Background Document

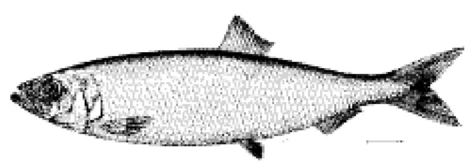
For the

New England Fishery Management Council

May 16-17, 2016 workshop on

Atlantic Herring Acceptable Biological Catch Control Rule

Management Strategy Evaluation



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1.0 INTRODUCTION

The New England Fishery Management Council (Council) is currently developing Amendment 8 to the Atlantic Herring Fishery Management Plan (FMP). Through Amendment 8, the Council expects to establish a long-term control rule for specifying the acceptable biological catch (ABC) for Atlantic herring that manages Atlantic herring within an ecosystem context (Section 6.4). A control rule is a formulaic approach for establishing an annual limit or target fishing level that is based on the best available scientific information. It provides guidance to the Science and Statistical Committee (SSC) regarding how to specify the ABC for Atlantic herring based on scientific uncertainty, stock status, and the Councilôs risk tolerance. The Council is developing Amendment 8 alternatives for the control rule using Management Strategy Evaluation (MSE). This document provides background information to support a May 16-17, 2016, public workshop on the MSE, during which participants will share their ideas about the objectives of the Atlantic herring control rule, control rules to consider, and how to evaluate the potential for the control rules to meet the identified objectives.

2.0 ABC CONTROL RULES

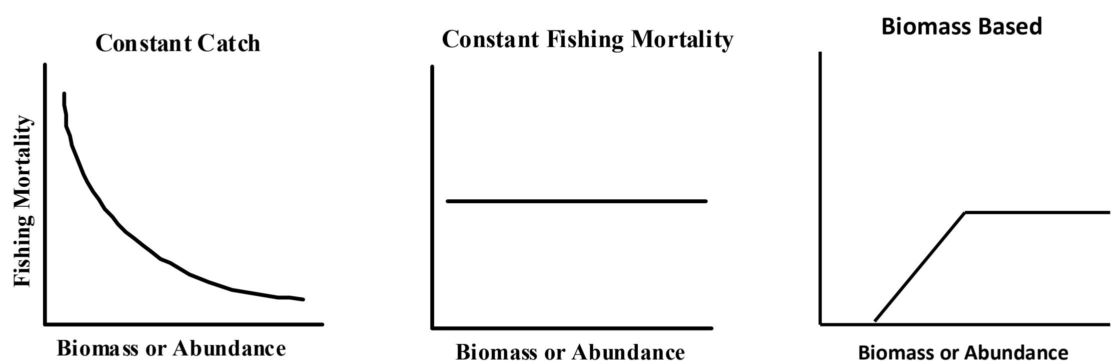
An Acceptable Biological Catch (ABC) control rule specifies a target amount of catch or a fishing mortality rate that depends on some measure of recent stock abundance. Many control rules exist, and they vary in their ability to achieve fishery objectives, but there are three generic types of control rules (Figure 1).

A óconstant catchô control rule harvests the same amount of fish regardless of abundance. Consequently, as abundance declines, the fishing mortality rate (i.e., catch divided by abundance) increases, because the fishery is removing a larger proportion of the stock.

A óconstant fishing mortalityô control rule removes the same fraction of the population regardless of abundance, and consequently catch increases linearly with abundance (e.g., 75% F_{MSY}).

A óbiomass basedô control changes the fishing mortality rate depending on abundance, typically with the fishing mortality rate increasing with abundance to some maximum rate. The linear change in fishing mortality can vary in steepness, and fishing mortality does not necessarily need to equal zero at a particular level of abundance.

Figure 1 - Generic types of control rules relating the fishing mortality rate to biomass or abundance



Many other variations of control rules exist, but these are the basic types. Variations to these basic types can produce a broad range of results. In the U.S., some characteristics of an ABC control are defined by law. For example, ABC cannot have a greater than 50% chance of exceeding the catch associated with F_{MSY} (i.e., the Overfishing Limit (OFL)), and so F_{MSY} should likely serve as an upper bound for any control rule considered. Beyond that, previous research can likely inform decisions about what control rules might be eliminated a priori as unlikely to meet fishery objectives.

The ABC control rule currently in place for the Atlantic herring fishery (Section 6.3) does not fit neatly into any one of these generic types, but combines approaches:

> *Atlantic herring ABC will be specified annually as the catch that is projected to produce a probability of exceeding F_{MSY} in the third year that is less than or equal to 50%.*

Essentially, a fishing mortality rate is applied, and the catch associated with it is set for a three-year period. However, below a certain biomass threshold, a stock rebuilding program would be required, which has no intuitive relationship between biomass and F, because it depends on assumptions that go into determining rebuild time.

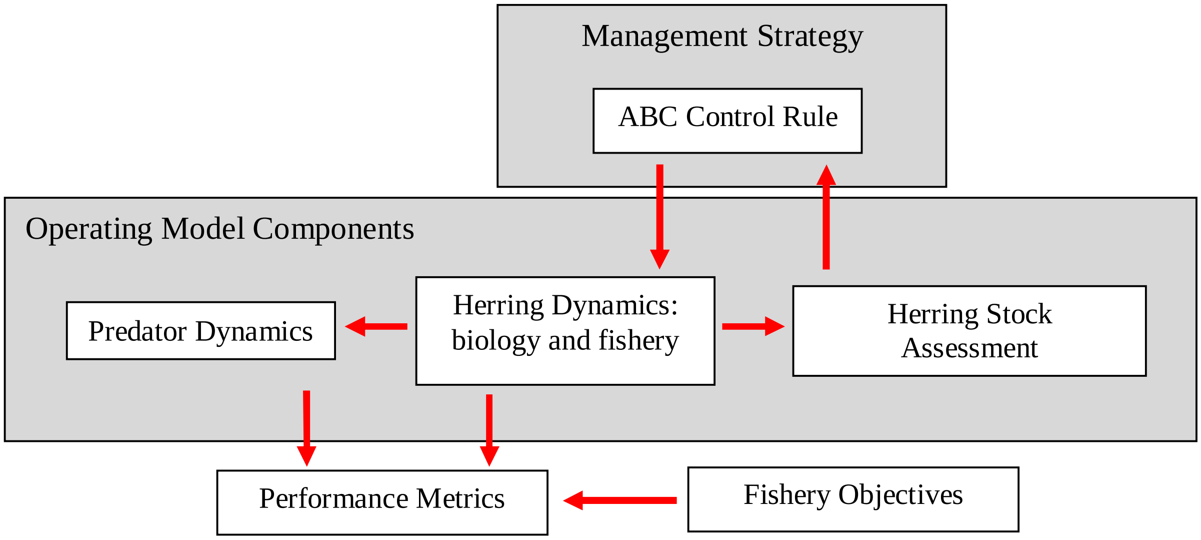
3.0 MANAGEMENT STRATEGY EVALUATION

Management Strategy Evaluation (MSE or Management Procedures) is an inclusive process whereby stakeholders collaboratively identify the characteristics necessary to construct a simulation that evaluates some aspect of the assessment and management system, here ABC control rules. These characteristics are identified through workshops. Of particular importance to the construction of the MSE is identification of fishery objectives and corresponding quantitative performance metrics, and relevant uncertainties (related to the biology, ecosystem, assessment, management, etc.). An example fishery objective might be maintaining enough herring as forage, with a corresponding performance metric of a minimum abundance of herring. Example uncertainties might include those related to stock assessment, fish reproduction (i.e., stock-recruitment), and the strength of interactions between predator and prey.

With this information, a simulation is constructed that involves a mathematical representation (i.e., operating model) of the necessary biological aspects of the system, the fishery, assessment, and management (e.g., a level of ABC). The operating model should account for the uncertainties identified in the workshop(s) (Figure 2). In some cases, uncertainty about a process may be so large as to warrant construction of multiple operating models that attempt to bound the plausible range of the given process. For example, the degree to which predator abundance depends on herring abundance might be poorly understood, and so two operating models might be constructed with a high and low degree of predatory dependence, respectively (Figure 3). With each operating model, the performance of the ABC control rules is simulated. Performance metrics are then compared for the control rules under each operating model to evaluate which control rules are more or less robust to the uncertainties.

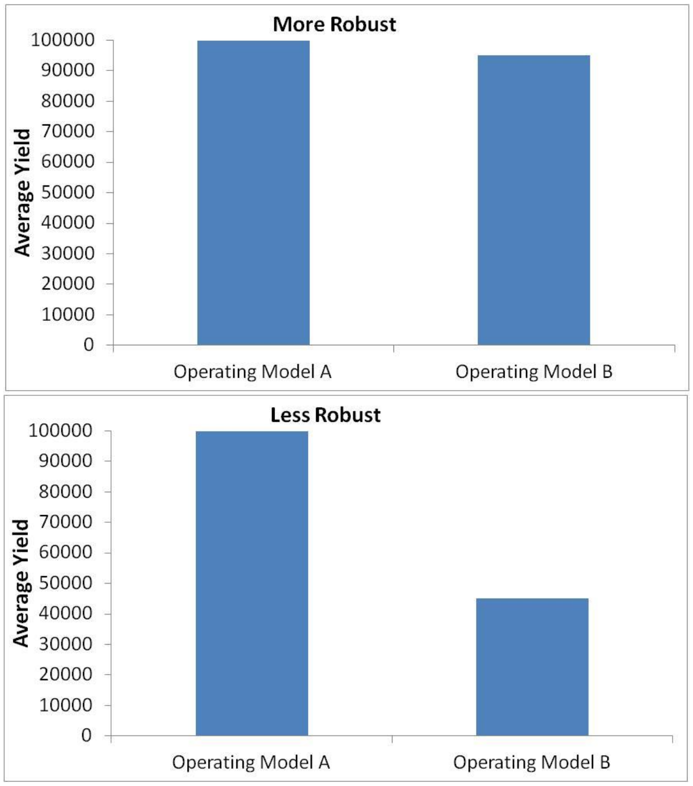
Ideally, a preferred management alternative or range of alternatives (ABC control rules in this case) that is robust to the uncertainties is identified by the stakeholder group. In other words, management alternatives that will perform reasonably well for the fishery objectives regardless of the operating model (i.e., regardless of what is happening in reality). Another benefit of the MSE process is improved common understanding of what is or is not well understood about the system, which can help inform research priorities and future refinement of the MSE. In the end, the MSE will only be as useful to the degree to which those involved collaboratively work to create a useful approximation of reality that bounds the major uncertainties.

Figure 2 - Schematic of an operating model for the MSE. In this case, the ABC control rule is the management strategy being evaluated, and potentially many are considered.



Source: Adapted from Punt et al. (2014).

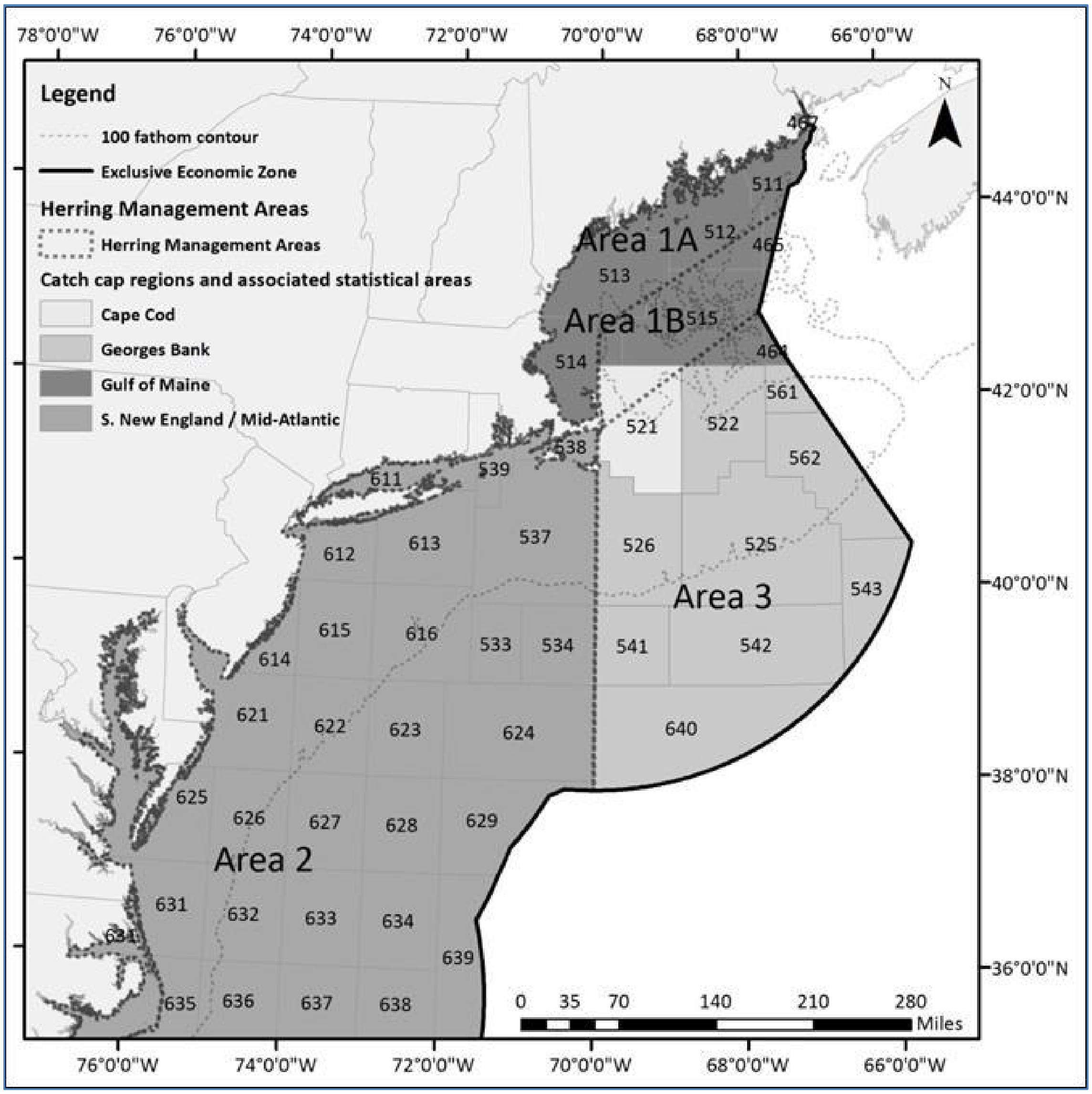
Figure 3 - An example performance metric (average yield) demonstrating a more robust control rule and a less robust control rule for two operating models



4.0 ATLANTIC HERRING MANAGEMENT

The Atlantic herring (*Clupea harengus*) fishery specifications are set every three years, including the OFL, ABC, and stock-wide Annual Catch Limit (ACL). In recognition of the spatial structure of the Atlantic herring stock complex (multiple stock components that separate to spawn and mix during other times of the year), the stockwide ACL is divided and assigned as sub-ACLs to four management areas (Figure 4). This is done using the best available information regarding the proportion of each spawning component of the Atlantic herring stock complex in each area/season to minimize the risk of overfishing an individual spawning component to the extent practicable.

Figure 4 - Atlantic herring management areas and river herring/shad catch cap areas



5.0 FMP GOAL AND OBJECTIVES

The goal and objectives of the Atlantic Herring Fishery Management Plan are as follows (NEFMC 2006):

Goal

- Manage the Atlantic herring fishery at long-term sustainable levels consistent with the National Standards of the Magnuson-Stevens Fishery Conservation and Management Act.

Objectives

- Harvest the Atlantic herring resource consistent with the definition of overfishing contained in the Herring FMP and prevent overfishing.
- Prevent the overfishing of discrete spawning components of Atlantic herring.
- Avoid patterns of fishing mortality by age which adversely affect the age structure of the stock.
- Provide for long-term, efficient, and full utilization of the optimum yield from the herring fishery while minimizing waste from discards in the fishery. Optimum yield is the amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, taking into account the protection of marine ecosystems, including maintenance of a biomass that supports the ocean ecosystem, predator consumption of herring, and biologically sustainable human harvest. This includes recognition of the importance of Atlantic herring as one of many forage species of fish, marine mammals, and birds in the Northeast Region.
- Minimize, to the extent practicable, the race to fish for Atlantic herring in all management areas.
- Provide, to the extent practicable, controlled opportunities for fishermen and vessels in other mid-Atlantic and New England fisheries.
- Promote and support research, including cooperative research, to improve the collection of information in order to better understand herring population dynamics, biology and ecology, and to improve assessment procedures.
- Promote compatible U.S. and Canadian management of the shared stocks of herring.
- Continue to implement management measures in close coordination with other Federal and State FMPs and the Atlantic States Marine Fisheries Commission management plan for Atlantic herring, and promote real-time management of the fishery.

6.0 HISTORY OF ATLANTIC HERRING ABC CONTROL RULES

6.1 AMENDMENT 4 AND 2010-2012 ATLANTIC HERRING FISHERY SPECIFICATIONS

In April 2011, several modifications to the Atlantic herring fishery specifications process were made through Amendment 4 to the Atlantic Herring FMP, in compliance with the 2007 re-authorization of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). Most relevant to the current Management Strategy Evaluation, Amendment 4 established and interim ABC control rule and revised the specifications process. Through this action, the Councilôs Scientific and Statistical Committee (SSC) makes a recommendation for setting ABC, which must be less than or equal to the OFL, considering scientific uncertainty. A stock-wide ACL is set, less than or equal to the ABC, considering management uncertainty.

During the 2010-2012 Atlantic herring fishery specifications process, developed concurrently with Amendment 4, the SSC pointed out two of sources of considerable scientific uncertainty:

1. The most recent Atlantic herring stock assessment (TRAC 2009) had a strong retrospective pattern, in which estimates of stock size are sequentially revised downward as new data are added to the assessment; and
2. Maximum Sustainable Yield (MSY) reference points estimated from the biomass dynamics model were inconsistent with the age-based, stochastic projection; such that fishing at the estimate of F_{MSY} was expected to maintain an equilibrium biomass that was less than the current estimate of B_{MSY}.

Given this scientific uncertainty, the SSC determined that a permanent herring ABC control rule cannot be established until a benchmark assessment is conducted to address these issues. In the meantime, the Council recommended that Amendment 4 contain an interim ABC control rule based on the SSCôs 2010ï 2012 herring ABC recommendation:

> *That ABC be based on recent catch in the herring fishery (e.g., the single-most recent year or a three- or five-year average), and that the Council determines the desired risk tolerance in setting the ABC.*

The 2010-2012 Atlantic herring ABC specification were adopted using the following control rule:

> *That ABC be based on the recent three-year average catch in the herring fishery (2006-2008; 106,00 mt).*

The Council considered this to be a placeholder until a benchmark stock assessment for Atlantic herring could be completed and a more appropriate long-term control rule for Atlantic herring could be developed by the Council.

6.2 AMENDMENT 4 LAWSUIT

On August 2, 2012, the United States District Court for the District of Columbia issued a remedial order in the civil action Flaherty, et al. v. Blank, et al. to address deficiencies with respect to Amendment 4 to the Herring FMP. A letter from the National Marine Fisheries Service (NMFS) to the Council on August 31, 2012, described the legal deficiencies identified by the Court:

- NMFS did not satisfy its obligation to independently determine whether the Councilôs designation of ñstocks in the fisheryò complied with the MSFCMA;
- NMFS did not adequately consider whether Amendment 4 complied with the National Standard 9 requirement to minimize bycatch to the extent practicable; and
- NMFS failed to consider the environmental impacts of alternatives to the ABC control rule and accountability measures in Amendment 4.

In its August 2012 letter, NMFS also recommended that the Council, as part of the 2013-2015 Atlantic herring fishery specifications, consider a range of alternatives for the Atlantic herring ABC control rule and AMs and explain how the measures adopted in Amendment 5 to the Herring FMP minimize bycatch, to the extent practicable, in the Atlantic herring fishery.

6.3 2013-2015 ATLANTIC HERRING FISHERY SPECIFICATIONS

To address both the August 2012 letter from NMFS and the need to reconsider the interim ABC control rule established in Amendment 4, the Council considered a wider range of ABC control rule alternatives for the 2013-2015 Atlantic herring fishery specifications. Following the benchmark stock assessment (NEFSC 2012), the SSC, with input from the Herring Plan Development Team (PDT) and guidance from the Council, considered three alternatives (including No Action) for a herring ABC control rule for the 2013-2015 fishing years (NEFMC 2012b). One control rule set ABC at 75% of the fishing mortality rate at maximum sustainable yield (F_{MSY}) for 2013-2015, while the other control rule applied a constant catch over these years. In this particular situation, these two approaches resulted in a Atlantic herring ABC over the three years which was approximately the same. The SSC could not find any scientific reason to prefer one approach over the other and considered them to be comparable in terms of the risk of overfishing, given the available information. All considerations led the SSC to conclude that either approach could be applied for the next three years with low probability of overfishing or causing the Atlantic herring resource to become overfished. In turn, the SSC recommended that the Council consider either approach for specifying Atlantic herring ABC for 2013-2015.

While not an explicit term of reference, the SSC discussed the role of Atlantic herring in the ecosystem and options for setting ecosystem-based ABCs, as requested by NMFS in the August 31, 2012 correspondence regarding the Amendment 4 lawsuit. The SSC concluded that both approaches for setting ABC would result in fishing mortality rates over the next three years that are well below the natural mortality rate for Atlantic herring and would produce a stock size that is well above the standard biomass target, thereby likely meeting ecosystem-based biomass targets for a forage species by default if not by design (NEFMC 2012b).

Based on analysis provided by the Herring PDT and these recommendations from the SSC, the Council selected its preferred alternative for the 2013-2015 ABC at its September 2012 meeting, based on applying a constant catch over a three-year period:

> *Atlantic herring ABC will be specified annually as the catch that is projected to produce a probability of exceeding F_{MSY} in the third year that is less than or equal to 50%.*

However, after further discussion and consideration of the Amendment 4 Court Order and August 2012 NMFS correspondence, the Council requested the SSC to consider two additional ABC control rule alternatives, the ñLenfestò and ñPacificò control rules, based on harvest control strategies for other forage fish. These two alternatives were recommended for consideration by

EarthJustice in its comments to the Council regarding the 2013-2015 herring fishery specifications. In November 2012, the Council tasked the SSC with considering these additional alternatives.

The SSC evaluated the two additional ABC control rule alternatives in November 2012 in terms of: 1) the short-term catch advice, i.e., the 2013-2015 herring fishery specifications, and 2) development of long-term control rules to address the issue of whether the increased natural mortality rate in the assessment fully captured all the ecosystem needs (including humans) related to forage species. Regarding the short-term catch advice, the SSC stated that it would be difficult to adopt the Pacific control rule, because the specific values of the biomass cutoff, buffer, and fraction have not been developed for Atlantic herring. This rule also would produce large and sudden changes in ABC based on small changes in biomass, which the SSC felt should be avoided. The SSC noted that the spawning stock biomass expected in 2015 under either of the previously-reviewed alternatives was well above the targeted 40% unfished amount suggested in the Pacific control rule. Similarly, the ABC alternatives already under consideration were broadly consistent with the biomass aspect of the Lenfest control rule (maximum fishing mortality threshold of 50% F_{MSY}) at currently estimated stock sizes and associated reference points. Thus, the SSC affirmed its original recommendations for specifying ABC for the 2013-2015 fishing years and concluded that the original alternatives considered by the Council were broadly consistent with the intent of the other control rules included for consideration. The SSC noted that more analysis is needed to develop and implement long-term harvest strategies, like the Lenfest and Pacific control rules, and suggested that control rules for forage species should be part of a broader national workshop that involves the community that advises the Council system (NEFMC 2012a).

Further discussion by the Council indicated that because of uncertainties associated with adopting either of these control rules in the 2013-2015 Atlantic herring specifications and the need for additional analysis, these alternatives should be considered but rejected in the specifications package. However, the Council agreed that these alternatives may be revisited, as both the Herring PDT and the SSC supported further consideration of a long-term control rule for Atlantic herring, perhaps forage-based, through a more comprehensive management action. The SSC suggested that the Council consider how to manage the Atlantic herring resource over the long-term, i.e., as a typical fishery with MSY-based reference points, or at a reduced fishing rate and higher stock size to account for its role in the ecosystem. A control rule which could be set for more than three years would need to consider a wide range of possible stock conditions and have a known objective. The Herring PDT noted that reference points and projections required under a new harvest control strategy should be developed through a scientific assessment and technically reviewed before adopted for the long-term management of the fishery.

The Council considered all available information, and it affirmed the 2013-2015 ABC specification for the Atlantic herring fishery based on a constant catch control rule, updating the interim ABC control rule established in Amendment 4. OFL was specified as 169,000 mt in 2013, 136,000 mt in 2014, and 114,000 mt in 2015 and was calculated from a projection that applied F_{MSY} in each of the three years, but assumes that ABC during each year is 114,000 mt. The Council noted that it may modify this ABC control rule or implement a new one at any time through a future action, in the context of the Councilós long-term objectives for the management of this resource and the herring fishery. The Council noted that a change in management approach should include the development and evaluation of a full range of alternatives (including reference points) to be adopted in a harvest control rule for the Atlantic herring fishery. A more applicable solution for the long term will require additional analyses for the appropriate multiple reference points and should be evaluated in a full amendment to the Herring FMP (NEFMC 2014).

Subsequent to the implementation of the 2013-2015 Atlantic herring specifications, plaintiffs in the Amendment 4 lawsuit filed a new lawsuit challenging the 2013-2015 ABC control rule, claiming it failed to adequately account for herringҁs role as forage in the ecosystem or set a sufficient buffer between the OFL and ABC.

6.4 AMENDMENT 8

In November 2014, the Council prioritized developing an amendment in 2015 to consider control rules for the Atlantic herring fishery that account for herringҁs role as forage in the ecosystem. Through Amendment 8, the Council expects to establish a long-term control rule for specifying the acceptable biological catch (ABC) for Atlantic herring that manages Atlantic herring within an ecosystem context and addresses the goals of Amendment 8:

1. To account for the role of Atlantic herring within the ecosystem, including its role as forage.
2. To stabilize the fishery at a level designed to achieve optimum yield.
3. To address localized depletion in inshore waters.[1]

The purpose of Amendment 8 is also to address the biological needs of the Atlantic herring resource as well as the ecological importance of Atlantic herring to the greater Atlantic region in a manner that is consistent with the requirements and intent of the Magnuson-Stevens Act. Amendment 8 is being developed to address concerns during the Amendment 4 and 2013-2015 Atlantic herring specifications lawsuits and the issues raised by the SSC during the development of the 2013-2015 Atlantic herring specifications, when the SSC was asked by the Council to examine some alternative control rules that recognize the special ecosystem status of herring as important forage.

The scoping period for this action was held February 26 ï April 30 and August 21 ï September 30, 2015. All scoping comments and a concise summary are available for review at: http://www.nefmc.org/library/amendment-8-2. Through the 290 comments received (i.e., 29 oral and 261 written), 468 people gave input (duplicates removed) on Amendment 8, in addition to the 28,000 people (duplicates possible) who signed the three large form letters. However, many comments were given by people who represent businesses or organizations, and the total number of people those commenters represent cannot be determined. Most all of the comments supported addressing concerns about localized depletion and developing an approach for managing herring that explicitly accounts for its role in the ecosystem. People shared their perceptions of current problems and desired outcomes of this action. A relatively small number of comments were specific to control rule alternatives.

[1] An ABC control rule is not designed to directly address concerns related to localized depletion. Thus, the workshop will not focus on localized depletion. However, the Council is developing alternatives related to this issue separately, but within Amendment 8.

6.5 2016-2018 Specifications

Following the April 2015 Atlantic Herring Operational Assessment (Deroba 2015), the SSC met on May 20, 2015 to review the results and develop recommendations for the Atlantic herring OFL and ABC for the 2016-2018 fishing years. The SSC reviewed a number of projections and possible approaches for specifying ABC (control rules) and recommended that the Council specify ABC for the 2016-2018 fishing years using the interim ABC control rule for Atlantic herring as adopted for 2013-2015. This approach produced an ABC of 111,000 mt for 2016, 2017 and 2018, and associated OFLs of 138,000 mt in 2016, 117,000 mt in 2017, and 111,000 mt in 2018. The SSC provided the following rationale for this recommendation:

- Key attributes of the stock and assessment (SSB, recruitment, F, survey indices, etc.) have not changed substantially since the benchmark assessment, on which the current control rule was based. However, survey indices suggest that the 2011 year class is the second largest in time series and will contribute significantly to the total population abundance and biomass in 2016-2018.
- The most substantial change since the benchmark stock assessment (NEFSC 2012) is that the retrospective pattern has become worse in the operational assessment. The assessment implemented a Mohnœs rho correction to SSB in an attempt to account for the retrospective pattern, but there is no guarantee that the retrospective pattern will persist in sign and magnitude.
- Although the probability of overfishing may reach 50% in the third year, the probability of the stock becoming overfished is close to 0% in all years.
- The realized catch in the Atlantic herring fishery is generally well below the ABC, which reduces the expected risk of overfishing.
- In the assessment model, the current ratio of catch to estimated consumption is 1:4, which means that fishing is likely not the largest driver of stock abundance at present, however this does not negate the need to manage the fishing removals on this stock.
- A constant catch strategy is the preferred approach of the Council and the industry.

These considerations led the SSC to conclude that ABC should remain relatively constant for 2016-2018, or perhaps be reduced modestly. The recommended ABC of 111,000 mt, compared with status quo estimate of 114,000 mt, achieves that outcome. Additionally, the SSC noted that the current high herring biomass, bolstered by two very large year classes, likely meets ecosystem goals, including forage considerations, by default if not design, as ecosystem goals are not explicitly identified in the current ABC control rule (NEFMC 2015).

6.6 Future Specifications

It is expected that the 2019-2021 specifications will be developed using the control rule adopted through the Amendment 8 process.

7.0 HERRING AS FORAGE IN THE ECOSYSTEM

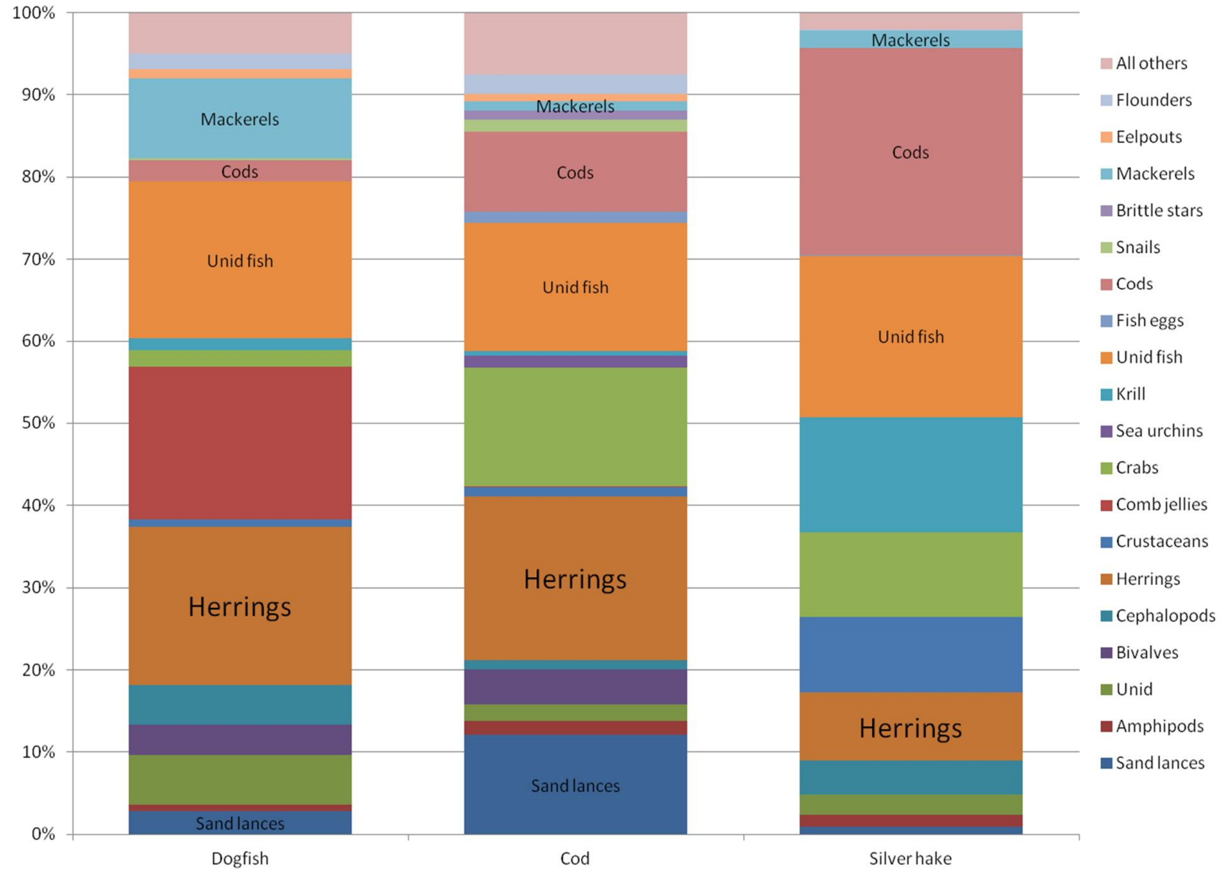
Atlantic herring play an important role as forage in the Northeast U.S. shelf ecosystem. They are eaten by a wide variety of fish, marine mammals, birds, and (historically) by humans in the region. The structure of the Northeast U.S. shelf ecosystem features multiple forage species rather than a single dominant forage species. Herring share the role of forage here with many other species including sandlance, mackerels, squids, and hakes, although herring are distinguished by a high energy density (caloric content) relative to other pelagic prey in the ecosystem. This diversity of forage options leads to a complex and diverse food web supporting many different predators. The relative importance of herring as forage varies by predator group, due to differences in predator life history, foraging style, and bioenergetics. Therefore, predator responses to changing herring populations vary, and depend on the extent to which other forage is available.

In the Northeast Fisheries Science Center (NEFSC) fish food habits database, Atlantic herring are found most often in the stomachs of spiny dogfish, Atlantic cod, and silver hake. These predators are generalists. Although they most commonly have herring in their diets, herring make up no more than 20% of the diet composition for any of these predators (Link & Almeida 2000; Smith & Link 2010). Similarly, diet estimates for marine mammals show that herring are important, but not dominant, generally comprising 10-20% of diets for baleen whale, toothed whales, and pinnipeds (Smith et al. 2015). Juvenile hake and herring are important forage for puffins in the Gulf of Maine, along with sandlance, and recently, juvenile haddock and redfish (Kress et al. 2016). Common and Arctic tern chicks in the Gulf of Maine were fed primarily juvenile herring and juvenile hake in equal amounts, followed by sandlance, and other fish (Hall et al. 2000). Endangered Species Act-listed Atlantic salmon, as adults at sea, feed on forage fish such as herring, mackerel, sandlance, and capelin (off Greenland; Renkawitz et al. 2015). Large adult bluefin tuna are one of the few potentially herring-dependent predators (~half of the diet is herring) in the Northeast U.S. shelf ecosystem (Chase 2002; Logan et al. 2015). However, recent studies suggest that bluefin tuna may require large herring, rather than abundant herring, to maintain body condition (Golet et al. 2015).

In some ecosystems, pelagic schooling fish are major predators of the pelagic eggs and larvae of other fish. However, fish eggs and larvae appear to be only a small component of Atlantic herring diet in federal waters of the Northeast U.S. shelf. Invertebrates (copepods, krill, amphipods, and other zooplankton) make up the majority (68%) of identified herring prey in the NEFSC food habits database, while fish larvae, eggs, and all other vertebrates combined make up less than 5% of herring diet (27% of stomach contents could not be identified). This database reflects mainly adult herring food habits on the continental shelf of the Northeast U.S. from 1992-the present. Limited information also suggests that juvenile herring primarily eat invertebrates and only rarely fish eggs and larvae in nearshore Gulf of Maine waters (Sherman & Perkins 1971).

Climate and environmental conditions can be major drivers of pelagic fish dynamics. In the Northeast U.S., Atlantic herring and other pelagics have lower biological sensitivity to climate risks than other species in the region due to high mobility, but as a result, have a high potential to change distribution. Overall, experts have rated the impact of climate change on Atlantic herring in this ecosystem to be negative to neutral relative to other Northeast species. All Northeast U.S. species have high or very high exposure to climate change risks, as this ecosystem is changing more rapidly than much of the world ocean (Hare et al. 2016).

Figure 5 - Estimated diet from Gulf of Maine, Georges Bank, and southern New England combined for Spiny dogfish, Atlantic cod, and silver hake



Source: NEFSC diet database, 1973-2012

8.0 ATLANTIC HERRING FISHERY

The U.S. Atlantic herring fishery occurs over the Mid-Atlantic shelf region from Cape Hatteras to Maine, including an active fishery in the inshore Gulf of Maine and seasonally on Georges Bank (Figure 4). The fishery is generally prosecuted south of New England in Area 2 during the winter (January-April), and oftentimes as part of the directed mackerel fishery. There is overlap between the herring and mackerel fisheries in Area 2 and in Area 3 during the winter months, although catches in Area 3 tend to be relatively low. The herring summer fishery (May-August) is generally prosecuted throughout the Gulf of Maine (GOM) in Areas 1A, 1B and in Area 3 as fish are available. Restrictions in Area 1A have pushed the fishery in the inshore GOM to later months (late summer). The midwater trawl (single and paired) fleet is restricted from fishing in Area 1A in the months of January through September because of the Area 1A sub-ACL split (0% January-May) and the purse seine-fixed gear only area (all of Area 1A) that is effective June-September. A sub-ACL split for Area 1B (0% January ï April, 100% May ï December) is effective for all vessels during the 2014 and 2015 fishing years.

Fall and winter fishing (September-December) tends to be more variable and dependent on fish availability; the Area 1A sub-ACL is always fully used, and the inshore GOM fishery usually closes around November. As the 1A and 1B quotas are taken, larger vessels become increasingly dependent on offshore fishing opportunities (Georges Bank, Area 3) when fish may be available. Atlantic herring is also caught in state waters and in the New Brunswick weir fishery.

8.1 ATLANTIC HERRING CATCH

The Atlantic herring stockwide ACL and management area sub-ACLs are tracked/ monitored based on the ***total catch – landings and discards***, which is provided and required by herring permitted vessels through the vessel monitoring system (VMS) catch reports and vessel trip reports (VTRs) as well as through Federal/state dealer data. Atlantic herring harvesters are required to report discards in addition to landed catch through these independent reporting methods.

Atlantic herring catch (Table 1) has been somewhat consistent over 2003-2014 (and in previous years), averaging about 91,925 mt from 2003-2014, with the highest catch of the time series observed in 2009 (103,943 mt) and lowest in 2010 (72,852 mt). However, the quota allocated to the fishery (stockwide ACL/OY) has decreased 50% over the twelve-year period. Consequently, and without increasing fishing effort, the Atlantic herring fishery has become more fully used in recent years, and the fishery used 100% of the total Atlantic herring ACL for the first time in 2012. The 2013-2015 Atlantic herring fishery specifications increased the stockwide Atlantic herring ACL by more than 15,000 mt from the 2010-2012 specifications; an additional 5,000 mt was caught under the higher quota in 2013 and 2014, and overall, the fishery used about 90% of the stockwide Atlantic herring ACL.

Table 1 - Total annual Atlantic herring catch, 2003-2014

Year	Total Herring Catch (mt)	Total Quota Allocated (mt)	% Caught
2003	101,607	180,000	57%
2004	93,205	180,000	52%
2005	96,116	150,000	64%
2006	98,714	150,000	66%
2007	85,819	145,000	59%
2008	83,240	143,350	58%
2009	103,943	143,350	73%
2010	72,852	91,200	80%
2011	86,245	93,905	92%
2012	90,561	90,683	100%
2013	95,764	106,375	90%
2014	93,247	104,088	90%
Source: NMFS.			

8.2 ATLANTIC HERRING PERMIT CATEGORIES AND VESSELS

Limited-access Atlantic herring vessel permit categories:

Category A ï limited access in all management areas;

Category B ï limited access in Areas 2 and 3 only;

Category C ï limited access in all management areas, with a 25 mt (55,000 lb) Atlantic herring catch limit per trip and one landing per calendar day.

Open-access Atlantic herring vessel permit categories:

Category D ï open access in all management areas, with a 3 mt (6,600 lb) Atlantic herring catch limit per trip and one landing per calendar day;

Category E ï open access in Areas 2 and 3 only, with a 9 mt (20,000 lb) Atlantic herring catch limit per trip and landing per calendar day.

The Category E Atlantic herring permit was established through Amendment 5 and implemented in March 2014. Vessels that have not been issued a limited access herring permit, but that have been issued a limited access mackerel permit, are eligible for this permit.

Active Vessels in the Atlantic Herring Fishery

Since 2008, the number of vessels with either a limited access or an open access Atlantic herring permit has decreased annually (Table 2 and Table 3). This includes a decrease in the limited access directed fishery vessels (Categories A and B), which comprise the majority of the herring fishery, with 43 permitted in 2014. In 2014, 44% of the limited access vessels were active (defined broadly as landing at least one pound of Atlantic herring during the fishing year). Many of the Category A, B, and C vessels are also active in the Atlantic mackerel fishery (managed by the Mid-Atlantic Fishery Management Council). Although there have been far fewer active limited access versus open access vessels, the limited access vessels account for about 97% of annual Atlantic herring landings and revenues.

For the open access vessels, just 3-5% of the Category D permits have been active since 2009 (Table 2 and Table 3). The Category E permit was implemented during permit year 2013 (May-April). In 2014, there were just over 50 E permits issued, mostly to vessels with a D permit as well. About 11% of the E permits were active that year.

Fishing Gear

Atlantic herring vessels primarily use purse seines, single midwater trawls or midwater pair trawls for fishing gear (Table 4). The midwater pair trawl fleet has harvested the majority of landings since 2008. Some herring vessels use multiple gear types during the fishing year. Single and pair trawl vessels generally fish in all areas (October-December in Area 1A), though Areas 1A and 1B account for less of their overall landings in recent years. The purse seine fleet fishes primarily in Area 1A and to a lesser extent, Areas 1B and Area 2, though in recent years, purse seines have not been active in Area 2. The single midwater trawl has been most active in Area 3. Small mesh bottom trawl vessels represented 5% of herring landings since 2008; other gear types (e.g., pots, traps, shrimp trawls, hand lines) comprise less than 0.5% of the fishery.

Table 2 - Fishing vessels with federal Atlantic herring permits, 2008-2011

Permit Category	2008	2009	2010	2011
A	44 (64%)	44 (66%)	43 (63%)	42 (64%)
B, C	5 (40%)	4 (75%)	4 (75%)	4 (50%)
C	53 (13%)	51 (25%)	51 (33%)	45 (20%)
Total Limited Access	**102 (34%)**	**99 (45%)**	**98 (48%)**	**91 (52%)**
D	2,390 (3%)	2,373 (3%)	2,231 (5%)	2,038 (4%)

Sources: NMFS Permit database (*http://www.nero.noaa.gov/permits/permit.html*) and VTR database.

Note: In parentheses are the percent active vessels, defined as having landed at least one pound of Atlantic herring. This includes all pair trawl vessels, whose partner vessel landed the catch. Data as of August 2015.

Table 3 - Fishing vessels with federal Atlantic herring permits, 2012-2014

Permit Category		2012	2013	2014
Limited Access	**A**	38 (61%)	40 (63%)	39 (67%)
	B, C	4 (50%)	4 (75%)	4 (50%)
	C	46 (24%)	44 (34%)	42 (21%)
	Total	**88 (41%)**	**88 (42%)**	**85 (44%)**
Open Access	**D**	2,026 (4%)	1,909 (4%)	1,788 (3%)
	D,E	n/a	n/a	53 (11%)
	E	n/a	n/a	1*
	Total	**2,026 (4%)**	**1,909 (4%)**	**1,842 (3%)**

Source: NMFS Permit database (*http://www.nero.noaa.gov/permits/permit.html*) and VTR database.

Note: In parentheses are the percent active vessels, defined as having landed at least one pound of Atlantic herring. This includes all pair trawl vessels, whose partner vessel landed the catch. Permit and landings data are as of August 2015 and do not include 2015 landings.

n/a = The Category E permits could first be issued at the end of 2013, but could not become active until 2014.

*Data confidentiality restrictions preclude reporting the percent active.

Table 4 - Atlantic herring landings by fishing gear type and area, 2012-2014

Gear Type	Area 1A (mt)	Area 1B (mt)	Area 2 (mt)	Area 3 (mt)	Total
Bottom Otter Trawl	534 (1%)	16,967 (64%)	0 (0%)	267 (0%)	17,768 (7%)
Single and Pair Midwater Trawl	14,677 (18%)	9,068 (34%)	44,746 (100%)	110,227 (100%)	178,718 (67%)
Purse Seine	68,409 (82%)	310 (1%)	0 (0%)	0 (0%)	68,719 (26%)
Other	3 (0%)	0 (0%)	3 (0%)	0 (0%)	6 (0%)
Total	83,623 (100%)	26,345 (100%)	44,749 (100%)	110,494 (100%)	265,211 (100%)

Source: VTR database. August 2015.

Note: Data include all vessels that landed one pound or more of Atlantic herring. Single and pair midwater trawl data are combined due to data confidentiality restrictions.

8.3 Atlantic Herring Prices, Use as Bait, and Substitute Goods

Between 2008-2014, Atlantic herring catch ranged from 72,852-103,943 mt while nominal prices generally ranged from about $160-350 per mt (Figure 6 and Figure 7). Overall, Atlantic herring prices have been increasing over time with a peak in 2013. Atlantic herring caught in the Northeast U.S. is eaten by consumers worldwide and used as lobster bait. There are likely to be good substitutes for both uses; therefore, prices are likely insensitive to quantity changes.

In general, prices will decrease when quantity supplied increases, and prices will increase when quantity supplied decreases. The extent to which prices are responsive to changes in quantities supplied (and therefore by changes in ACLs and sub-ACLs) depends on the availability of good substitutes. If good substitutes are available, then prices will not be sensitive to changes in quantity supplied. However, if good substitutes are not available, then prices will be quite sensitive to changes in quantity supplied.

Limited amounts of Atlantic herring are consumed as food domestically. In the world market, there is likely one substitute: European herring. U.S. production of Atlantic herring is quite small relative to the worldwide production. Since total U.S. landings of Atlantic herring have been near 100,000 mt annually, while total worldwide landings of Atlantic herring are near 2,000,000 mt. Therefore, U.S. producers of herring as human food are likely to be price takers on the world market. This means that moderate changes in the quantity of herring produced for food are unlikely to have an effect on price of herring.

Figure 6 - Average nominal price per metric ton of Atlantic herring, 2008-2012

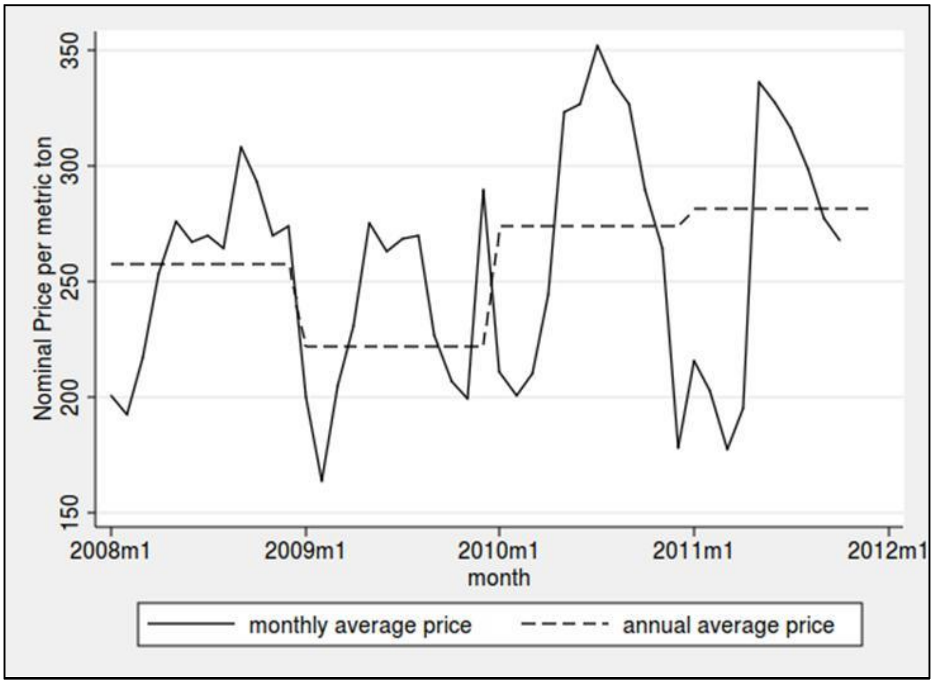
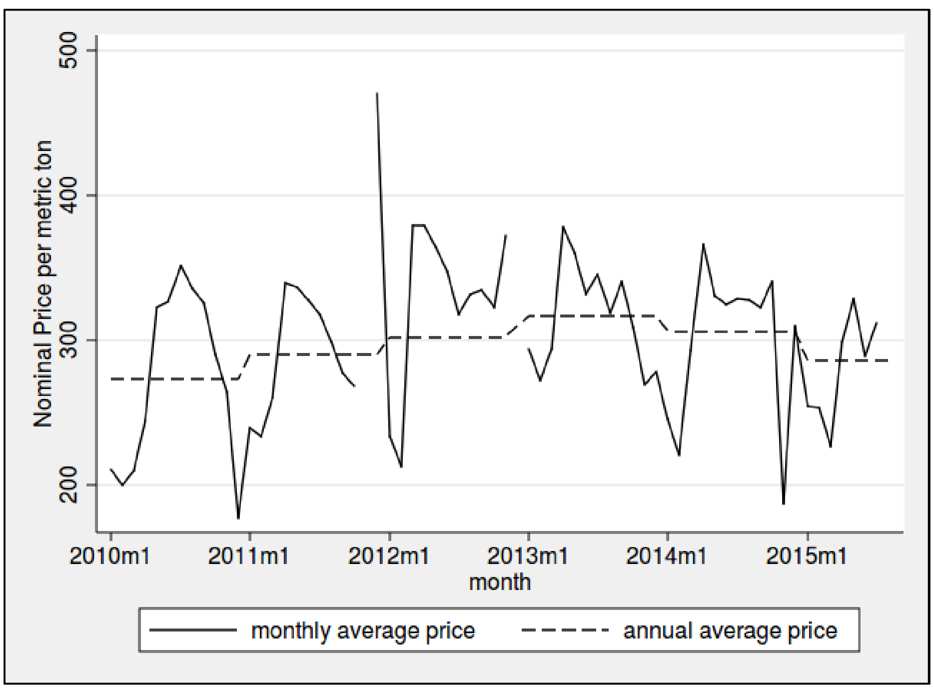


Figure 7 - Average nominal price per metric ton of Atlantic herring, 2010-2015



In the bait market, Atlantic menhaden, managed by the Atlantic States Marine Fisheries Commission, is one substitute for Atlantic herring. Use of menhaden for bait has increased in importance relative to fish meal and oil. Between 2001 and 2012, the percent of total menhaden landings that were used for bait rose from 13% to a high of 28% in 2012 (63,540 mt). In 2013, bait harvest composed approximately 22% of the total menhaden harvest. Menhaden landings for bait have recently dipped due to reductions in allowable catch; landings in 2013 were 35,043 mt, 34% below the average landings during 2010-2012 (52,900 mt) (ASMFC 2015). During 2008-2011, *ex-vessel* menhaden prices ranged from $139-$169 per mt. This is about 33-50% lower than *ex-vessel* herring prices. If the quantity of Atlantic herring supplied into the bait market declines dramatically, more menhaden may be used as bait, moderating the increases in herring prices.

Menhaden is primarily used to produce fish meal and oil. However, the Atlantic Herring FMP prohibits use of herring for fish meal, so herring is not a substitute in the production of those goods.

Atlantic herring is used as bait for many fisheries, such as lobster, tuna, and various recreational fisheries. A more detailed description of the bait sector of the industry is in Amendments 1 and 5 to the Herring FMP. According to NMFS dealer data, 77% of the Atlantic herring landed from 2012-2014 was sold as bait; most of the rest was used for human consumption. Ports in Maine (61%) and Massachusetts (36%) landed 97% of all herring used for bait.

The lobster industry, particularly in Maine, is dependent on herring as a bait source, though it depends on price and availability. A 2008 survey of 6,832 lobster license holders in Maine revealed that 58% of respondents answered ñvery muchò to the question ñCould the supply or price of herring for bait impact your decisions on how to fish?ò (MEDMR 2008). For lobstermen surveyed from Maine, New Hampshire and Massachusetts who harvest in Lobster Conservation Management Area A (inshore Gulf of Maine), herring is the predominant bait source (Table 5).

Table 5 - Bait use in the inshore Gulf of Maine lobster fishery

	Maine							**NH**	**MA**
	Zone A	**Zone B**	**Zone C**	**Zone D**	**Zone E**	**Zone F**	**Zone G**		
Herring	90%	86%	73%	73%	84%	37%	75%	60%	76%
Pogies	3%	2%	0%	15%	14%	39%	11%	4%	13%
Redfish	1%	8%	12%	4%	1%	19%	8%	0%	0%
Racks	1%	2%	1%	2%	0%	1%	1%	26%	6%
Alewives	1%	1%	0%	1%	0%	0%	0%	0%	0%
Other	4%	2%	13%	5%	0%	4%	4%	9%	4%

Source: Dayton et al. (2014).

New Hampshire vessels may be less dependent on herring as a bait source than the aforementioned survey indicates. Atlantic herring is a small percentage of the bait used by these vessels (Table 6), ranging between 1.8% in 2010 and 4.6% in 2005. In terms of herring per trap just in Lobster Management Area (LMA) 1, the most used was in 2005 and the least in 2010. This correlates with overall high and low points in the percent of herring bait used. Historically, Atlantic herring is used for bait by smaller inshore vessels more than larger offshore vessels, because it is typically less expensive; in addition, alternative bait options like skates tend to be preferred for longer soaks in offshore waters.

Table 6 - Bait use in the lobster fishery in New Hampshire

Year	Herring Bait (lbs)	Other Bait (lbs)	Total Bait (lbs)	% Herring of all Bait	# Types of Bait	Herring Per Trap LMA 1 (lbs)
2005	8,200	169,725	177,925	4.6%	11	0.33
2006	9,700	293,125	302,825	3.2%	13	0.20
2007	8,300	226,350	234,650	3.5%	10	0.18
2008	7,658	247,000	254,658	3.0%	12	0.16
2009	8,825	189,690	198,515	4.4%	11	0.25
2010	3,350	181,728	185,078	1.8%	11	0.14
2011	6,100	249,900	256,000	2.4%	9	0.21
Source: NH Fish & Game Department.						

9.0 DEFINITIONS

9.1 TERMS

Overfishing Limit (OFL). The catch that results from applying the maximum fishing mortality threshold to a current or projected estimate of stock size. When the stock is not overfished and overfishing is not occurring, this is usually F_{MSY} or its proxy.

$$\mathbf{OFL \geq ABC \geq ACL}.$$

Acceptable Biological Catch (ABC). The maximum catch that is recommended for harvest, consistent with meeting the biological objectives of the management plan. The MSA interpretation of ABC includes consideration of biological uncertainty (stock structure, stock mixing, other biological/ecological issues), and recommendations for ABC should come from the NEFMC SSC. ABC can equal but never exceed the OFL.

OFL – Scientific Uncertainty = ABC (Determined by SSC)

ABC Control Rule. The specified approach to setting the ABC for a stock or stock complex as a function of scientific uncertainty in the estimate of OFL and any other scientific uncertainty. The ABC control rule will consider uncertainty in factors such as stock assessment issues, retrospective patterns, predator-prey issues, and projection results. The ABC control rule will be specified and may be modified based on guidance from the SSC during the specifications process. Modifications to the ABC control rule can be implemented through specifications or framework adjustments to the Herring FMP (in addition to future amendments), as appropriate.

Annual Catch Limit (ACL). A stockwide ACL accounts for both scientific uncertainty (through the specification of ABC) and management uncertainty (through the specification of the stockwide ACL and buffer between ABC and the ACL). The ACL is the annual catch level specified such that the risk of exceeding the ABC is consistent with the management program. The ACL can equal but never exceed the ABC. ACL should be set lower than the ABC as necessary due to uncertainty over the effectiveness of management measures. The stockwide Atlantic herring ACL equates to the U.S. optimum yield (OY) for the Atlantic herring fishery and serves as the level of catch that determines whether accountability measures (AMs) become effective. The AM for the stockwide ACL, total fishery closure at 95%, reduces the risk of overfishing.

ABC – Management Uncertainty = Stockwide ACL = OY

9.2 ACRONYMS

ABC	Acceptable Biological Catch
ACL	Annual Catch Limit
AM	Accountability Measure
B_{MSY}	Biomass at Maximum Sustainable Yield
FMP	Fishery Management Plan
F_{MSY}	Fishing mortality rate at Maximum Sustainable Yield
GOM	Gulf of Maine
MSE	Management Strategy Evaluation
MSFMCA	Magnuson-Stevens Fishery Conservation and Management Act
NMFS	National Marine Fisheries Service
OFL	Overfishing Limit
OY	Optimum Yield
PDT	Plan Development Team
SSC	Scientific and Statistical Committee

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