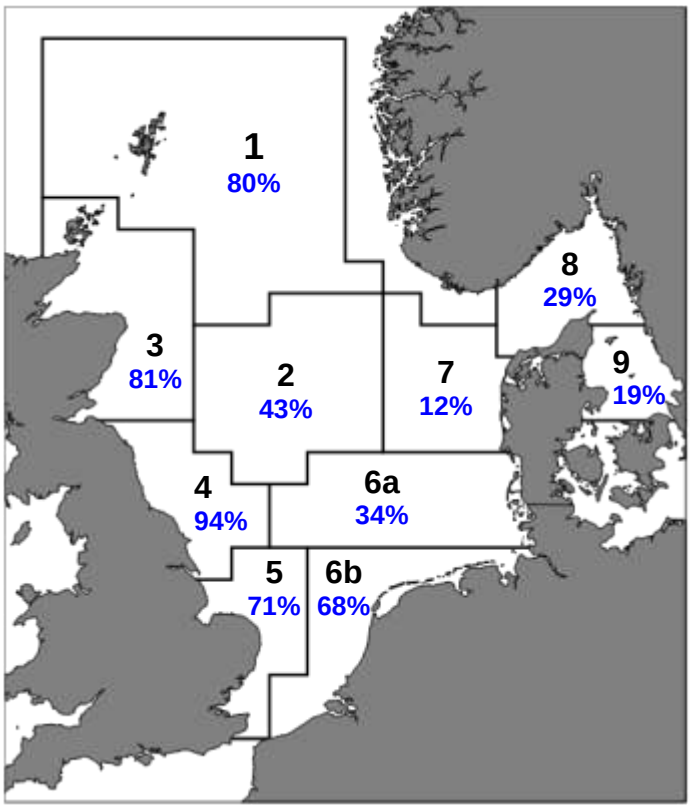

Figure 24 The proportions of responses from each area that provided information on whiting.

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.)

		VESSEL SIZE CLASS							
		Numbers				% by Gear Type			
		<15m	15-24m	>24m	ALL	<15m	15-24m	>24m	ALL
FISHING GEAR – 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%
FISHING GEAR – % 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.

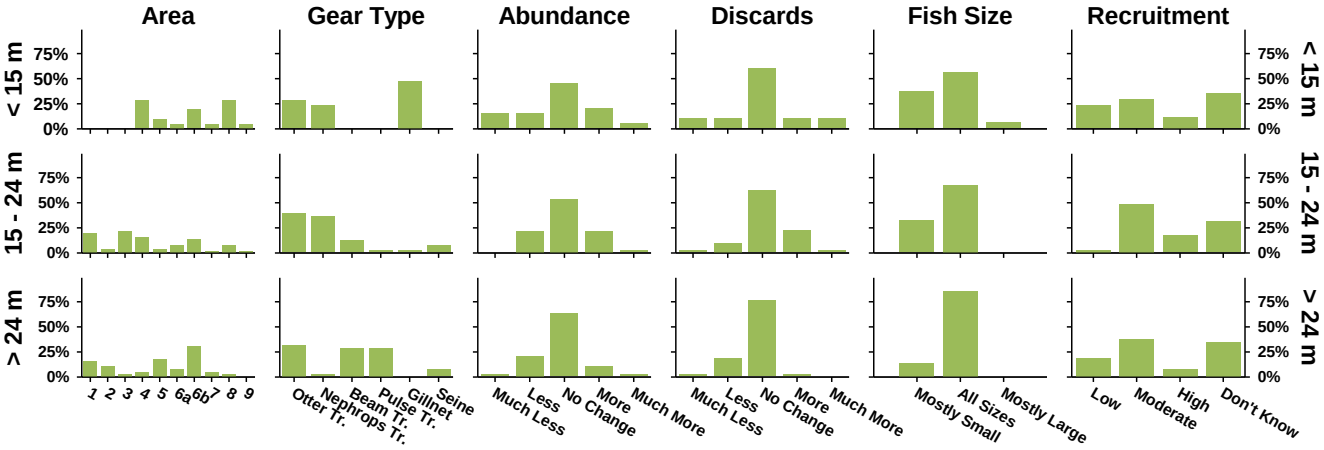

Figure 25 Breakdown of responses for whiting by fishing vessel size class. Percentage of responses for each size class in each category.

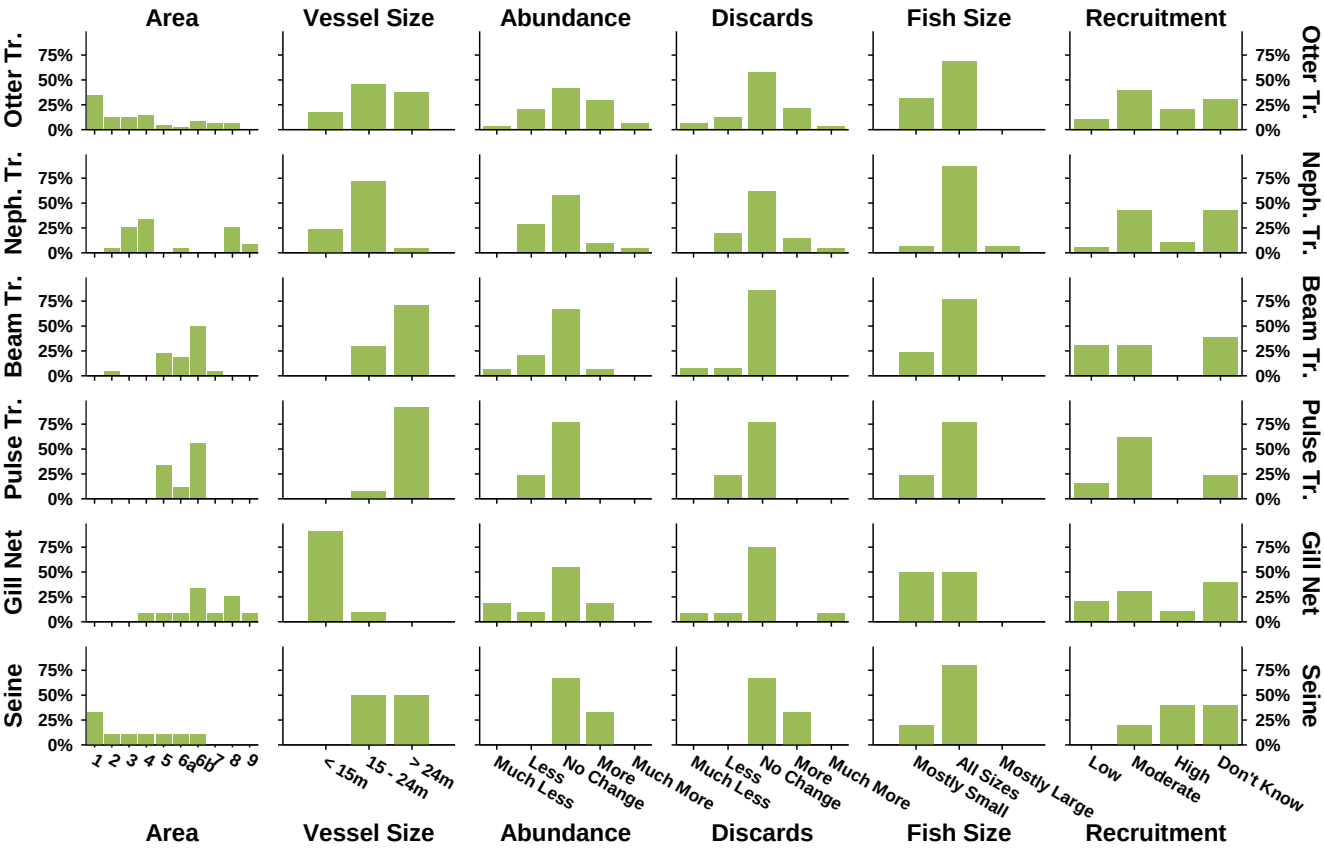

Figure 26 Breakdown of responses for whiting by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

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.

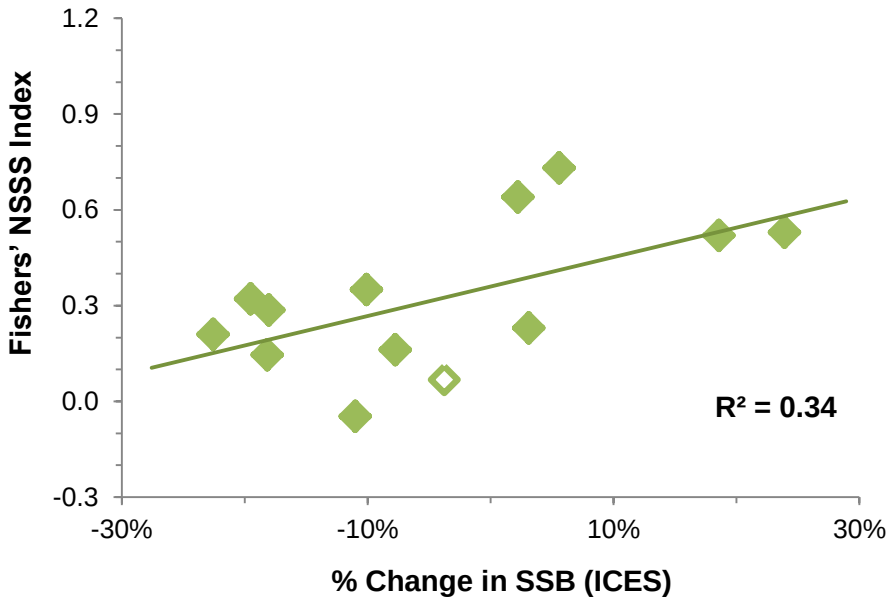

Figure 27 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea whiting spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination (R^2 values closer to 1 indicate a better agreement). The unshaded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

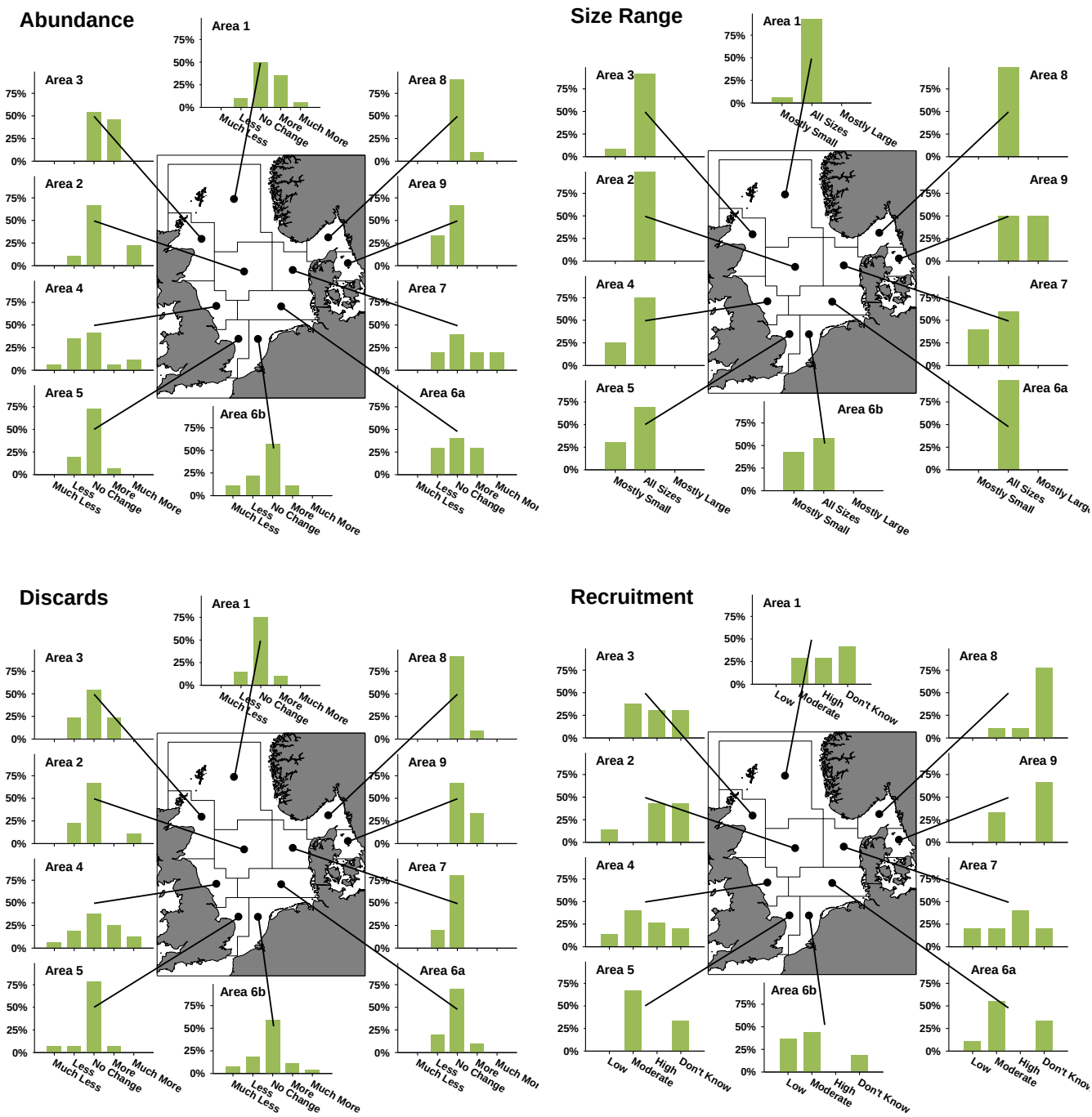

Figure 28 Perceptions of the abundance and size range of whiting, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category.

Abundance Index

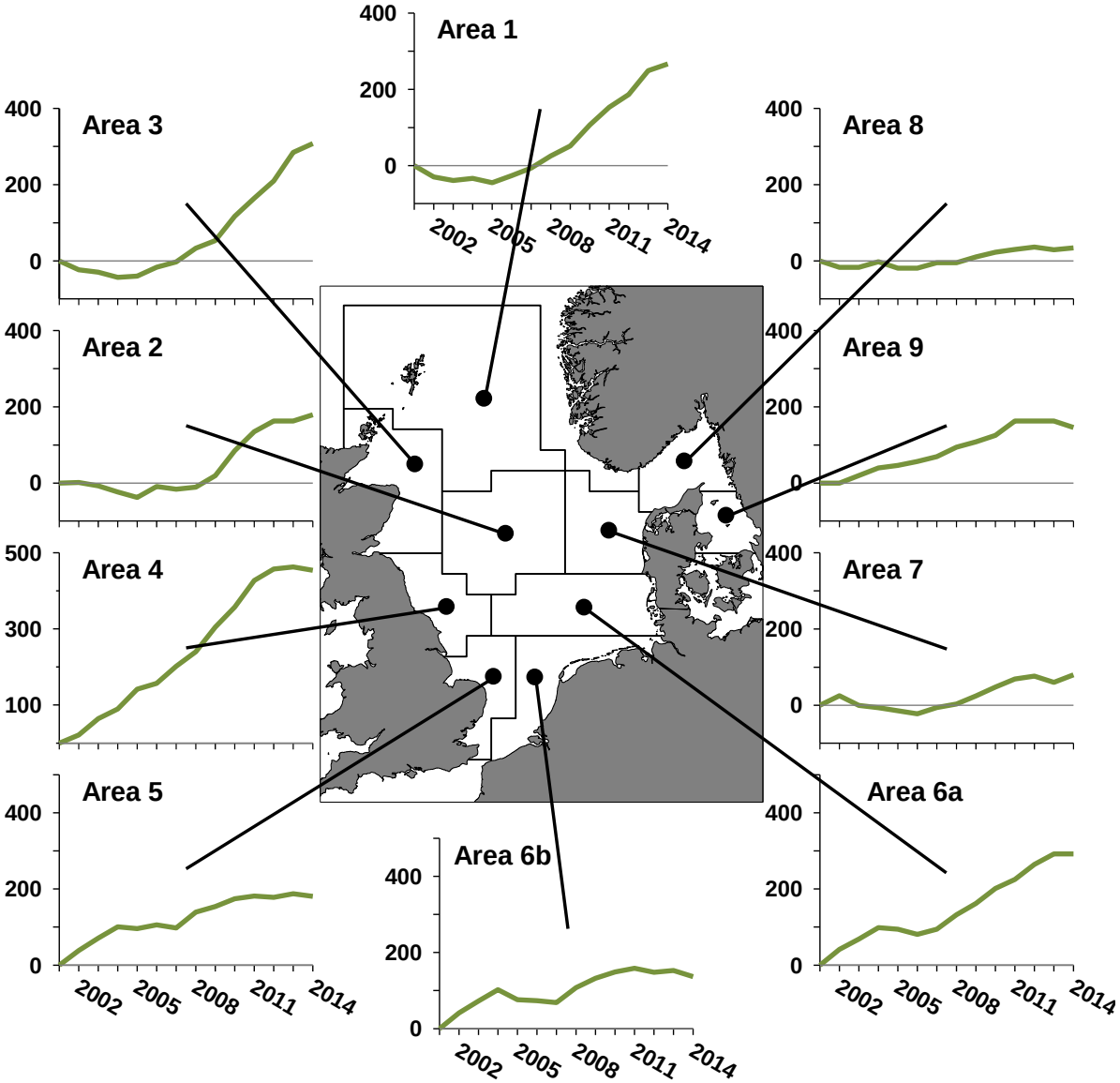

Figure 29 Cumulative time series of index of perceptions of abundance of whiting, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

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).

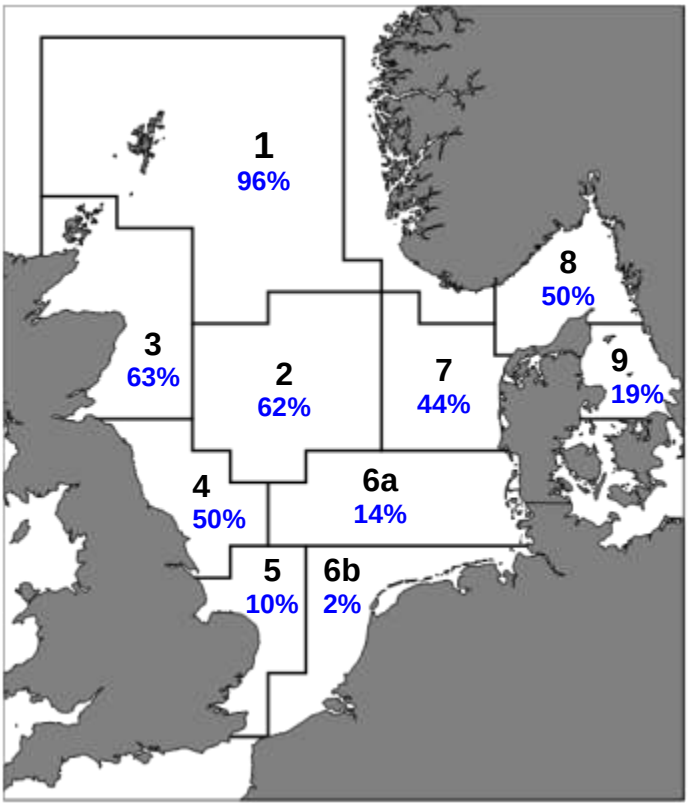

Figure 30 The proportions of responses from each area that provided information on saithe.

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.)

		VESSEL SIZE CLASS							
		Numbers				% by Gear Type			
		<15m	15-24m	>24m	ALL	<15m	15-24m	>24m	ALL
FISHING GEAR – 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%
FISHING GEAR – % 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.

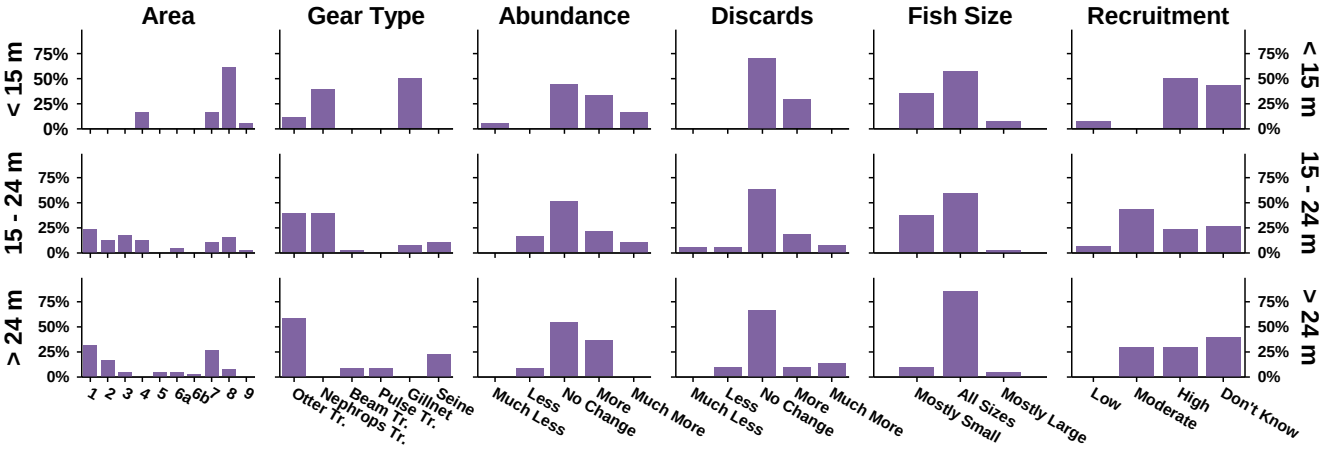

Figure 31 Breakdown of responses for saithe by fishing vessel size class. Percentage of responses for each size class in each category.

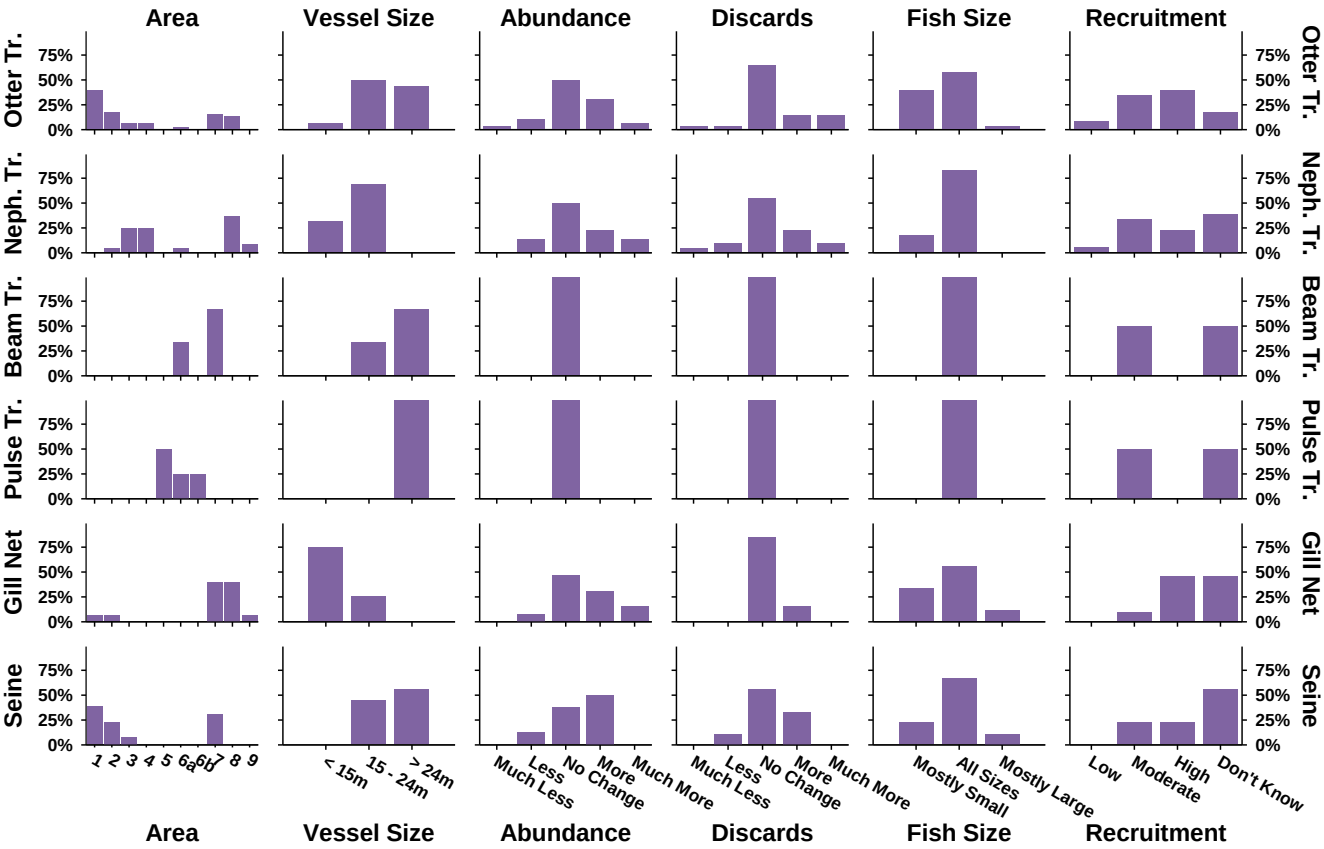

Figure 32 Breakdown of responses for saithe by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

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).

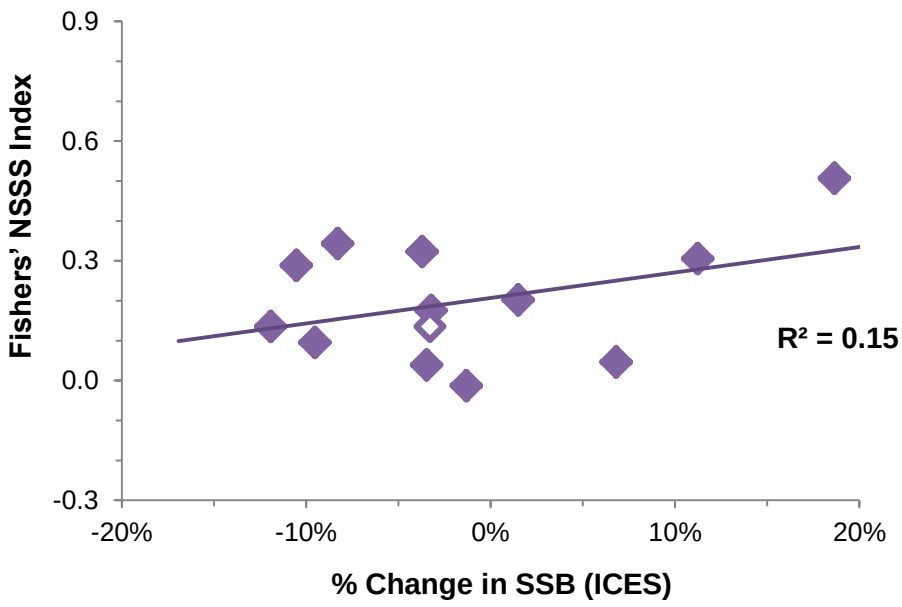

Figure 33 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea and West of Scotland saithe spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination (R^2; values closer to 1 indicate a better agreement).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

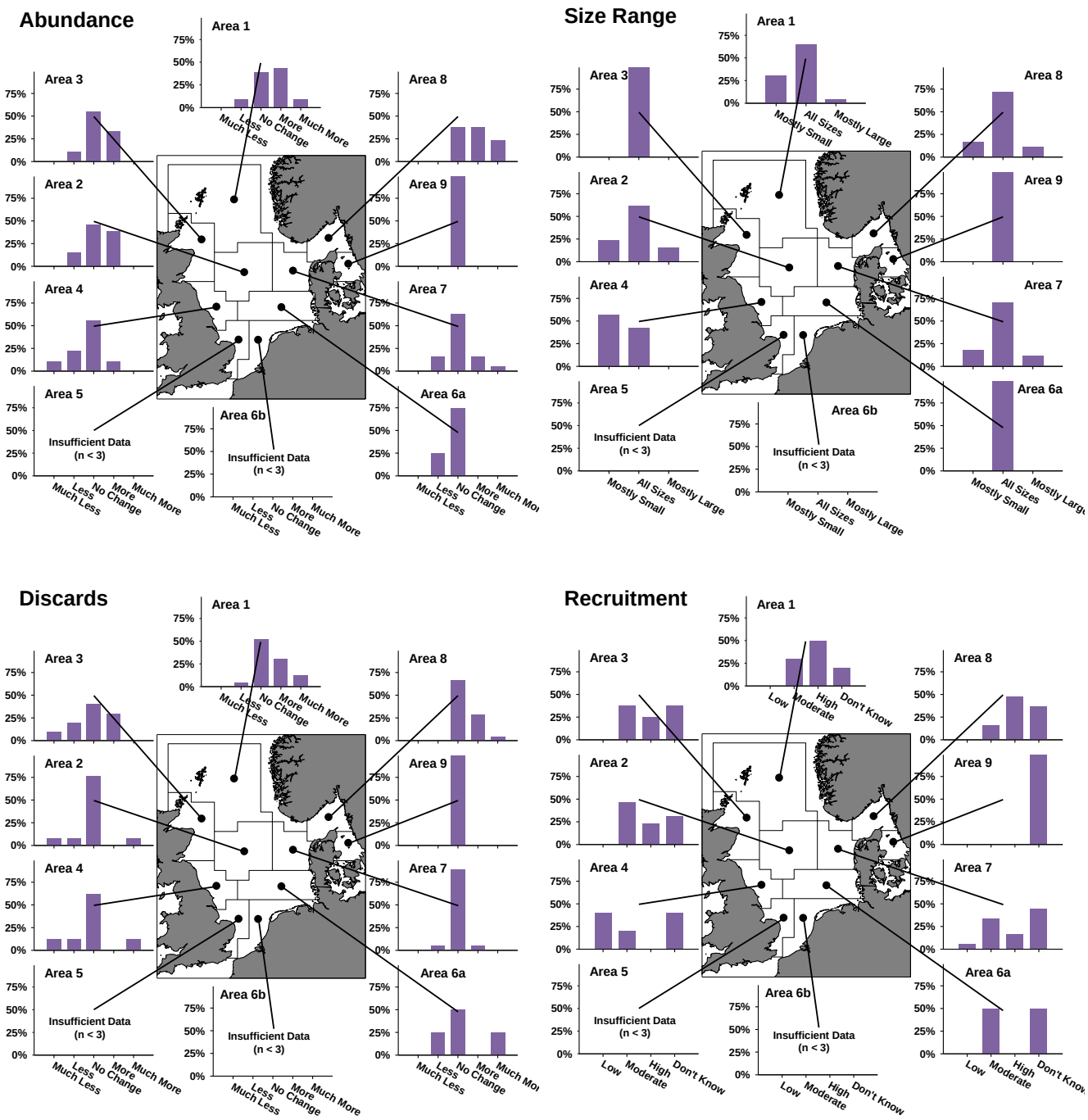

Figure 34 Perceptions of the abundance and size range of saithe, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category. No results are shown for Areas 5 and 6b due to the small number of responses from those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

Abundance Index

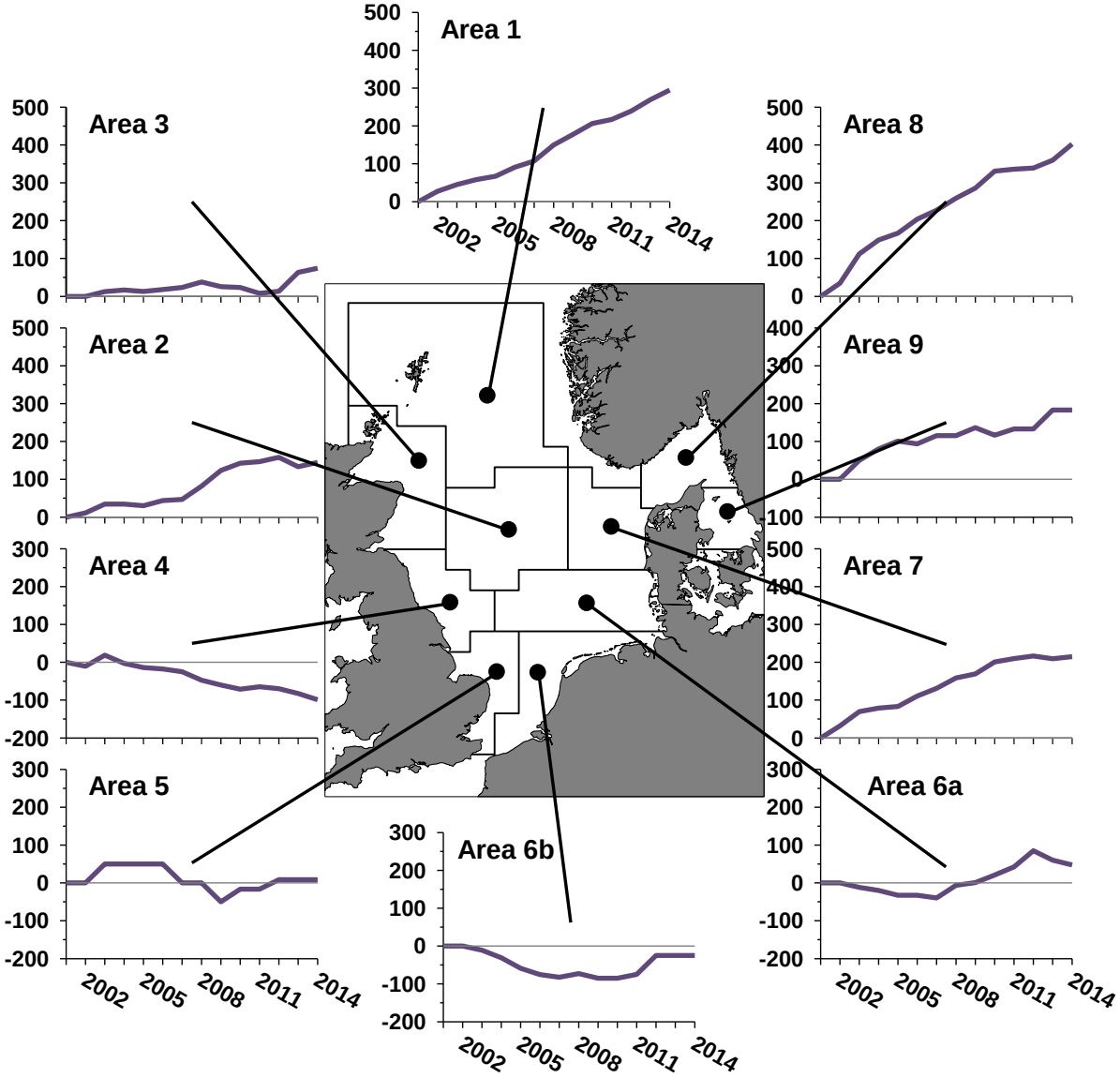

Figure 35 Cumulative time series of index of perceptions of abundance of saithe, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

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).

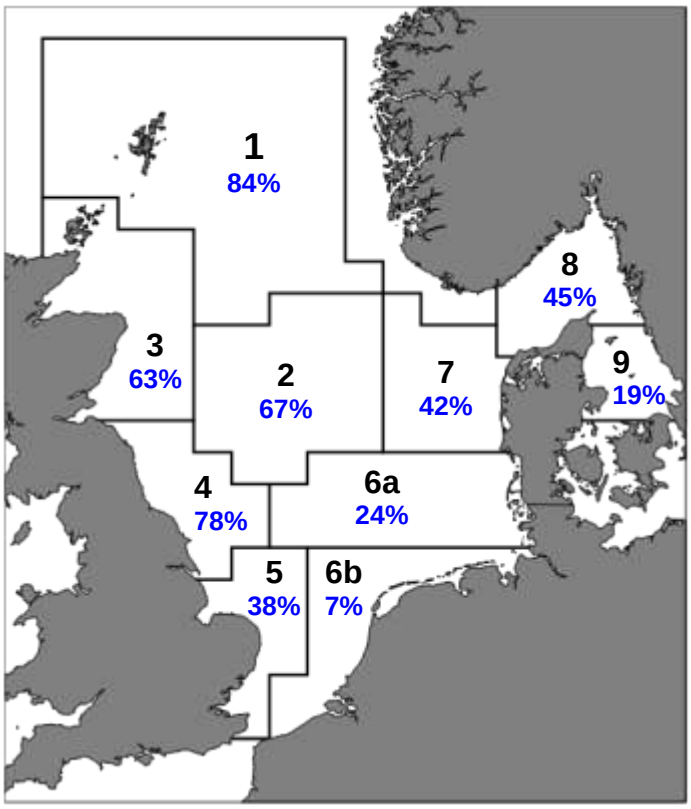

Figure 36 The proportions of responses from each area that provided information on monkfish.

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.)

		VESSEL SIZE CLASS							
		Numbers				% by Gear Type			
		<15m	15-24m	>24m	ALL	<15m	15-24m	>24m	ALL
FISHING GEAR – 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%
FISHING GEAR – % 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.

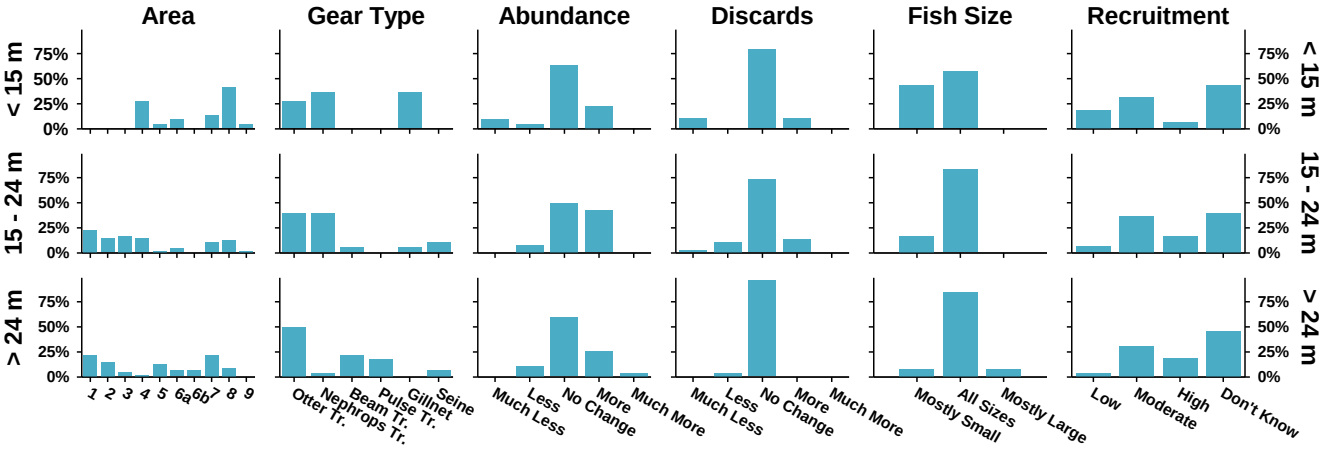

Figure 37 Breakdown of responses for monkfish by fishing vessel size class. Percentage of responses for each size class in each category.

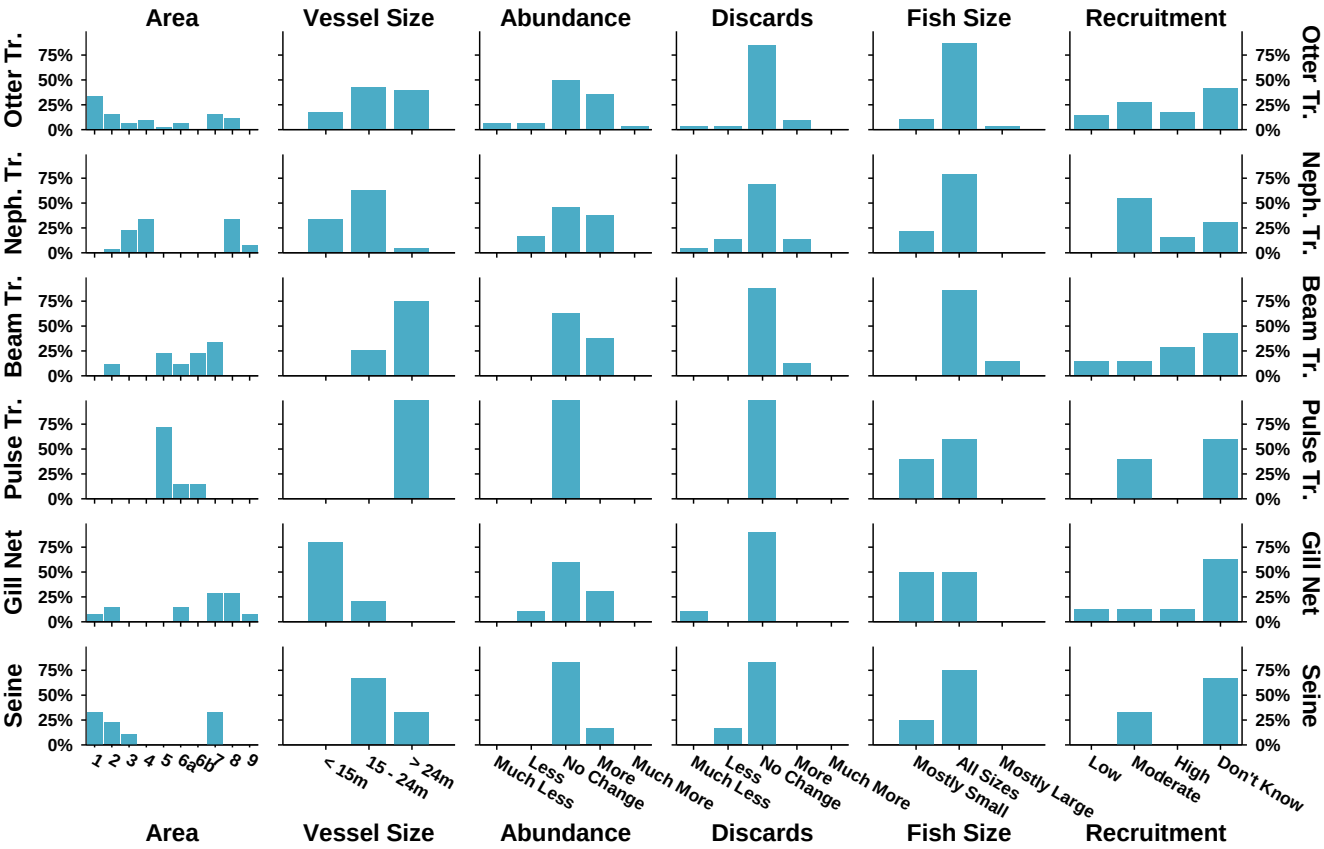

Figure 38 Breakdown of responses for monkfish by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

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).

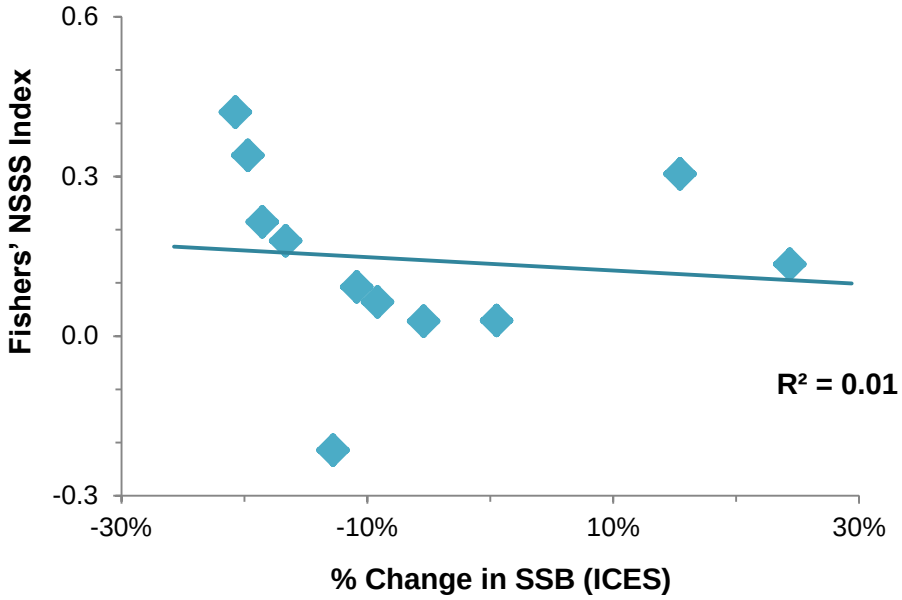

Figure 39 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea monkfish biomass (B), with fitted linear trend line and coefficient of determination. (R^2; values closer to 1 indicate a better agreement.)

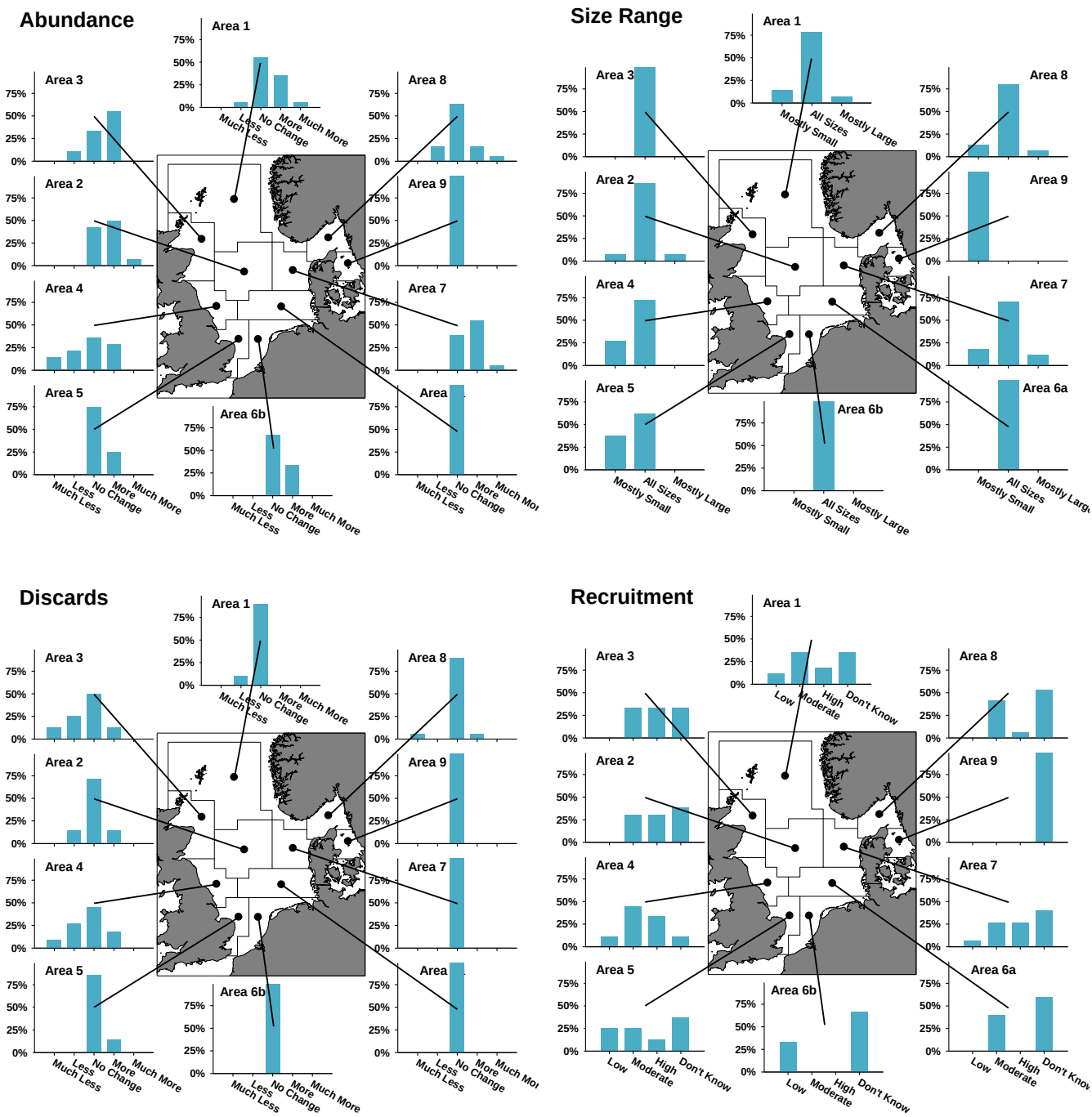

Figure 40 Perceptions of the abundance and size range of monkfish, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category.

Abundance Index

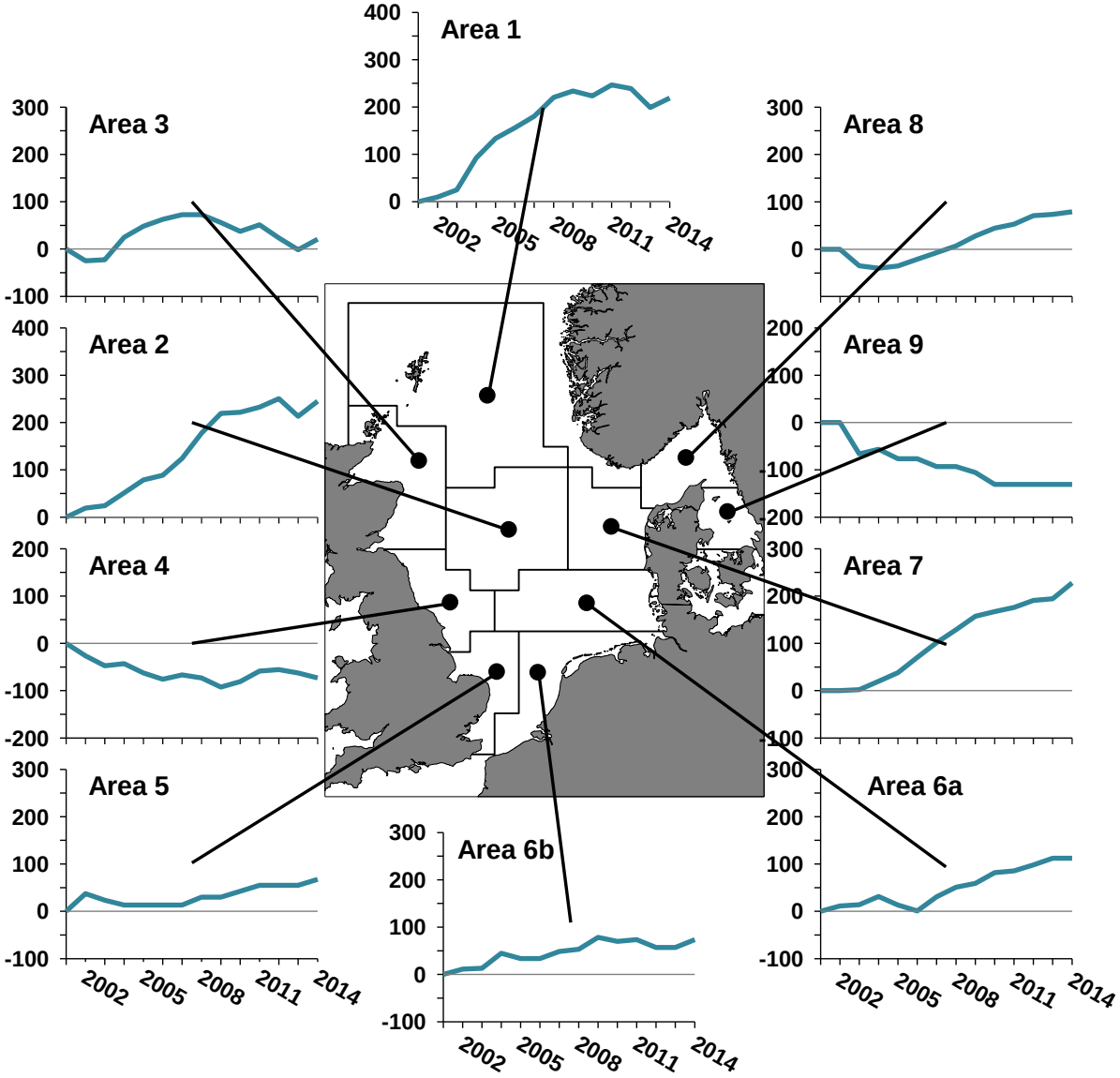

Figure 41 Cumulative time series of index of perceptions of abundance of monkfish, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

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).

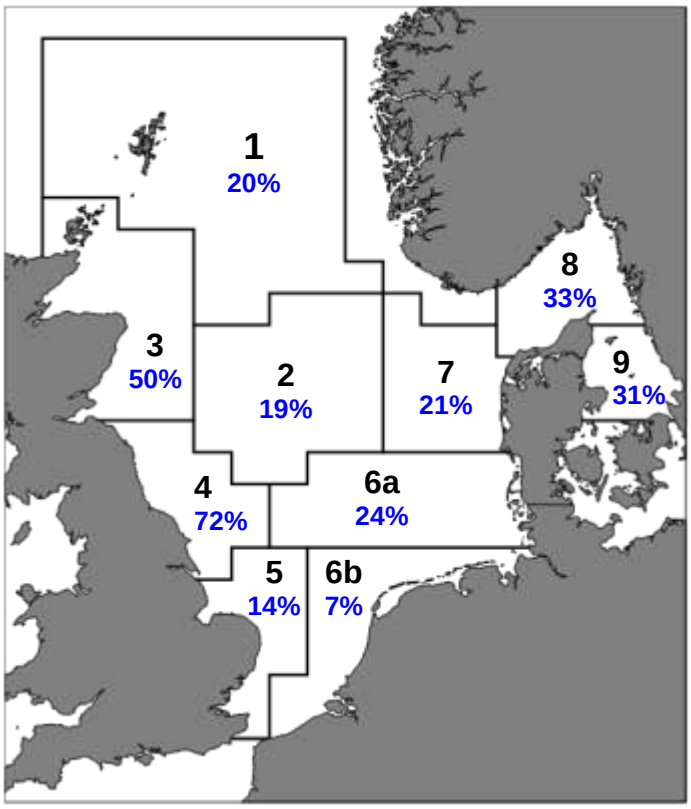

Figure 42 The proportions of responses from each area that provided information on *Nephrops*.

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.)

		VESSEL SIZE CLASS							
		Numbers				% by Gear Type			
		<15m	15-24m	>24m	ALL	<15m	15-24m	>24m	ALL
FISHING GEAR – 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%
FISHING GEAR – % 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.

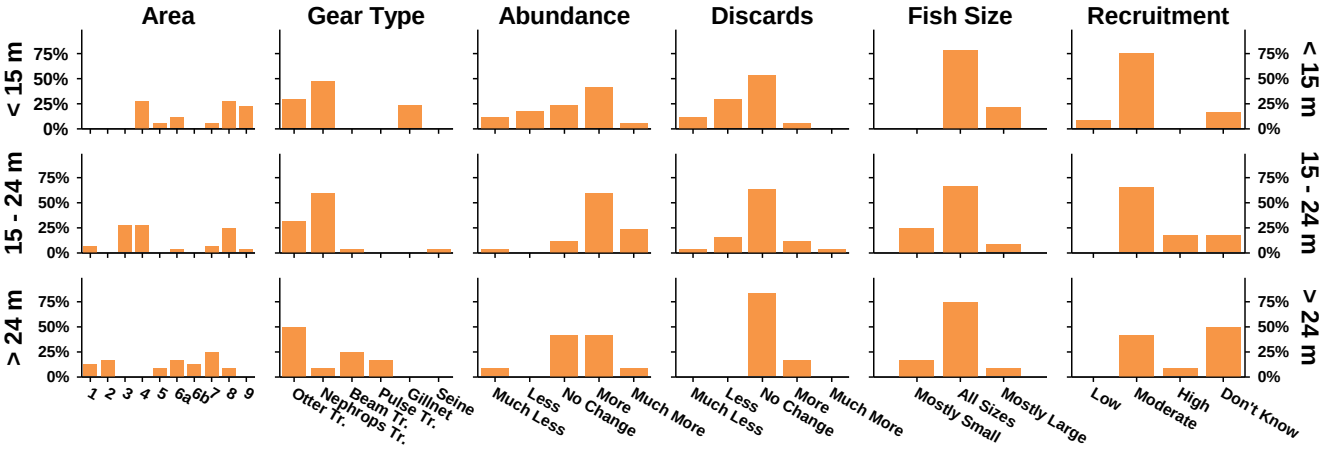

Figure 43 Breakdown of responses for *Nephrops* by fishing vessel size class. Percentage of responses for each size class in each category.

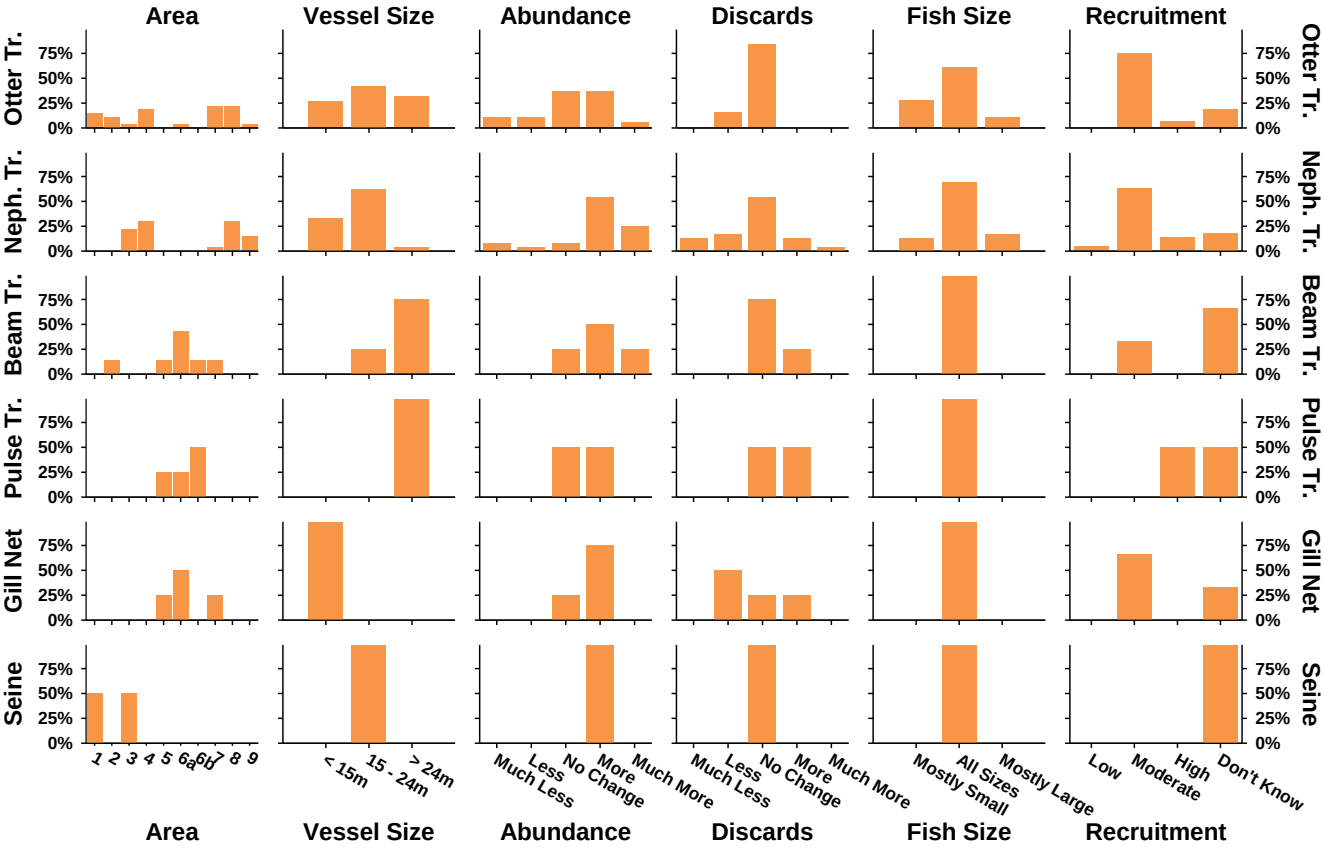

Figure 44 Breakdown of responses for *Nephrops* by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

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.

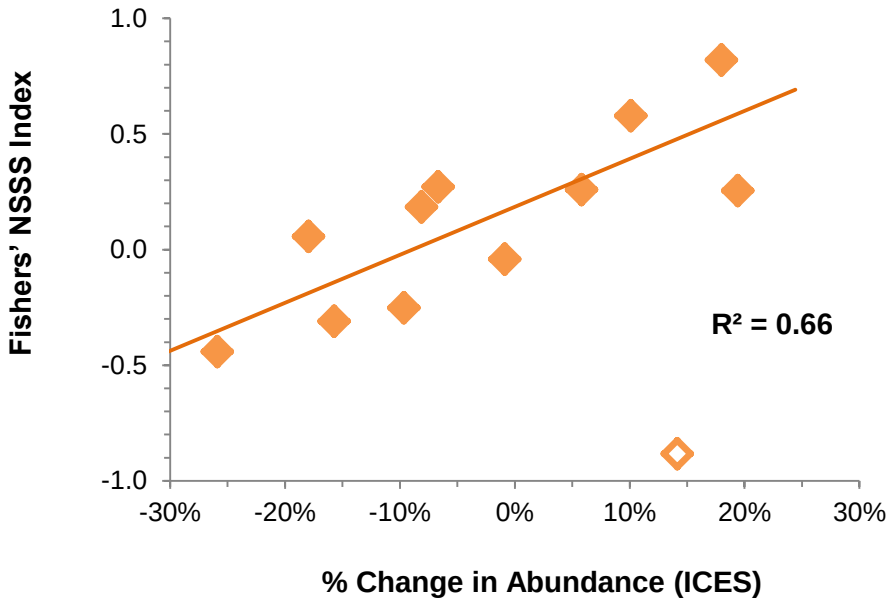

Figure 45 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the total estimated mid-year *Nephrops* abundance for the Farn Deeps (Functional Unit 6), Fladen Ground (FU 7), Firth of Forth (FU8) and Moray Firth (FU9) with fitted linear trend line and coefficient of determination for the years to 2012 (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.

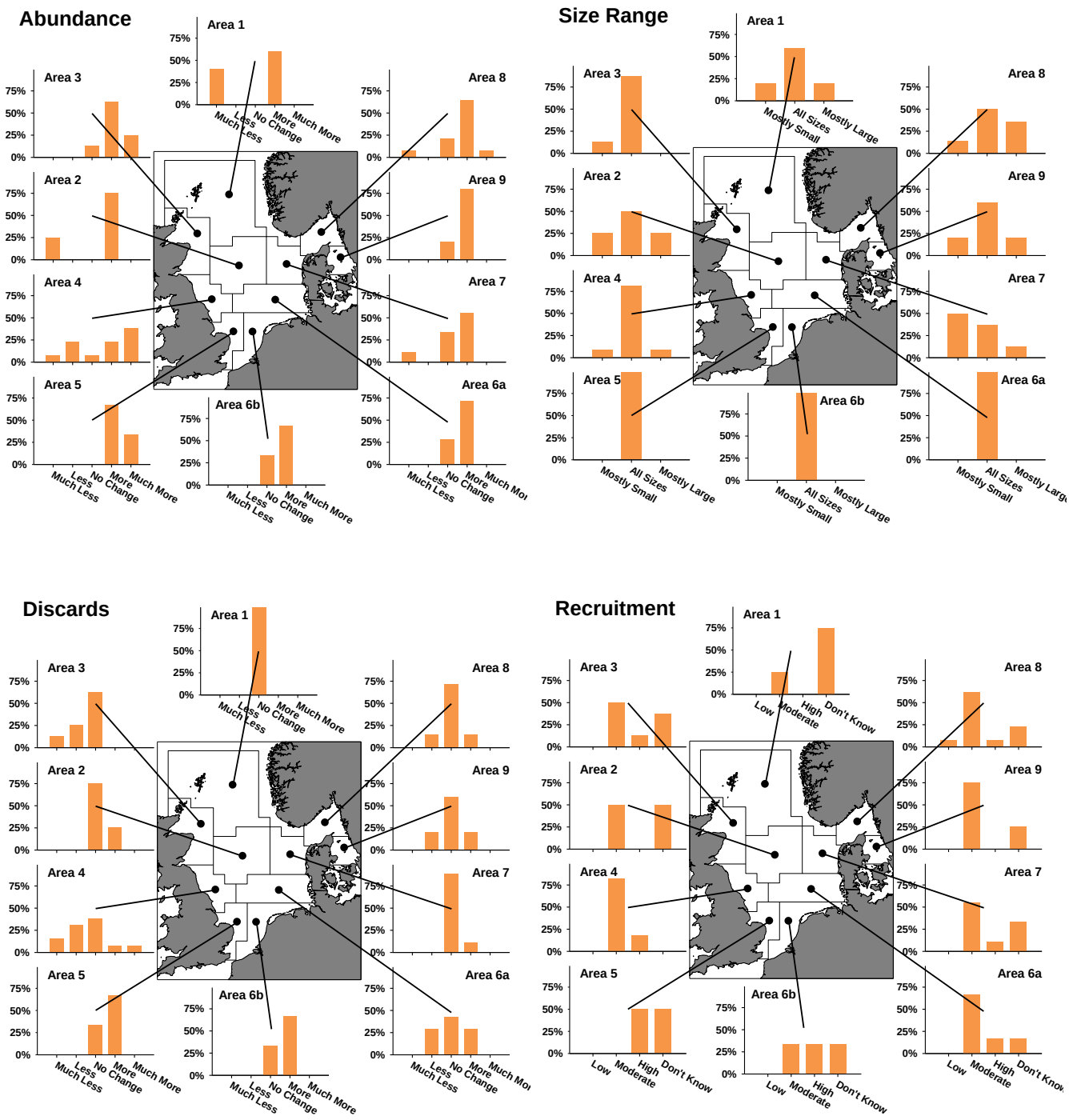

Figure 46 Perceptions of the abundance and size range of *Nephrops*, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category.

Abundance Index

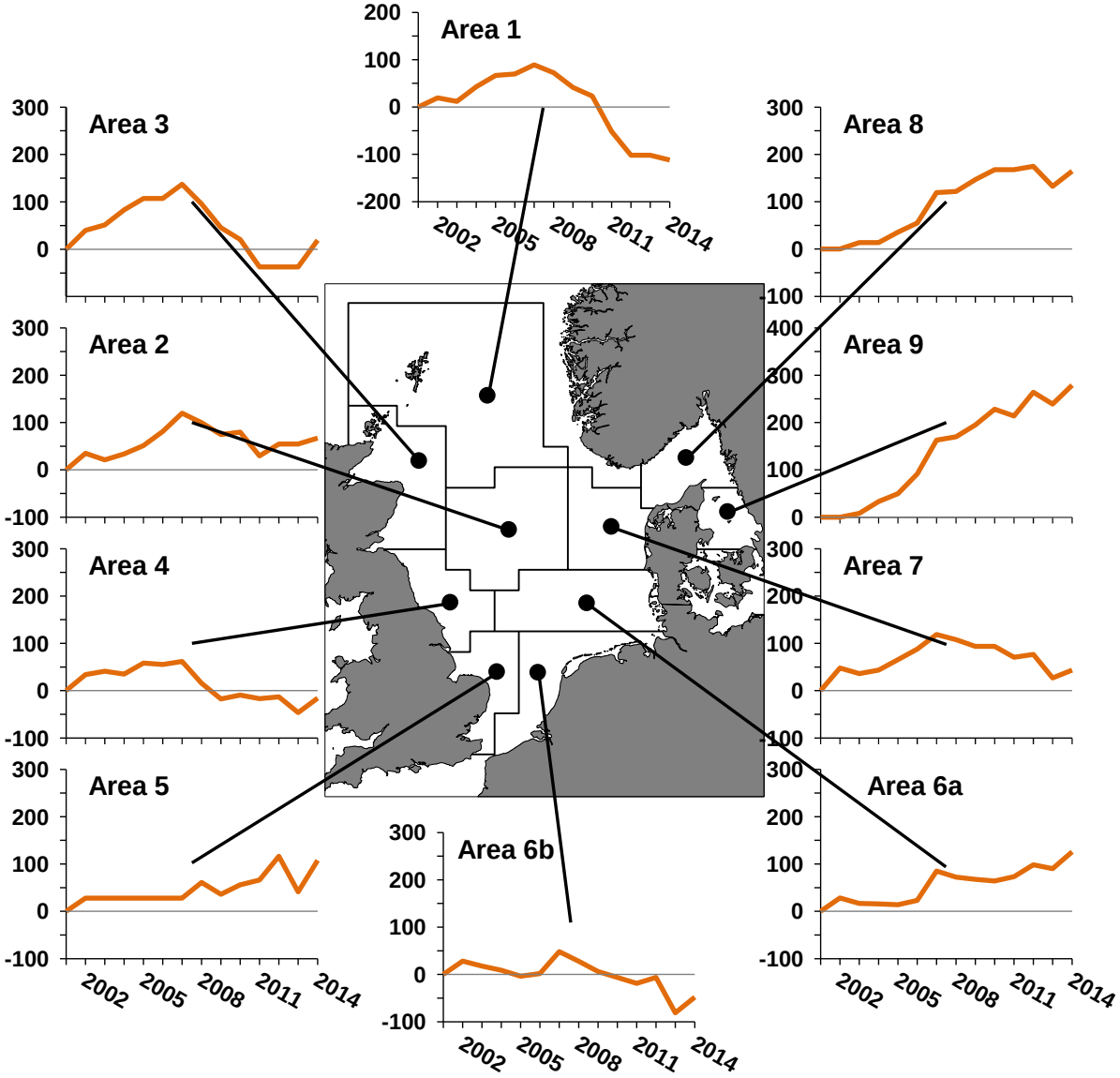

Figure 47 Cumulative time series of index of perceptions of abundance of *Nephrops*, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

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).

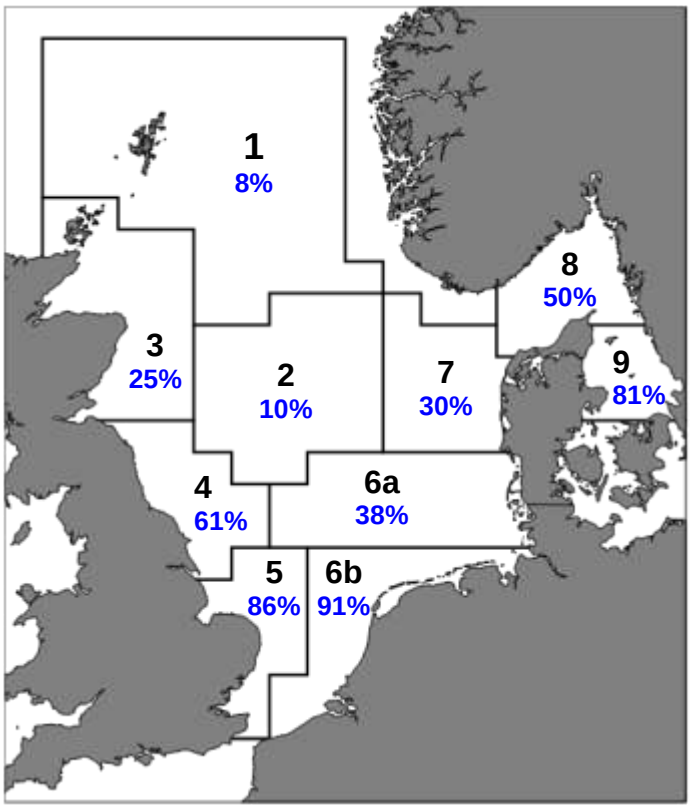

Figure 48 Proportion of responses from each area that provided information on common (Dover) sole.

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.)

		VESSEL SIZE CLASS							
		Numbers				% by Gear Type			
		<15m	15-24m	>24m	ALL	<15m	15-24m	>24m	ALL
FISHING GEAR – 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%
FISHING GEAR – % 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.

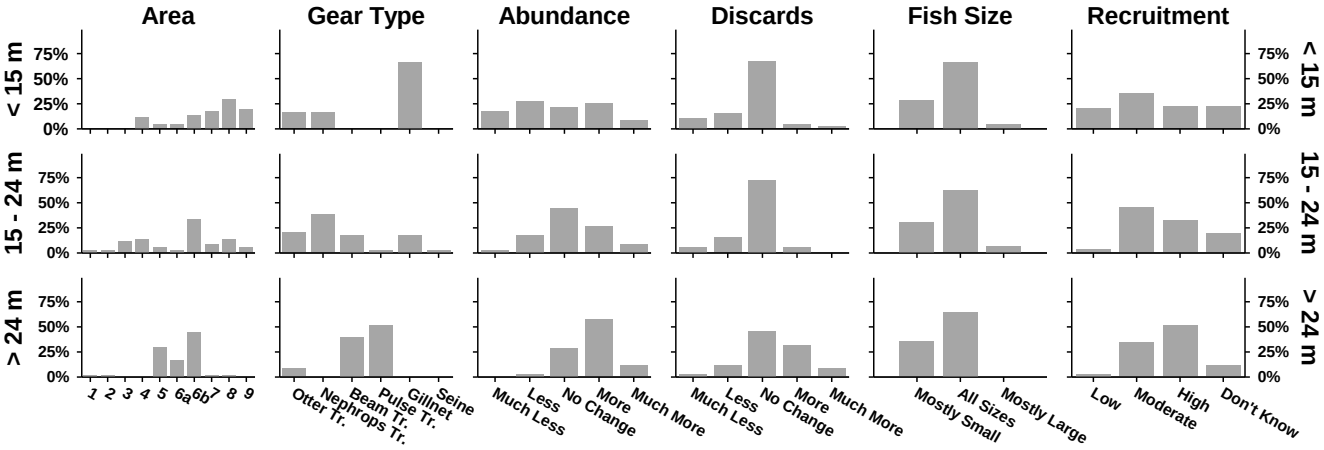

Figure 49 Breakdown of responses for common sole by fishing vessel size class. Percentage of responses for each size class in each category.

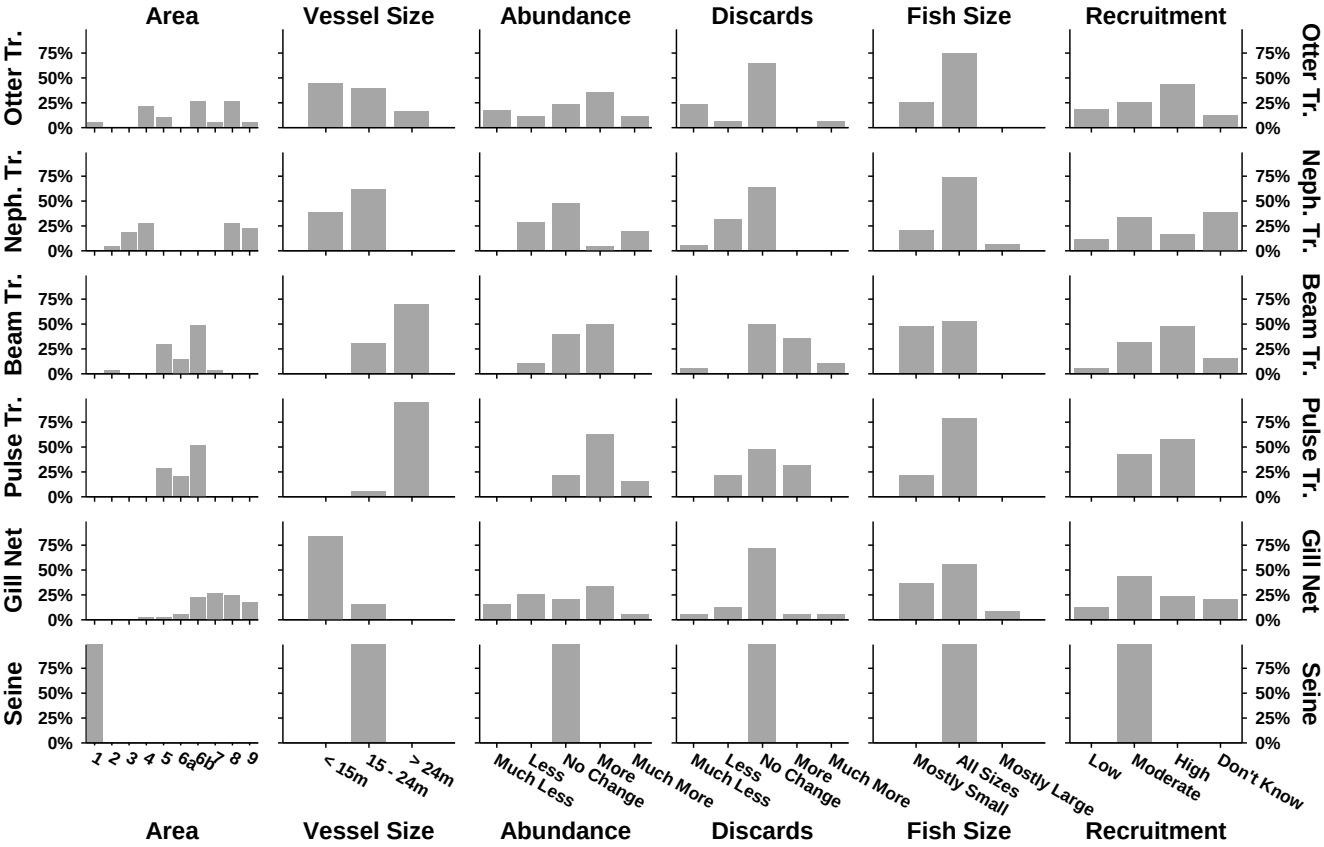

Figure 50 Breakdown of responses for common sole by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

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).

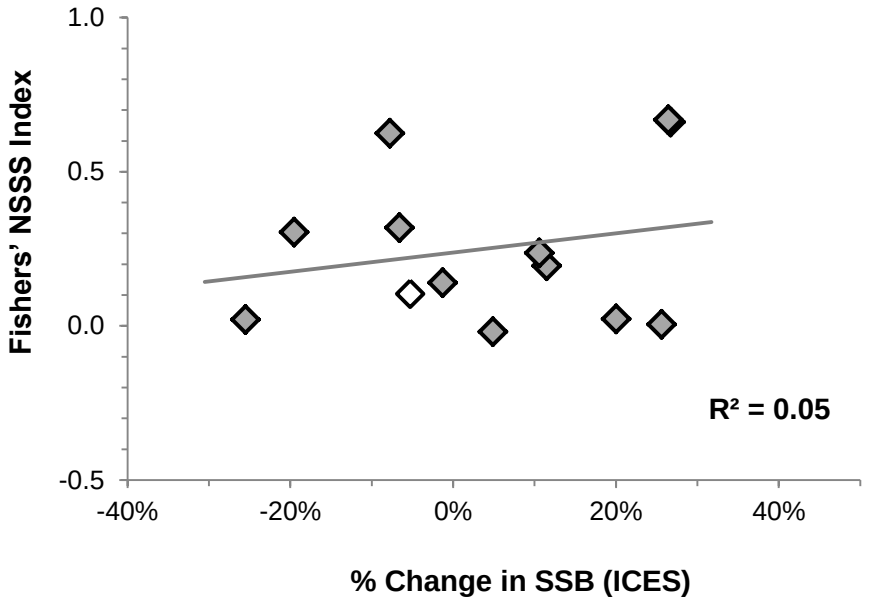

Figure 51 Plots of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea common sole spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination. Unshaded points are based on the predicted SSB for 2015. (R^2;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

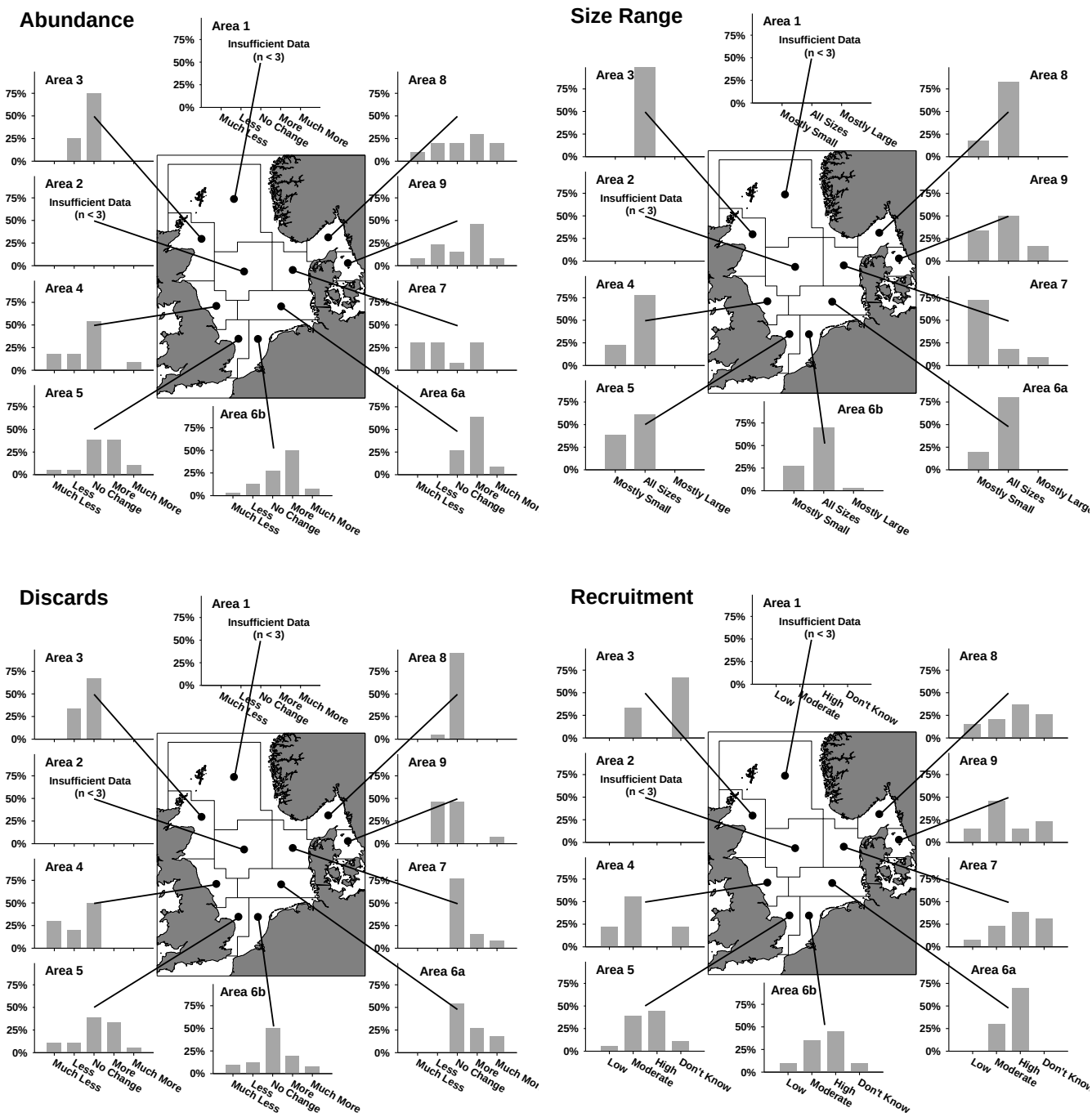

Figure 52 Perceptions of the abundance and size range of common sole, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category. No results are shown for Areas 1 and 2 due to the small number of responses from those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

Abundance Index

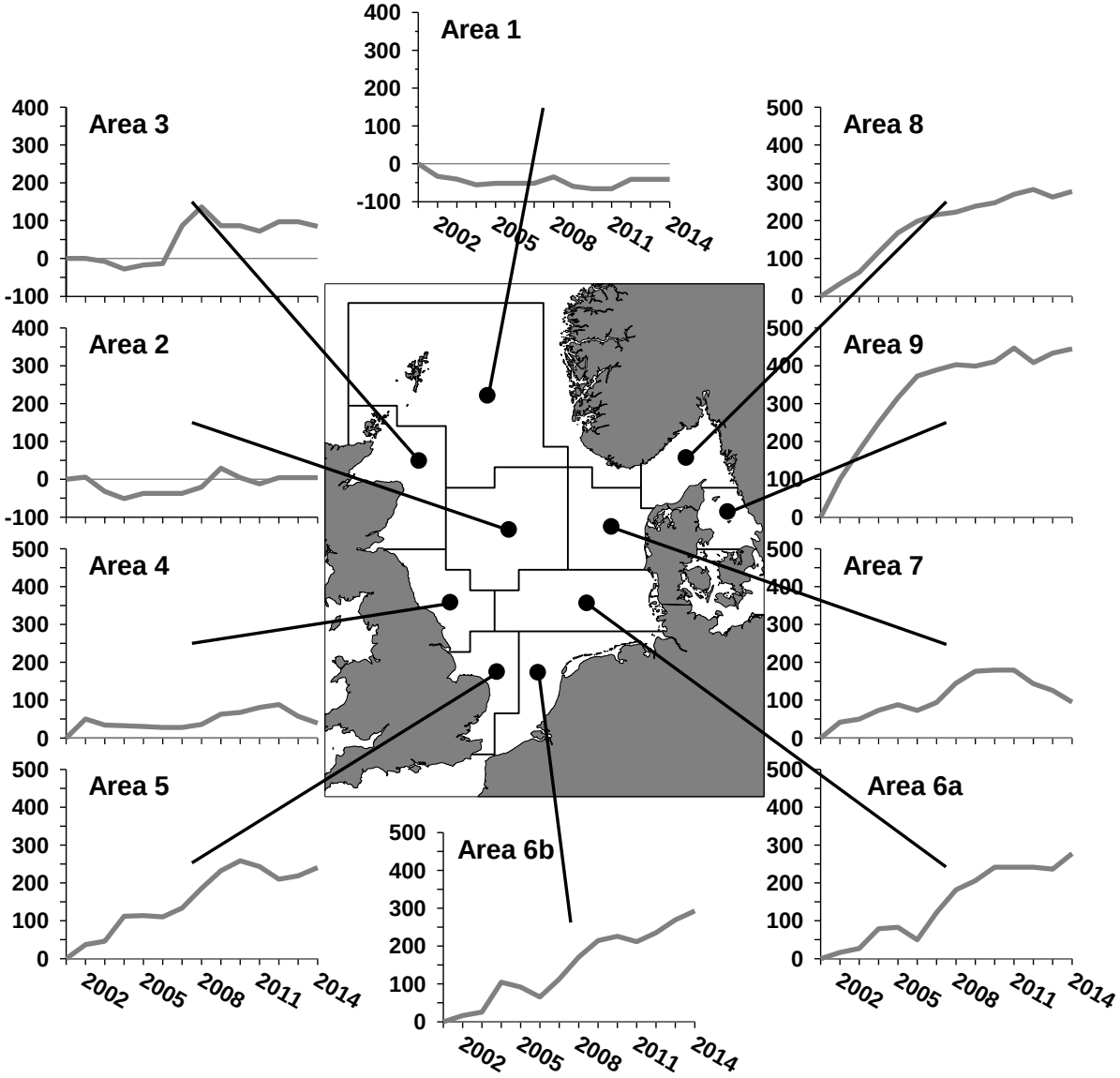

Figure 53 Cumulative time series of index of perceptions of abundance of common sole, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

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.

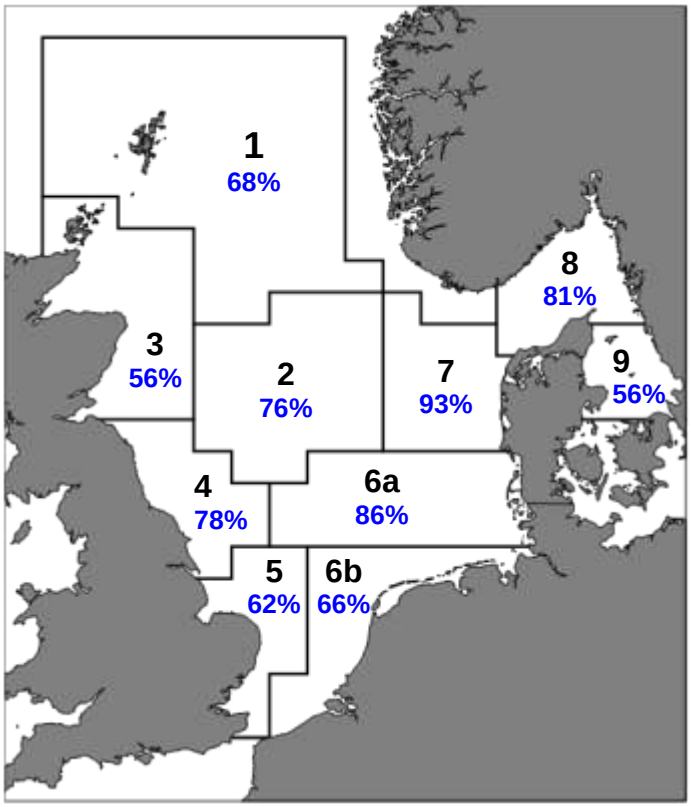

Figure 54 Proportion of responses from each area that provided information on plaice.

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.)

FISHING GEAR		VESSEL SIZE CLASS							
		Numbers				% by Gear Type			
		<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.

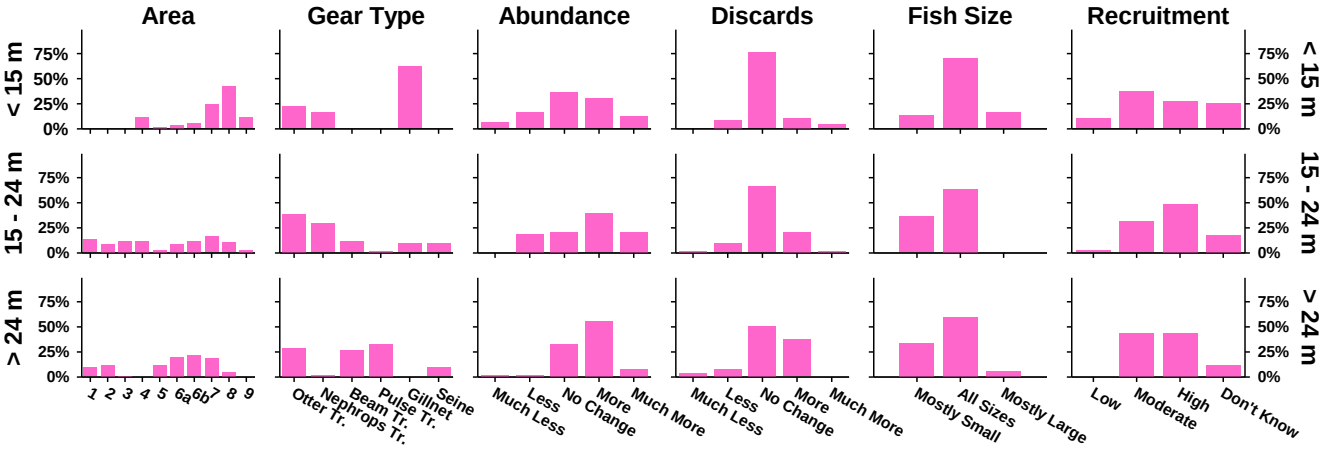

Figure 55 Breakdown of responses for plaice by fishing vessel size class. Percentage of responses for each size class in each category.

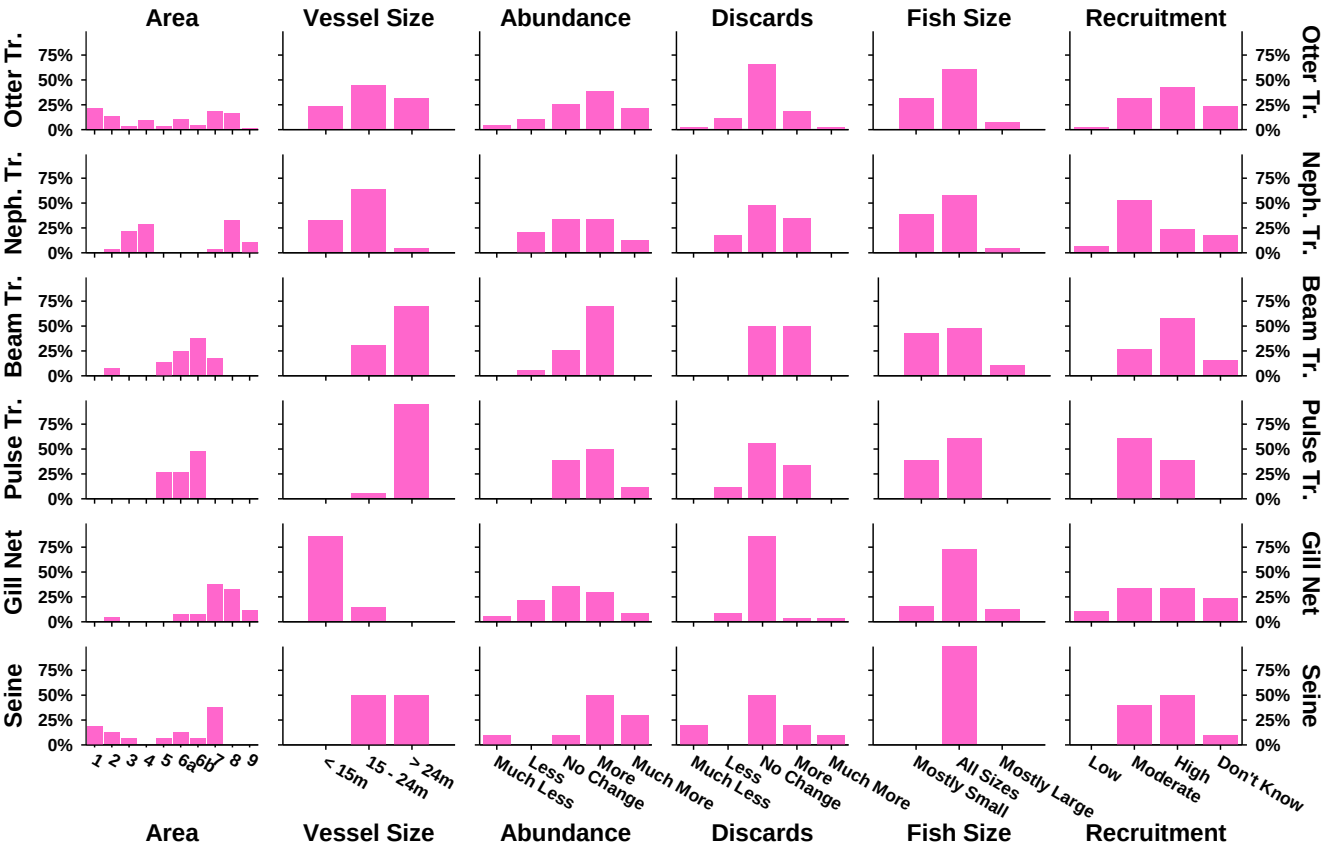

Figure 56 Breakdown of responses for plaice by fishing gear (Otter Trawl, *Nephrops* Trawl, Beam Trawl, Pulse Trawl, Gill Nets and Seine Net). Percentage of responses for each fishing gear in each category.

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).

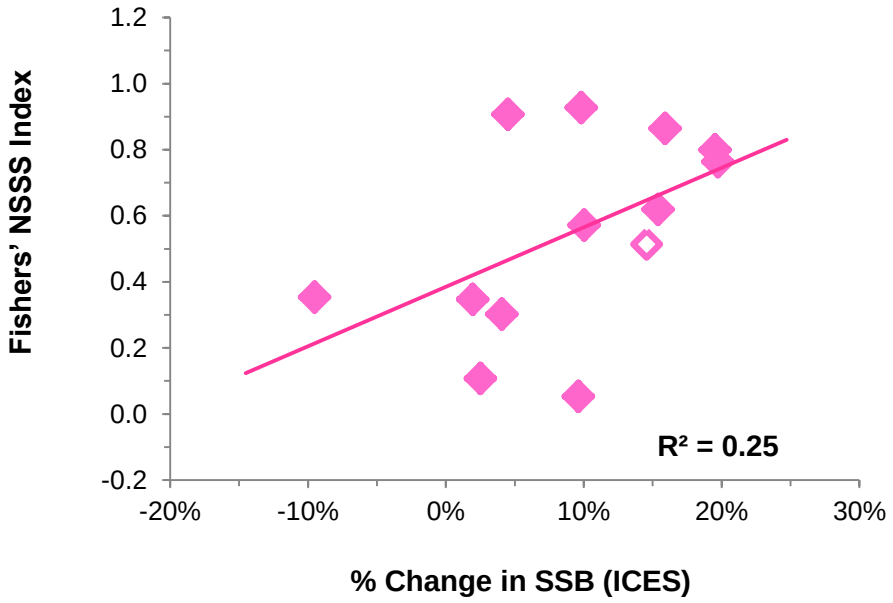

Figure 57 Plot of the annual Fishers' North Sea Stock Survey index against the percentage changes in the estimated mid-year North Sea plaice spawning stock biomass (SSB), with fitted linear trend line and coefficient of determination (R^2; values closer to 1 indicate a better agreement). The unshaded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

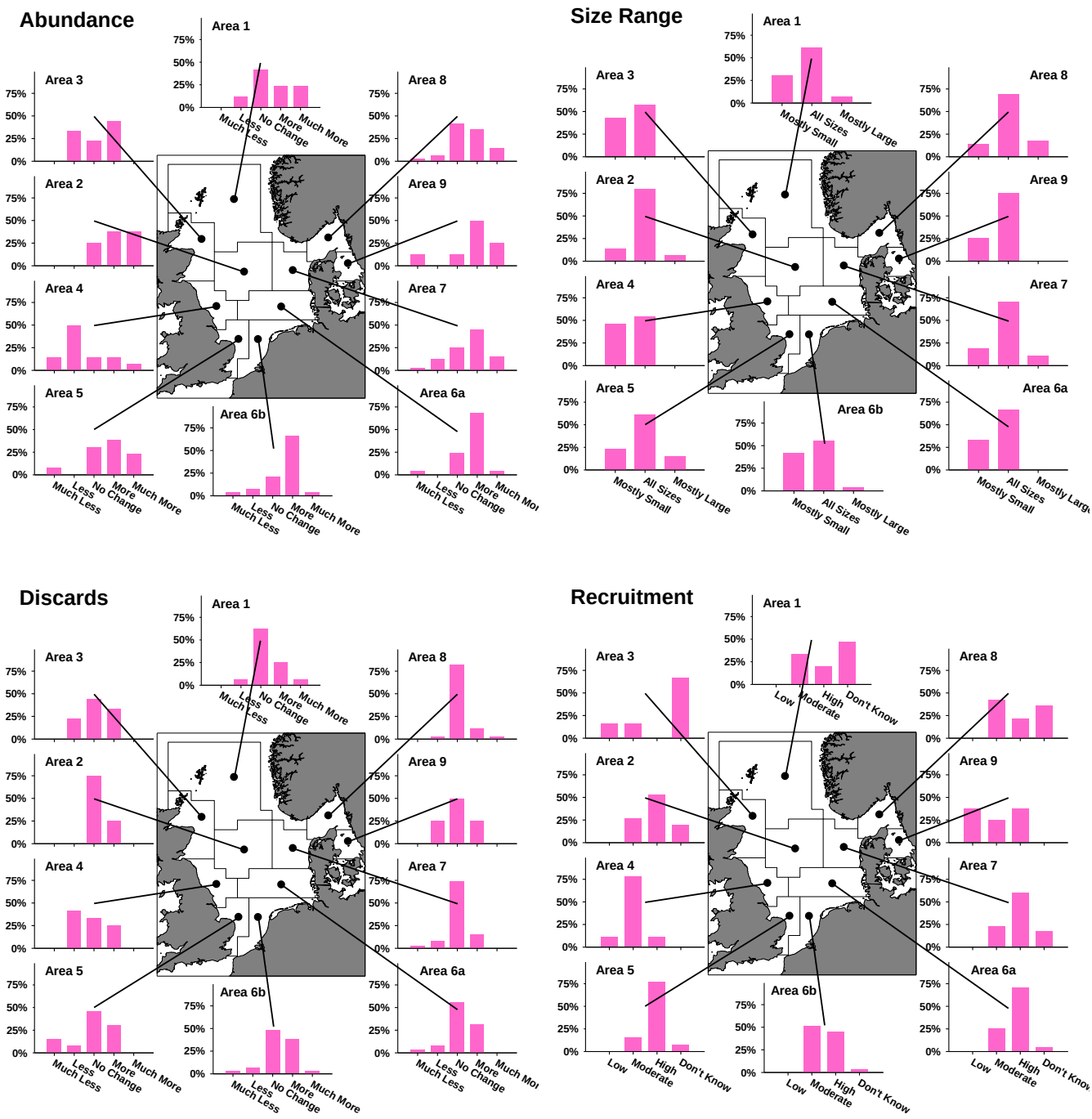

Figure 58 Perceptions of the abundance and size range of plaice, and of the levels of discarding and recruitment this year, compared to last year, by area. Percentage of responses from each area in each category.

Abundance Index

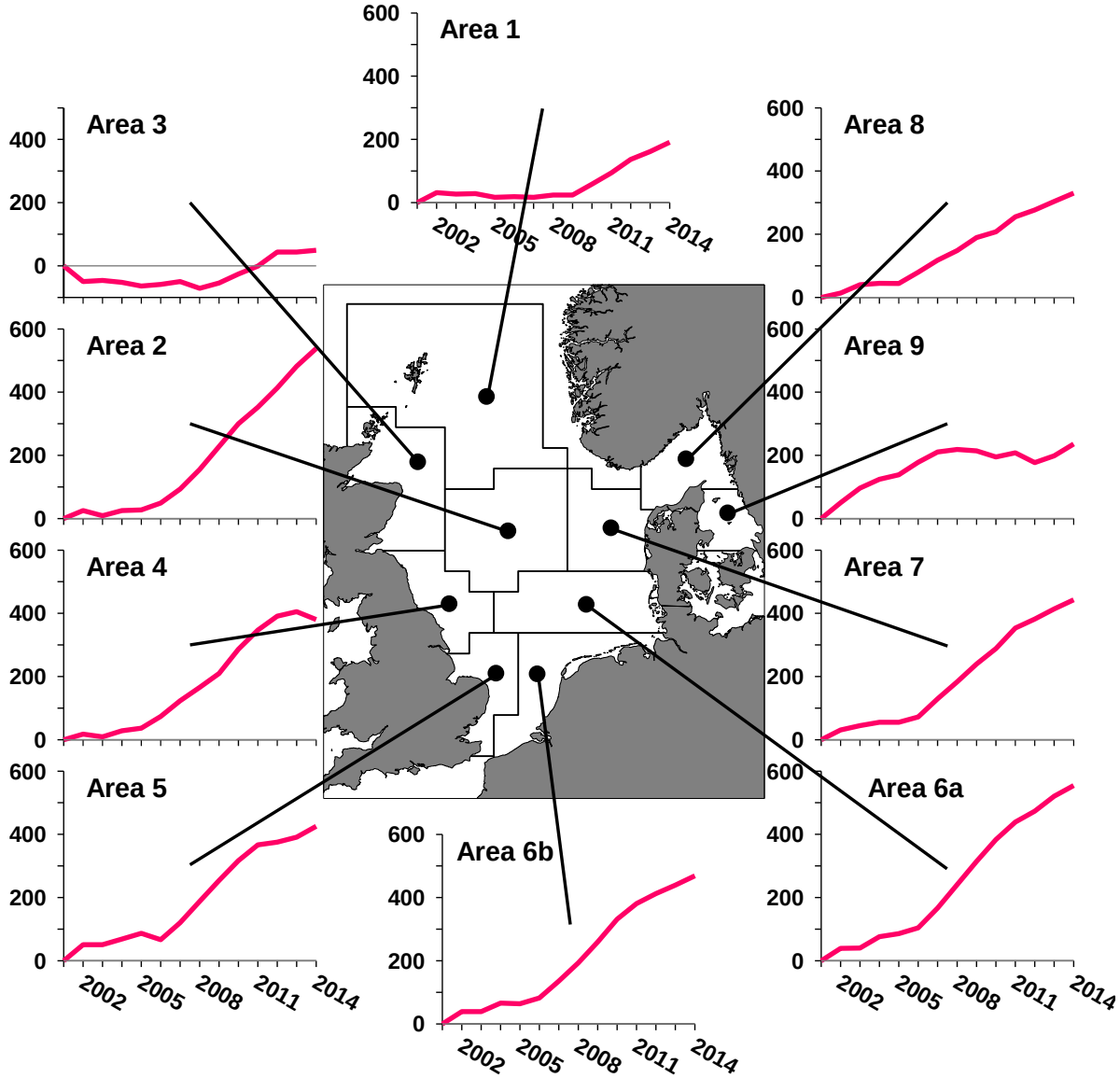

Figure 59 Cumulative time series of index of perceptions of abundance of plaice, by area (see page 14 for explanation of the index). (Note: the cumulative indices have been recalculated for previous years, which may result in some differences from previous reports.)

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.

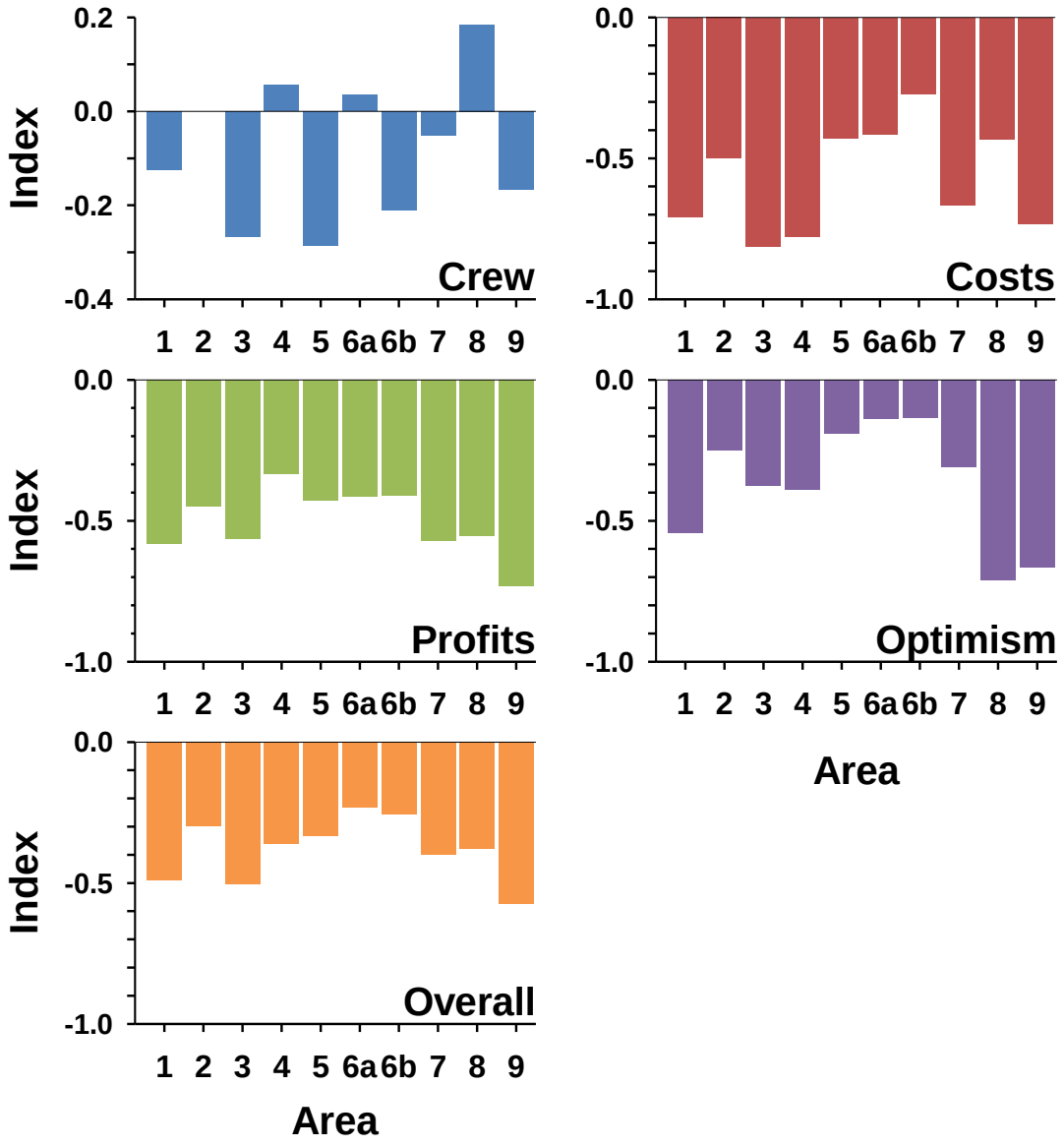

Figure 60 The indices of economic parameters for each area: perceptions of changes in difficulty of getting / retaining crew; costs, profits, optimism, and overall average economic parameter index. Negative index values indicate a more negative perception (e.g. higher costs, lower profits, etc.). See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

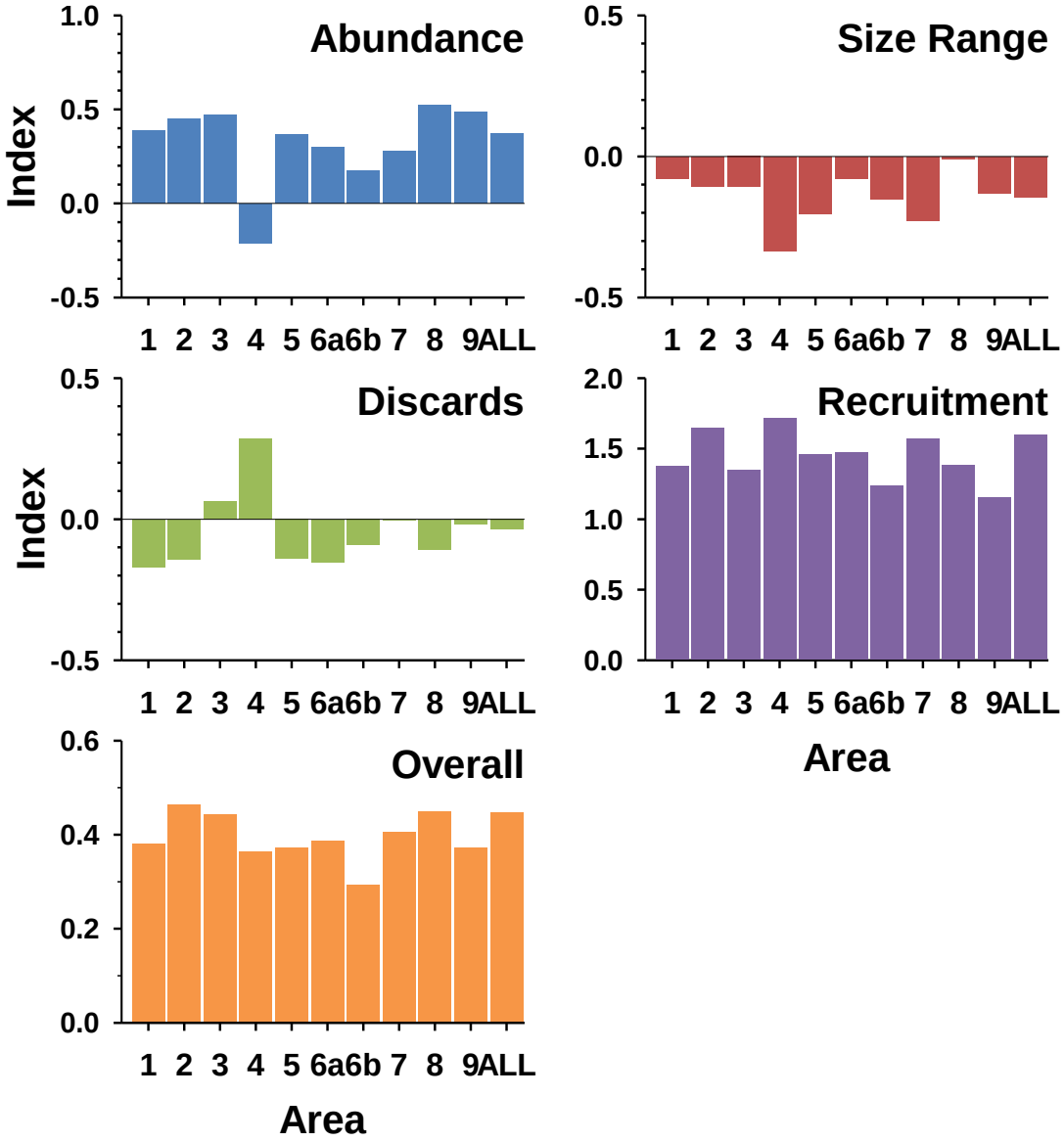

Figure 61 The indices for each area of perceptions of changes in the abundance of fish, the size range of fish caught, the levels of discards and the levels of recruitment. Negative index values indicate a more negative perception (e.g. lower abundance, higher discards, etc.). See p. 15 for explanation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