# DRAFT Appendix #

## To Amendment 8 to the

## Atlantic herring Fishery Management Plan

## Localized depletion literature review

## By the Atlantic Herring Plan Development Team

### *INTRODUCTION*

A **purpos**e of Amendment 8 to the Atlantic Herring Fishery Management Plan is:

> *"to propose measures to address potential localized depletion of Atlantic herring."*

The corresponding **need** is:

> *"to minimize possible detrimental biological impacts or socioeconomic impacts on other user groups (commercial, recreational, ecotourism) who depend upon adequate local availability of Atlantic herring to support business and recreational interests both at sea and on shore (NEFMC 2017)."*

The term localized depletion has many definitions in the literature, but relative to Amendment 8 to the Atlantic Herring Fishery Management Plan (FMP), the NEFMC **defined** localized depletion as (Amendment 8, Section XXX):

> *"In general, localized depletion is when harvesting takes more fish than can be replaced either locally or through fish migrating into the catch area within a given time period."*

The occurrence of localized depletion, as here defined, suggests that fishing for a prey species (e.g., herring) from a given area would either leave relatively immobile predators (e.g., monkfish) with insufficient prey for some time, or that relatively mobile predators (e.g., cod, tuna, whales) would leave the area in search of alternate prey.

This appendix summarizes the management cases regarding localized depletion, focusing on examples analogous to what the NEFMC is considering, but including other potentially relevant examples of user conflicts within a fishery or precautionary measures to ensure prey availability. In compiling this appendix, the Atlantic Herring Plan Development Team consulted staff of each Regional Fishery Management Council and/or NMFS regional staff to assist in identifying relevant cases, included references submitted by the public during scoping, and conducted its own literature search.

In addition to the management cases, there exists a large body of scientific literature considered by the PDT when developing the DEIS for Amendment 8. Many references were provided by the public as this action has developed. Some contain useful background about the information available concerning the relationships between Atlantic herring and its predators in this region. Others focus on other regions, but may have some degree of applicability. This appendix aims to include an exhaustive list of the references gathered by the PDT and provided by the public.

***MANAGEMENT CASES - CONSTRAINING PREY FISHERIES***

Below are management cases analogous to what the NEFMC is considering, where a management entity considered taking action to constrain a directed fishery for a prey species, addressing concerns that the fishery may be negatively impacting the prey availability for a predator, with follow-on impacts to the user groups of the predator (e.g., directed fishery, ecotourism).

*Squid Management in the Area South of Martha's Vineyard/Nantucket*

The Mid-Atlantic Fishery Management Council (MADMF) is currently developing a "Squid Capacity Amendment" to the Atlantic Mackerel, Squid, and Butterfish FMP, which considers measures to reduce latent longfin and *Illex* squid permits and to modify how Trimester 2 (May-August) of the longfin squid fishery is managed. In response to public scoping, the Council considered an additional objective to consider a longfin squid buffer zone (i.e., time-area closure) in the area south of Martha's Vineyard/Nantucket. Scoping comments indicated public concern that longfin squid fishing effort concentrated in this area may be negatively impacting fishing for predators in Nantucket Sound, due to localized depletion of prey and/or bycatch of recreationally-targeted species. In June 2016, the FMAT developed preliminary analysis of predators (striped bass, bluefish, black sea-bass, summer flounder) and prey (longfin squid, alewife, blueback herring, butterfish) in Nantucket Sound. The FMAT had difficulty linking any trends in abundance between predators and prey, indicating that it "will likely not be able to deduce any cause and effect associations given the myriad of factors that impact local fish abundances" (MAFMC 2016). In December 2016, the MAFMC decided to discontinue developing alternatives regarding localized depletion in this action, but may reconsider the issue in a later action. Rationale included the difficulty with quantifying impacts and a desire to focus on addressing other issues, some of which may limit squid effort in the area of interest (MAFMC 2017).

In 2010, the Massachusetts Division of Marine Fisheries (MADMF) issued letters of authorization (LOA) to a small number of draggers to fish within state waters south of Martha's Vineyard and Nantucket after the regular season that occurs April 23 – June 9, keeping the fishery open through December 31. In January 2014, MADMF proposed codifying this extension into regulation, rather than annually issuing LOAs, after receiving no public opposition to doing so. The extended season for the fishery occurred in 2014. In December 2014, MADMF proposed rescinding this exemption, prompted by concerns raised by island fishermen on the impacts of squid fishing on forage availability, benthic habitat impacts, and bycatch (MADMF 2014). In February 2015, a memo from the Director indicated that, "While there is similarly no concrete evidence of impacts on forage availability, it's commonsense that any consistent level of fish extraction concentrated on a single species will cause some amount of local depletion of that species" (MADMF 2015b). For 2015, as well as 2016, MADMF modified the regulation to extend the small-mesh trawl fishery by about a week after June 9, rather than through the end of the year, balancing user conflicts with the late run of squid and continued commercial interest in the squid fishery (MADMF 2015a; 2016).

*Atlantic menhaden*

In 2005, the Atlantic States Marine Fisheries Commission approved Addendum II to Amendment 1 of the Atlantic Menhaden Management Plan to implement a catch cap for Atlantic menhaden in Chesapeake Bay. This action was taken because the fraction of coast-wide landings was increasing for Chesapeake Bay and there was concern for the potential for localized

depletion. The cap was set equal to recent average landings and was effective for 2006-2010. At the time, the ASMFC determined that there was insufficient scientific data to satisfactorily determine whether localized depletion is occurring in the Bay or to identify specific reasons for predator finfish deficiencies or low larval menhaden recruitment. To address this, Addendum II established research priorities it examine the possibility of localized depletion (ASMFC 2005).

Subsequently, the catch cap has remained in place, extended through a few subsequent ASMFC actions, though the absolute value of the cap has changed relative to the stock-wide catch limit (ASMFC 2009; 2012). NOAA Chesapeake Bay Office, ASMFC, Maryland, and Virginia and others initiated the Atlantic Menhaden Research Program to address the ASMFC research priorities (ASMFC 2009). In 2009, the Center for Independent Experts convened a peer review of the program and projects funded to date (about 15). The three reviewers concluded that the projects were valuable and well executed, some studies pointed to the possibility of localized depletion, but on the whole, it had not yet been demonstrated to occur in Chesapeake Bay (Haddon 2009; Maguire 2009; Roel 2009). This review was the culmination of the research program, and the ASMFC has not been involved in sponsoring any additional localized depletion-related projects in Chesapeake Bay (M. Ware, ASMFC, pers. comm., 2017).

*Other references related to Atlantic menhaden*

- In 2006-2008, menhaden larval ingress, age at ingress, feeding incidence and success, and growth all experienced some degree of inter-annual variability in Chesapeake Bay (Lozano 2011)
- ASMFC research program further described by the EBFM Menhaden Species Team (2009).

*North Pacific Stellar Sea Lions and other predators*

The western Distinct Population Segment (WDPS) of Steller sea lions has been listed as endangered since 1997. Factors for the decline may include intentional shooting, disease, ecosystem change, and interactions with fisheries (competition, disturbance, direct and incidental mortality; https://www.npfmc.org/bering-seaaleutian-islands-groundfish/). Witherell et al. (2000) review the measures taken (as of 2000) by the North Pacific Fishery Management Council (NPFMC) to reduce potential impacts of localized depletion of prey for Stellar sea lions, as well as Pacific walrus. Regulations have focused on reducing potential effects of competition, and minimizing localized depletion of their prey (e.g., pollock, Pacific cod, Atka mackerel, salmon, octopus). There are protections for terrestrial habitat (e.g., no-transit zones near certain rookeries/haul-outs), but the most consequential measures spread the catch of pollock over time and space. Gulf of Alaska pollock are managed in four seasonal allocations across four areas. In contrast, cod is managed with two seasons and all other groundfish with one season across two areas.

Although studies have correlated Steller sea lion shore-based habitat with forage fish "hot spots," (Gende & Sigler 2006), there has not been scientific consensus regarding impacts of fishing on Stellar sea lions. Conners and Munro (2008) investigated the suspicion that the trawl fishery for Pacific cod was causing localized depletion, with negative consequences for Stellar sea lions in the Bering Sea. For this study, localized depletion was defined as the hypothesis "that intense fishing pressure may cause small-scale effects on local densities of the target fish—effects that are disproportionate to the managed overall harvest mortality rate." Their results were

inconsistent with the "hypothesis of strong stationary localized depletion," that the spatial scale of the current no trawl zones were was much smaller than "the relevant scale of fish movement".

In 2010, NMFS issued an ESA section 7 biological opinion (BiOp), which found that NMFS could not insure that the authorization of the groundfish fisheries was unlikely to jeopardize the continued existence of the WDPS of Steller sea lions or adversely modify or destroy designated critical habitat. Accordingly, NMFS issued an interim final rule with restrictions to the Atka mackerel and Pacific cod fisheries to reduce prey competition.

A legal challenge to the interim final rule resulted in NMFS preparing an EIS to allow sufficient public participation under the National Environmental Policy Act (NMFS 2014). The 2010 BiOp was subject to several external scientific reviews, which were all critical of the scientific justification used therein, indicating that there was insufficient evidence for a negative correlation between fishing and sea lions – a conclusion on which the BiOp was based (Bernard et al. 2011). NMFS did prepare an EIS, in consultation with the NPFMC, and in April 2014, NMFS issued a new BiOp with less restrictive measures for the fisheries, concluding that these measures would not jeopardize the continued existence of the WDPS of Steller sea lions (NMFS 2014).

> *"BC's [British Columbia's] area allocation of TAC was done for biological reasons as a precautionary measure to prevent excessive concentration of fishing effort and localized depletion of fishing resources near fishing ports. Stakeholders in BC were concerned that the IVQ trawl fishery entitlement and tradable IVQ shares could allow such concentration of effort" (PFMC 2004).*

<u>*Antarctic krill*</u>

The fishery for Antarctic krill is managed by the Commission for the Conservation of Antarctic Marine Living Resources (external to the U.S. fishery management system). In the late 2000s, the krill fishery had become more spatially and temporally concentrated (Bransfield Strait within Subarea 48.1) due to changes the krill population distribution (impacted by sea-ice cover and water temperature; ASOC 2011). The CCAMLR considered options for dividing the krill catch limits among small-scale management units, balancing a risk to predator populations and fishery performance (Hewitt et al. 2004; Hill et al. 2009; Watters et al. 2008). Since the 2010-2011 fishing season, a krill catch limit has been is set within four management subareas (Areas 48.1 – 48.4) to avoid concentrating catch in any one area and reducing the risk of impacting local ecosystems. In setting the trigger level for 2016-2017, the Commission noted:

> *"the need to distribute the krill catch in Statistical Area 48 in such a way that predator populations, particularly land-based predators, would not be inadvertently and disproportionately affected by fishing activity"(CCAMLR 2016, p. 219).*

It does not appear that other management measures (beyond a catch limit) are in place within a subarea (e.g., time/area closures), to prevent localized depletion. Also interesting is the Commission's recognition of the need to develop management based on data availability:

> *"In 2015, the Commission agreed that we need management approaches that are not dependent upon data unlikely to be available at the spatial and temporal scales required for a particular management approach (e.g. regular estimates of total krill biomass and total predator demand for krill for the whole of the Scotia Sea). This might seem pretty obvious, but it reflects the need to design management processes that are practical and can be implemented in the real world" (CCAMLR 2017).*

*Other references related to Antarctic krill*

- A model with spatial structure was developed to address concerns of localized depletion of krill in the vicinity of land-based predator breeding colonies (Plagányi & Butterworth 2012).
- A behavioral model, used previously to understand the interactions between penguins and krill, was extended to determine the indirect effect of krill fisheries on penguin foraging success and behavior in adjacent breeding sites (Alonzo et al. 2003).
- Constable and Nicol (2002) discuss the principles and approach required for developing small-scale management units that account for predators' needs when managing the Antarctic krill fishery.
- Hinke et al. (2017) assessed the degree of overlap between predators and the Antarctic krill fishery to examine how different data aggregations affect the extent and location of overlap.
- Santora et al. (2009) "found a negative relationship between abundance and patchiness of krill and predators, indicating that when krill is less abundant, its predators are less abundant and concentrated."
- Relationships between penguin and krill (Werner 2015).
- Croll and Tershy (1998) demonstrated seasonal and spatially overlaps of the krill fishery with peak penguin and fur seal prey demands, which may affect prey availability to penguins and fur seals.

*North Sea sand lance (Sand eel)*

Several references from the recent workshop on the science and management of sand eels in the North Sea [not in this document].

***MANAGEMENT CASES - PREVENTING DEVELOPMENT OF PREY FISHERIES***

The following examples are management actions taken to help ensure prey availability, though not directly a result of localized depletion concerns.

*North Pacific forage fish*

In 1997, the NPFMC prohibited directed fishing for forage fish including capelin and euphausiids (krill), though exempted herring, because of an existing fishery (Witherell et al. 2000).

*Pacific krill*

In 2006, the Pacific Fishery Management Council (PFMC) proposed a ban on the commercial fishery for all krill species in west Coast federal waters. At the time, there was no krill fishery in PFMC waters, or in California, Oregon or Washington state waters. There was no specific concern about localized depletion, but the PFMC made this recommendation in recognition of the importance of krill as a food source in the marine food chain. This proposal was implemented by NMFS in July 2009, noting that there was no indication that the status of the krill resource has contributed to status of predator species (NOAA 2009).

*Mid-Atlantic unmanaged forage fish*

NMFS is accepting public comment through May 30, 2017 in an omnibus amendment proposed by the MAFMC to prevent the development of new, and the expansion of existing commercial fisheries on certain forage species.

***MANAGEMENT CASES - RESOLVING WITHIN-SPECIES USER CONFLICTS***

Below are examples where a management entity considered taking action to constrain a directed fishery for a species, to address concerns about the availability of that species for a fishery by another user group. Again, all cases identified by staff of other regions are included here.

*Dolphin and wahoo management*

The original Dolphin and Wahoo FMP established by the South Atlantic Fishery Management Council (SAFMC) in 2004 included concerns about localized depletion in its problem statement and FMP objectives. However, SAFMC staff indicates that the SAFMC has not taken a specific action in this FMP to address localized depletion (K. MacLauchlin, pers. comm., 2017).

> A SAFMC concern: *"Owing to the significant importance of the dolphin/wahoo fishery to the recreational fishing community in the Atlantic, the goal of this fishery management plan is to maintain the current harvest level of dolphin and insure that no new fisheries develop. With the potential for effort shifts in the historical longline fisheries for sharks, tunas, and swordfish, these shifts or expansions into nearshore coastal waters to target dolphin could compromise the current allocation of the dolphin resource between recreational and commercial user groups. Further, these shifts in effort in the commercial fishery, dependent on the magnitude (knowing that some dolphin trips may land over 25,000 pounds in a single trip), could result in user conflict and localized depletion in abundance."*
>
> A problem the FMP aims to address: *"Localized reduction of fish abundance due to high fishing pressure."*
>
> A FMP objective: *"Address localized reduction in fish abundance. The Councils remain concerned over the potential shift of effort by longline vessels to traditional recreational fishing grounds and the resulting reduction in local availability if commercial harvest intensifies."* (Plummer et al. 2012; SAFMC 2003).

*Snapper grouper management*

The Snapper Grouper FMP was established by the SAFMC in 1983. In 1994, through Amendment 7 to the FMP, the following was added to the list of problems:

> *"Localized depletion where a species' abundance in an area is reduced by high fishing effort can cause conflict among fishermen."*

Amendment 7 indicates that "high fishing mortality rates have resulted in localized depletion of some species in certain areas" and that overfishing rates for certain areas is higher than the rate for the range of the species. However, no specific examples were included. Snapper and grouper species were "suspected to be experiencing localized depletion." Amendment 7 also indicates that:

> *"The issue of localized depletion needs to be addressed. However, the evidence to support actions to institute corrective measures is lacking."*
>
> *"The Council approved adding this new problem so that it can be evaluated and if action is needed, necessary regulation could be implemented through the framework."* SAFMC (1994, p.82-83).

The objective, "Evaluate and minimize localized depletion" has remained ever since. However, SAFMC staff indicates that the SAFMC has not taken a specific action in this FMP to address localized depletion (K. MacLauchlin, pers. comm., 2017).

*Alaska Halibut*

Meyer and Stock (2001) has some background on addressing localized depletion concerns in the late-1990s for Alaska halibut, and associated user conflicts among charter and commercial harvesters.

### *OTHER REFERENCES POTENTIALLY PERTINENT TO AMENDMENT 8*

Below is a list of references considered by the PDT when developing the DEIS for Amendment 8. Many references were provided by the public as this action has developed. Some contain useful background about the information available concerning the relationships between Atlantic herring and its predators in this region. Others focus on other regions, but may have some degree of applicability. To the extent possible, the PDT included some of this information in the analysis of potential impacts of alternatives considered in this action.

*Groundfish*

- Northwest Atlantic
    - Relationship between cod and herring documented in historical records (Ames 2010).
    - Richardson et al (2014) described and the availability of herring and sand lance. Haddock predation on herring eggs (Richardson et al. 2011).
    - Herring and other prey for gadids (Ames & Lichter 2013).
    - Sherwood et al. (2007) found that "among and within populations [of Newfoundland and Labrador cod] the benefits of a more pelagic diet in medium-sized (30–69 cm) cod included higher somatic condition, higher liver index (lipid stores) and greater spawning potential (decreased incidence of atresia)."
- Other
    - Neat et al. (2014) provide evidence that "cod living around the British Isles are comprised of at least one more distinct population unit that is currently recognized for stock management purposes. Failure to recognize this complexity of stock structure in past management plans is likely to have been a contributory factor to the over-exploitation of cod stocks around the British Isles."
    - Hanselman et al (2007) investigated localized depletion for three Alaska rockfish species (Pacific ocean perch, northern rockfish, and dusky rockfish), which are sedentary and patchy population distributions. The study examined fishery CPUE within small areas between 1991-2004. Pacific Ocean perch exhibited intra-annual localized depletion (i.e., CPUE declines) most often, but the depletion did not persist across years. Northern and dusky rockfish showed less depletion and occasional significant increases in CPUE occurred. Northern rockfish showed potential serial depletion in one area. However, these results could be affected by hyperstability (large local populations), migration, or switching of target fisheries mid-year.
    - Barbeaux et al. (2014) estimated location and scale specific fishing exploitation rates of eastern Bering Sea walleye pollock.

*Bluefin tuna*

- Tuna diet
  - Golet et al. (2015) found that tuna prefer larger herring relative to more herring.
  - Butler et al. (2015) demonstrate feeding activity of Atlantic bluefin tuna on the Gulf of Mexico spawning grounds, with diets including teleosts, cephalopods, crustaceans and a pelagic tunicate.
  - Logan et al. (2015) compared diet composition of tuna between the late 1980s to early 2000s.
  - Other (Chase 2002; Estrada et al. 2005; Logan & Lutcavage 2013; Logan et al. 2011; Logan et al. 2013; Logan et al. 2007).
- Tuna distribution/migration
  - (Brill & Lutcavage 2001; Galuardi & Lutcavage 2012; Golet et al. 2013; Gutenkunst et al. 2007; Lutcavage et al. 2000; Lutcavage et al. 1997; Lutcavage & Kraus 1995; Schick et al. 2004; Schick & Lutcavage 2009; Weber et al. 2013).
- Tuna fishery
  - (Fromentin & Powers 2005).
- Tuna other
  - (Chapman et al. 2011; Goldstein et al. 2007; Golet et al. 2007; Heinisch et al. 2014; Logan et al. 2008; Logan & Lutcavage 2010; Logan & Lutcavage 2008)

*Whales/marine mammals*

- Prey consumption
  - (DeMaster et al. 2001; Friedlander et al. 2009; Kenney et al. 1997; Matthiopoulos et al. 2008; Payne et al. 1990)
- Relationship with sand eels
  - (Payne et al. 1986)
- Distribution/feeding behavior
  - (Hazen et al. 2009; Parks et al. 2014; Piatt & Methven 1992; Stevick et al. 2006; Ware et al. 2014; Weinrich et al. 1997; Wiley et al. 2011)
- Whale watch industry
  - Localized depletion theory examined by analyzing the search times of whale-watching vessels relative to herring fishing; a moderate impact found of herring fishing on search times, but strong evidence that search times decrease when and where herring are spawning (Lee 2010).
- EBFM
  - (Heltzel et al. 2011)

*Sea birds*

- Northwest Atlantic
  - Relationship with Atlantic herring
    - (Breton & Diamond 2014; Hall et al. 2000; Kress et al. 2016)
  - Other (Gaston et al. 2009; Glass 2000; Heinemann 1992; Nisbet 2017; Safina et al. 1988)
- North Sea
  - Relationship with sand eels
    - (Daunt et al. 2008; Frederiksen et al. 2008; Frederiksen et al. 2004).

- Marine Protected Areas
    - A 2012 special issue of *Biological Conservation* on the role of sea birds relative to Marine Protected Areas (particularly Garthe et al. 2012; Ludynia et al. 2012; Thaxter et al. 2012): http://www.sciencedirect.com/science/journal/00063207/156
- Sea birds other
    - (Bertrand et al. 2012; Cury et al. 2011; Goyert 2015; Paredes et al. 2012; Rindorf et al. 2000; Robertson et al. 2014; Rock et al. 2007)

*Atlantic herring*

- Consumption by predators (Overholtz & Link 2007).
- Role in ecosystem (Bakun et al. 2009)
- Stockwell, J., *et al.,* "Effects of Fishing on Herring Aggregations," NOAA Project Code 08-HERR-03, at 1 (Undated).

*Other*

- Fishery impacts
    - Hilborn et al. (2017) explored the impact of fishing low trophic level "forage" species on higher trophic level marine predators including other fish, birds and marine mammals
    - Cianneli et al. (2013) reviewed the theory, consequences and evidence of eroding population spatial structure in harvested marine fishes.
    - Englehard et al. (2008) explored the effects of fishing mortality versus natural predation on sandeels
    - Walker (1999) examined density-dependent responses to the effects of shark stock reduction.
    - Bearzi et al. (2008) found that the decline in short-beaked common dolphins from western Greece was caused largely by prey depletion resulting from overfishing.
    - Historical baselines of human impacts (Erlandson & Rick 2010; Thornton et al. 2010; Thurstan et al. 2016)
    - Potentially coupled with climate change (Last et al. 2011; McCay et al. 2011; Trenkel et al. 2014)
    - Brazilian monkfish fishery (Perez et al. 2005)
- Stellwagen Bank (NOAA 2010)
- Managing forage fish (DFO 2009; Essington & Plagányi 2014; Pikitch et al. 2012)
- Managing stock components/spatial structure (Kerr et al. 2017; Molton et al. 2013; Ying et al. 2011)
- Role of marine protected areas (McGilliard et al. 2011)
- Shark philopatry (Hueter et al. 2005)

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