FISHERY DEPENDENT DATA IN NEW ENGLAND GROUNDFISH STOCK ASSESSMENTS

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BACKGROUND

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

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

$$CPUE_t = q\, N_t$$

where q is a catchability coefficient and N_t 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).

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

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).

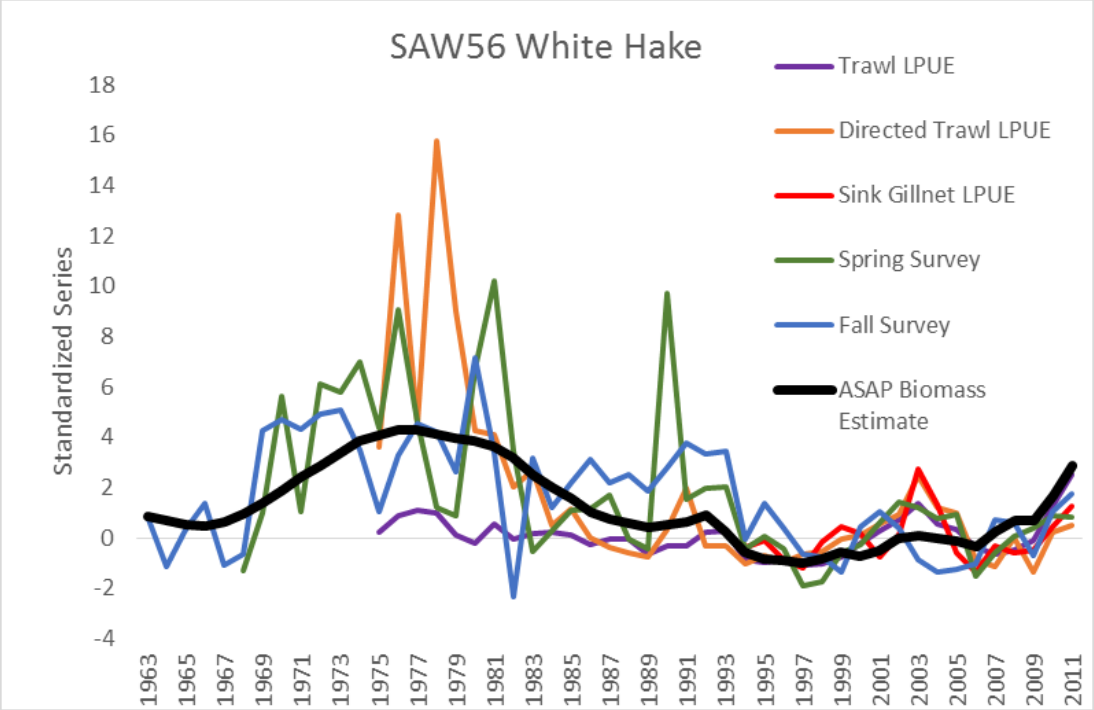
The Working Group conducted sensitivity analyses that included the commercial and recreational LPUE indices separately within the base model assessment. Model fits to both the commercial and recreation LPUE indices exhibited a poor fit with strong residual patterning. The Working Group concluded that 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.

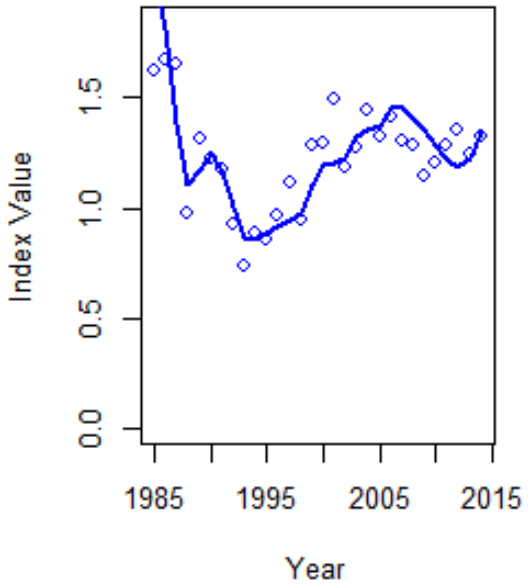


Figure 1. Bluefish model (solid line) fit to the MRIP CPUE index (open circles; from NEFSC, 2015a).

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.

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.