Atlantic States Marine Fisheries Commission
Habitat Committee

November 7, 2022
9:30 am – 4:00 pm

Agenda

The times listed are approximate; the order in which these items will be taken is subject to change; other items may be added as necessary.

1. Welcome and Introductions (*R. Babb*)	9:30 am
2. Committee Consent (*R. Babb*) [Briefing material {BM} 1, 2] • Approval of Agenda • Approval of Spring 2022 Meeting Notes	9:40
3. Atlantic Coastal Fish Habitat Partner Update (*L. Havel*)	9:45
4. Northeast Regional Habitat Assessment Update (*J. Coakley and M. Bachman*)	10:15
5. Bluefish Benchmark Stock Assessment Habitat Section Update (*L. Havel and K. Wilke*) [BM 3]	10:35
6. Status Updates (*L. Havel, C. Enterline, R. Babb*) [BM 4, 5, 6] • Habitat Management Series: Acoustics • *Habitat Hotline Atlantic* • Fish Habitats of Concern	10:50
7. Lunch (on your own)	12:00 pm
8. East Coast Climate Change Scenario Planning Update (*T. Kerns*)	1:15
9. Species Assignments Check-in (*R. Babb & T. Kerns*) [BM 7]	1:30
10. Overview of Climate Resiliency Work in New Jersey (*M. Yepsen*)	2:00
11. Aquaculture Update from NOAA Greater Atlantic Regional Fisheries Office (*K. Madley, M. Bachman*)	2:45
12. Other Business (*R. Babb*) • Elect Chair and Vice Chair **Action**	3:30
13. Adjourn	4:00

**The field trip will begin at 8:30 on Tuesday morning. Please meet in the lobby by that time to ensure we can visit each planned site. We will return to the hotel by 12:15 pm.*

The meeting will be held at The Ocean Place Resort (1 Ocean Boulevard, Long Branch, NJ; 732.571.4000)

Atlantic States Marine Fisheries Commission
Habitat Committee Meeting Notes
May 23, 2022
Virtual Meeting 9 am – 4 pm

Members present: Zina Hense (DE), Jimmy Johnson (Chair, NC), Lou Chiarella (NOAA GARFO), Jessica Coakley (MAFMC), Mark Rousseau (MA), Kate Wilke (TNC), Russ Babb (Vice Chair, NJ), Phil Colarusso (EPA Region 1), Eric Schneider (RI), Michelle Bachman (NEFMC), Sharleen Johnson (SC), Marek Topolski (MD), Claire Enterline (ME), Josh Carloni (NH), Rob LaFrance (CT), Alexa Fournier (NY), Cindy Cooksey (NOAA SERO), Dave Dippold (PA), Kent Smith (FL), Paul Medders (GA), Wilson Laney (NCCF)

Others present: Dewayne Fox (Delaware State University), Dave Kazyak (USGS), Dave Secor (University of Maryland Center for Environmental Science), Shannon White (USFWS)

Staff present: Lisa Havel, Toni Kerns, Deke Tompkins

1. Welcome and introductions (*J. Johnson*)
   Welcomed new Habitat Committee member Zina Hense, who is replacing Jeff Tinsman in his retirement.

2. Committee consent (*J. Johnson*)
   The agenda was approved by consensus.

3. The state of Delaware River sturgeon (D. Secor, *D. Fox, D. Kazyak*)
   presentations sent to Habitat Committee members – for internal use only. Do not share.

   Atlantic sturgeon abundance peaked around 1888. Industrial scale fishing, technological developments including caviar processing and fishing gear technology contributed to declines.

   In the late 19th century they were ranked only 2nd to shad in terms of value.

   They looked at CPUE as a way to get at historical abundance.

   The 1997 ASMFC stock assessment was trying to get reference points, including female abundance. The sum catch over time series is a deterministic approach and probably an underestimate. These days we'd probably use a more probabilistic approach. Others have done other methods.

   Why did Delaware dominate the historical populations? Maybe part of it was bias of agents surveying. But there is a lot of historical evidence that the Delaware was the biggest caviar fishery.

   There's tremendous diversity of watershed attributes and estuarine attributes. We've discovered a lot of Atlantic sturgeon populations. There has been unexpected resilience of these populations. What do the different watershed and tributaries pose as habitat risks? There are big city impacts on some of these watersheds. Naticoke creek is a small watershed with local impacts of shoreline development. Old history matters, but there is recent legacy of habitat impacts in each of these watersheds.

   A single sturgeon from the river was almost as valuable as a car in 1923.

   Genetic work showed the Hudson River stock 3x more prevalent than the Delaware River fish. Kent asked if there was any work looking at genetic depression. Dave said it doesn't look like there is right now.

There are multiple independent lines of evidence suggesting a population size of hundreds of individuals.

Adults and subadults mix extensively in the coastal environments. Gill net incidental catch is shared among DPSs. Within the river systems, it is DPS-specific threats.

The Delaware River is the largest freshwater port system in the world, and is an amazing industrial complex. But it is also the longest undammed river and supports Atlantic sturgeon populations.

The vessels require low tide to pass under the bridges, leaving very little room for the fish underneath.

Sturgeon like the fast flowing water in the channels. There is no place for them to go when the ships come in and either suck them into propellers or hit them. The fish don't exhibit behavioral avoidance. They spawn on rocky spawning habitat – rocky areas overlaid with vessel transit. There are a lot of vessel strikes.

It's impossible to sample eggs and larvae (too busy?), so researchers have to deduce where the spawning grounds are.

Right now there is a blame game. USACE says they only deepen the river, and it's the ships that are the problem. This punts the issue to the Coast Guard. Dewayne followed a vessel around for several days and found they go back and forth a lot. Large tractor tugs also strike sturgeon. They are also too expensive and ships have to maintain their own propulsions.

There is suitable spawning habitat (gravel/rock) out of the shipping/navigation channel. But how do we get the fish to use it? Maybe they can establish no-passing zones? That might be feasible. There have been new spawning reefs created for some lake sturgeon that have worked.

It was asked if ASMFC can push this issue. There's only so much NOAA Fisheries and the presenters can do.

Kent said there are a lot of parallels to manatee habitat use. They can slow boats down, create other safe areas of really attractive habitat. They need to reduce the amount of interaction.

Wilson asked if the sturgeon are spawning within Critical Habitat in the Delaware – yes, it's all Critical Habitat.

ASMFC needs to designate some areas of Fish Habitat of Concern – it seems that we have enough information to do that. Dewayne has mapped hot spots. Sand wave or sand dune habitats are pretty important (and sometimes are targeted for beach renourishment). Sturgeon are acting like 8 ft rainbow trout. They hide behind the sand dune/sand wave habitat and then when the tide turns, they go upstream. Others have been looking at this at the mouth of the Chesapeake as well. Right outside the mouth of the Delaware Dewayne knows of 5 DPSs gathering.

Wilson will consult with the presenters on FHOC designations.

4. <u>ACFHP update (*L. Havel*)</u>
ACFHP was working with a fundraising consultant. They need an arm that can accept donations. Beyond the Pond is the branch of NFHP that can accept donations, but they don't have reliable infrastructure for grant management or for fundraising. Lisa met with the Beyond the Pond Board to

figure out how they can properly administer funds and fundraise. There are two different needs and two different staff are needed.

ACFHP is still really struggling to find the 1:1 operational match. In a year it's going to be a big problem. Lisa has been spending a lot of time on NFHP conservation priorities and Board meeting planning and revisions to documents over the last 1.5 years. This is hope that ACFHP and NFHP can start functioning properly under the new ACE Act.

NFHP is find that a lot of the infrastructure funding is going through NFWF or the agencies directly for infrastructure funding. It doesn't seem like agencies will be leaning on NFHP for input or to administer any of the funds. The NFHP Board Chair voiced his disappointment in that. ACFHP is still working on having a database of projects ready to fund. The Atlantic Coast Joint Venture shared their project database, and there's a lot of overlap with ACFHP goals. It has over 100 projects in it.

AFS magazine will be featuring a monthly article highlighting a different Fish Habitat Partnership each month.

5. Northeast Regional Habitat Assessment update (*M. Bachman, J. Coakley*)
presentation sent to Habitat Committee members

Here is the current link to the Shiny App displaying NRHA results - if people want to have a look: https://nrha.shinyapps.io/sandbox/_w_a00c51bd/#!/.

Communications related to rollout of NRHA products may be helpful to TCs, Stock Assessment workgroups, science group at ASMFC (Jessica will schedule a call—they may be interested in the tools).

6. Species assignments check-in (*L. Havel/T. Kerns*)
The striped bass amendment passed at the spring meeting. The striped bass report to Congress should be out soon.

Kate noted there are big changes in the bluefish population recently, especially in the Chesapeake Bay. It's more likely due to habitat than fishing. No one volunteered ideas on what actions should be taken by the Habitat Committee.

7. Habitat Hotline 2022 (*L. Havel*)
Claire offered the idea of offshore wind development impacts to habitat. This would be good to coordinate with the release of the acoustics document, which will likely be next year.

Kent said we might also talk about other renewables. Kinetic energy and marine/estuarine environments (tidal energy, wave energy, harnessing the Gulf Stream). There are other renewables that are coming in to play.

Commissioners are interested in seeing the Commission be more active in offshore wind (says Wilson). Toni isn't sure where the Commission is going to head here…some are interested in the Commission hiring a staff member to work on wind, but that would take funding. Keeping track of wind takes more than just one person. Wilson suggested we could ask the Commissioners about how they would like to see this committee involved/weighing in on offshore wind. What should the specific focus be for the Habitat Hotline?

Russ: NJ state agency is doing a lot of the cooperating/consulting work on offshore wind and it's sucking up staff time. Three draft EISs, monitoring guidance, etc.

Eric asked: If Offshore Wind: States may have permitting input on cable laying and armoring (materials?), so perhaps best practices or considerations might be helpful. In addition, EMF and fish/crustacean monitoring pre-post construction. Offshore: is there a position on foundation decommissioning (there may not be consensus from industry)?

From Kent: we might be able to learn from the oil industry structure decommissioning. There has been a big push to cut off superstructure and leave remaining sub-structure in place as artificial reefs. There is traction for this in the Gulf of Mexico on behalf of the regulatory agencies. I would imagine similar considerations would be made for wind structure foundations.

Lisa reminded everyone that we are talking about a high-level Habitat Hotline, not an in-the-weeds wind paper. HH should be more warm and fuzzy—don't want it to get unruly. (Russ)

What is it that we want the general public to know? Easy to read public synopsis?

Russ suggested nature based solutions and resilience/living shorelines.

Maybe something to tie into FHOC doc?

Lisa said there is infrastructure funding available – once in a generation—is there something there?

Claire - Maine will have a lot of projects lined up next year—right now lots of unknowns as far as what we might do (next year maybe?)

Alexa – we have a bond act coming up if it passes would be lots of funding for living shorelines, habitat restoration.

Kent – lots of prioritizing going on right now for the funding that will be available—what type of habitat and where—we could have a discussion about how we are setting priorities. RAWA funding? It will be a lot of "neglected" or non-game species—not sure how much will go to aquatic habitat work. FL is collaborating with partners to work collaboratively on largescale projects and see who has the capacity.

Russ: Claire is spot on. I think there could be a lot to talk about esp. with RAWA possibly next year with a lot of potential habitat implications.

Most state agency folks think this might be a topic better suited for 2023.

What IS coastal resilience? How does it feed into habitat and coastal restoration? Upcoming funding opportunities to undertake projects and address these topics and pull it all together. Habitat threats (e.g. Dewayne's presentation on sturgeon). Take a look at all state wildlife action plans and look at species of greatest conservation need and figure out how many are ASMFC species. That would help us focus on those species and threats to them. Claire says Maine has some SGCN that are ASMFC species.

Phil suggested: How to create resilience in seagrass to create resilience to climate change. Learning from coral communities. Genetics? How to create resilience in these important habitats.

Other ideas:
Coastal development
Pollution
Marine debris (without going down climate change rabbit hole/overlapping too much with last year's HH)

8. Habitat Management Series: Acoustics document
   We wanted it to be a useful document for managers on acoustics. Michelle, Jessica, Brian Hooker, others worked on the outline and starting draft. They turned it over to a contractor and it didn't turn out how they wanted. Marek helped everyone gather references and re-jig it. It still doesn't fit what many folks were looking for—including Jessica and Lou. Jessica doesn't have more energy to spare for it (nor do others).

   Maybe nail down a framework of what we want to see?—well, there is an original outline and Michelle helped restructure the doc according to that outline. Wilson thought we were explaining why sound is important for fishes in their environment, what do they use sound for? What sources of sound interfere with those uses? Third section: how do you mitigate adverse sound on fish?

   Phil comments: the mitigation section has value independent of the source of noise. If the expectation is to raise awareness so people will think about it during project review, then this doc does it. If you are thinking about it in a regulatory setting where you want quantitative ability to affect projects, it's not at that point. Phil shares both Wilson and Lou's thought…it would be helpful to get more quantitative. E.g., they've been dealing with noise issues related to blasting of rock in a navigation improvement project in Boston. The impact of noise from this project has led to the loss of eelgrass. There is a study that shows cellular damage to SAV from levels of noise consistent with a typical medium sized vessels.

   Lou: As an aside- We need to reevaluate how/when we use contractors to develop reports for us. We seem to have too many examples of the processes going poorly and getting products that are not really what we paid for. We need a better process to develop statements of work and holding contractors accountable. It also takes way too long to get reports drafted and completed in a timely manner. Lou is speaking out of frustration. There is some utility and need to be clear on what it is and what it isn't and we should just get it out.

   There's a need to include activities beyond vessel operations: pile driving is a big one. Construction-based impacts are some of the most important that Lou is seeing.

   Shared folder for related literature:
   https://drive.google.com/drive/folders/1PQId37LgcvYHYK7eDcfX1MMHy9q0MHxE

   Arthur Popper from UM and Lyndie Hice-Dunton from ROSA are working on this effects of sound on fishes: https://www.nyetwg.com/_files/ugd/78f0c4_275f9f2ac5e84b07ae420e0cf5b5b2eb.pdf

   Claire volunteered to help with re-formatting the document. We will work to reframe the introduction to what is written in the rest of the document, acknowledging what this document does and does not cover.

9. Climate Change Document
   Once Lisa received the Connecticut spreadsheet information, she will update the spreadsheet, create the graph, and write an introduction about how much more work is happening now compared to our last publication in 2018. This will likely be ready by the August meeting.

10. Fish Habitats of Concern
    Josh will re-word the lobster FHOC so more specific areas within Southern New England are designated.

    For Atlantic croaker, the Committee decided to remove any policy recommendations, as well as any information on bycatch.

The Commission at times struggles with dealing with habitat impacts to species…trying to provide an instep for these species. Each year the Commission does a traffic light for some species. HC could flag habitat issues to Lisa. Then the Habitat Committee can be brought into the Board meeting to remind the Board of these habitat impacts, e.g. bycatch of spot and croaker and habitat issues. That would be a good time for the Board to consider policy based on habitat issues.

Wilson will finish writing the sturgeon designation, and then Lisa will share it with the TC.

Next steps: Species leads will review and accept the changes for each of the FHOC designations, based on TC edits and discussion from today.

11. Other Business (*J. Johnson*)
    Circled back to Habitat Hotline discussion and agreed to having a 1-hr call to finalize theme, lead, and articles. Lisa will send a Doodle poll to select a date.

12. Adjourn 4:00

B3.4.5 Habitat Description

Adult and juvenile bluefish are found primarily in waters less than 20 meters (m) deep along the Atlantic coast (Shepherd and Packer 2006). Juveniles may be estuarine dependent (Munch 1997) although they also occur in nearshore ocean waters (Taylor et al. 2006); juvenile habitat use may vary by cohort (Taylor et al. 2007; Wuenschel et al. 2012). Adults use both estuarine and ocean environments and favor warmer water temperatures although they are found in a variety of hydrographic environments (Ross 1991; Shepherd and Packer 2006; Wuenschel et al. 2012). Bluefish can tolerate temperatures ranging from 11.8°-30.4°C, however they exhibit stress, such as an increase in swimming speed, at both extremes (Olla and Studholme 1971; Klein-MacPhee 2002). Temperature and photoperiod are the principal factors directing activity, migrations, and distribution of adult bluefish (Olla and Studholme 1971, Taylor et al. 2007).

Literature Cited

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Munch, S. 1997. Recruitment dynamics of bluefish, *Pomatomus saltatrix*, on the continental shelf from Cape Fear to Cape Cod, 1973-1995. M.S. thesis, State University of New York at Stony Brook, NY, 127 p.

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Taylor, D.L., Nichols, R.S., and K.W. Able. 2007. Habitat selection and quality for multiple cohorts of young-of-the-year bluefish (*Pomatomus saltatrix*): Comparisons between estuarine and ocean beaches in southern New Jersey. Estuarine, Coastal and Shelf Science 73:667-679.

Wuenschel, M.J., Able, K.W., Buckel, J.A., Morley, J.W., Lankford, T., Branson, A.C., Conover, D.O., Drisco, D., Jordaan, A., Dunton, K., and D.H. Secor. 2012. Recruitment patterns and habitat use of young-of-the-year bluefish along the United States east coast: insights from coordinated coastwide sampling. Reviews in Fisheries Science 20:80-102.

Bluefish WG Questions:

- What is the importance of estuaries (generally, or specific estuaries) where juveniles live on overall bluefish abundance?

Estuaries are nursery habitat for bluefish larvae and juveniles and provide habitat for adult bluefish as well. In the United States Atlantic Ocean, adult bluefish abundance is highest in the mid-Atlantic and New England, suggesting that estuaries in these regions may be increasingly important as waters in southern estuaries become too warm for this species. Some spawning batches (i.e., cohorts) may depend more on estuaries than others. Loss of (or adverse changes to) estuarine habitat would undoubtedly decrease the overall productivity of bluefish in the Atlantic.

- What are the impacts of shifting natural shorelines and habitat destruction on overall bluefish abundance and/or distribution?

Juvenile and adult bluefish are pelagic, but are regularly caught near ocean beaches. If modifications result in the loss of shallow water, there could be a negative impact on juveniles that rely on this habitat as refugia from larger predators. Additionally, bluefish are generalist predators; there may be indirect effects on bluefish abundance and/or distribution resulting from destruction of habitat of their prey.

- What are the impacts of man-made surfactants (e.g., jet fuel) entering estuarine and ocean habitats on bluefish egg, larval, or juvenile survival?

Bluefish spawn offshore and their eggs float. Surfactants that disrupt chemical processes at the surface may decrease egg viability (e.g., via inhibition of trans-membrane oxygen flow). Larvae and juveniles may be similarly directly affected and may also experience indirect effects because of surfactant effects on their prey (i.e., phytoplankton and zooplankton).

Comparing results for bluefish from the Northeast and South Atlantic Climate Vulnerability Assessment (SA: unpublished. NE: Hare et al. 2016 PLOS One).

Category	**SA Finding**	**NE Finding**
Overall Climate Vulnerability Risk	Moderate	Low
Climate Exposure	Very High	High
Biological Sensitivity	Low	Low
Distributional Vulnerability Rank	High	High
Directional effect in region	Neutral (highly uncertain)	Positive
Climate effects on abundance and distribution	As temperatures in nursery habitats increase, productivity may decrease. Changes in Gulf Stream dynamics might impact transport of larvae to the Mid-Atlantic. Warmer winter temperatures might allow	Changes in distribution are not yet documented for this species in the region, but bluefish distributions have changed in the Mediterranean due to warming waters.

	a larger portion of age-1 bluefish to migrate northward during their first winter.	

Anthropogenic Noise Impacts on Spawning and Ecology of Atlantic Fisheries: Implications for Managers and Long-Term Fishery Productivity.

REVISED BY R. GRANT GILMORE, JR., PH.D.

Commented [1]: need consensus on authors and acknowledgements

Report Objective:

It is well documented that sources of human-generated noise impact coastal and marine fishes through disruption of physiological processes and interruption of fish auditory communication. In turn, fish health and behavior are impacted. These impacts can range from short-term to long-term, however both can lead to changes in fish aggregations, habitat use, spawning success, and mortality. The purpose of this report is to summarize the important of sound and the impacts of anthropogenic noise to fishes managed by the Atlantic States Marine Fisheries Commission.

While there is vast literature on the production and use of sound by marine mammals, including the effects of human-generated sound on these species, this is beyond the scope of this report, given ASMFC's fisheries management focus.

I. Introduction

The oceans are full of both natural and anthropogenic sounds. The auditory system is the most important sensory system for many aquatic organisms, including most fishes (Tavolga 1960, 1980; Richardson et al, 1995; Stocker 2002; Au and Hastings 2008; Staaterman et al. 2013, 2014). Because water is denser and more viscous than air, the propagation of light and the diffusion of chemicals are both severely inhibited. In contrast, sound can move over four times faster and travel farther with less transmission loss underwater than it can through the air (Rogers and Cox 1988; Ward 2015).

Unfortunately, many human activities occurring in coastal and marine habitats add noise to the natural soundscape, and these noises affect aquatic organisms and their interactions with one another (Duarte et al 2021). For example, as rates of sound production correlate to rates of spawning and reproductive success, any disruptions to the effective communication range for fish and invertebrate species has the potential to reduce reproductive output and recruitment.

This Report aims to provide general information about the importance of sound to marine species, focusing on those managed by ASMFC, the impacts that anthropogenic noise can have on marine species, and the characteristics of natural sounds and anthropogenic noise. The report provides case studies for selected ASMFC managed species demonstrating the effect of anthropogenic noise on spawning and communication. The following section describes mitigation measures for certain human-induced noise are provided where they are known. Finally, the report provides a list of data gaps and research needs to improve our understanding of the impact of noise on ASMFC managed species.

II. The natural soundscape and its importance to fishes

Because the movement of light and chemicals can be diffuse in the marine environment, whereas sound propagates quickly and for long distances in water, marine animals have evolved a wide array of physiological and behavioral mechanisms to detect and use sound.

The natural soundscape of the ocean environment includes tectonic activity, sea surface agitation, and sea ice activity. These sounds range from <10 Hz to >150,000 Hz with varying intensities and intermittency. Ocean waves and seismic activity produce constant low frequency noises of a moderate intensity, while dramatic seismic events, such as earthquakes or volcanic eruptions, produce relatively short bursts of very loud sounds. Weather, such as precipitation or high wind speeds, contributes to surface agitation causing increased abundance of 100-10,000 Hz noise (Martin et al 2014; Nowacek 2007; Peng 2015). Most abiotic, natural sounds are caused by surface agitation such as bubbles or spray impacting the water's surface. Weather conditions contribute to agitation, causing increased abundance of 100-10,000 Hz noise from precipitation or high wind speeds for the duration of the event (Martin et al. 2014; Nowacek 2007; Peng 2015).

Fishes and other marine animals produce sound intentionally as part of their communication, reproduction, predator avoidance, foraging, and navigation and orientation (Peng 2015), as well as unintentionally they move, forage, and release gas (Paxton et al. 2017). Field and laboratory studies of fish physiology and behavior indicate that sound is a preferred sensory mechanism to detect predators or prey, find suitable habitat, orient, migrate, communicate, attract mates, and coordinate spawning (Putland et al. 2018). Not only do many species use sound to locate reproductive partners or indicate reproductive intent (Bass et al. 1997; Maruska and Mensinger 2009; Lamml and Krammer 2005; Montie et al. 2016, 2017), but some species, like the Pacific marine toadfish *Porichthys notatus*, become more sensitive to particular frequencies or their counterpart's sounds during periods of reproductive availability (Sisneros 2009; Maruska et al. 2012). Rates of sound production correlate to rates of spawning and reproductive success. Territorial species use aggressive, threatening calls to delineate an individual's territory and intimidate or deter competitors or predators (Ladich 1997; Vester et al. 2004; Maruska and Mensinger 2009**)**. Other uses of sound include navigation and orientation, especially for planktonic larval stages of fishes and invertebrates (Radford et al. 2011; Vermeij et al. 2010), avoidance of predators (Remage-Healey et al. 2006; Hughes et al. 2014), communication (Buscaino et al. 2012; Janik 2014; van Oosterom 2016), and the determination of suitable habitats for settlement (Simpson et al. 2004).

Commented [EC2]: This section needs to have the citations checked for ASMFC species. State explicitly if they are ASFMC examples. If none, add some.

III. Sources of anthropogenic noise in the oceans

Noise (unwanted sound) generated from human activities covers the full frequency of sound energies used by marine fishes (Duarte et al 2021). The contribution of human noise to ocean acoustics has increased over time as activities such as shipping, mineral and oil mining, and coastal construction have grown in their scale (Pijanowski et al 2011). More recently and emerging sources of sound, such as offshore aquaculture and renewable energy development will contribute noise in their construction, maintenance, and operation.

Anthropogenic sources of ocean noise are acute (episodic) and chronic (ongoing or continuous). Both types may occur within estuaries, on the continental shelf, or in open-ocean regions. Acute sources include pile driving, dredging, cable laying, bridge removal, and seismic surveys. Chronic sources include commercial and recreational boating, shipping activities, and operation of wind turbine generators. These activities and their impacts are summarized below.

Below, Figure 1 from Duarte et al. 2021 shows the duration and spatial scale of both natural sounds and anthropogenic noise in the ocean as well as the sound frequencies of marine animal sound production and hearing ranges together with anthropogenic noise sources. These visual displays demonstrate that the scale, frequency, and extent of anthropogenic noise overlaps with the activity of marine animals' behavior in different ways.

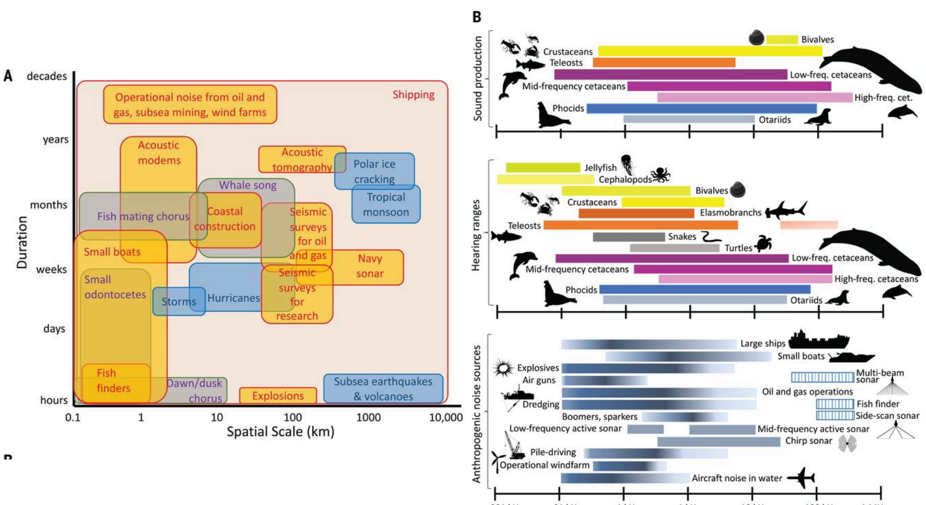

Figure 1 (from Duarte et al 2021). (A) Extent and duration of selected biophony (rounded gray squares), geophony (rounded blue squares), and anthrophony (rounded yellow squares) events. Events (rounded squares) reflect the spatial and temporal period over which signals or bouts of signals typically occur. (B) Approximate sound production and hearing ranges of marine taxa and frequency ranges of selected anthropogenic sound sources. These ranges represent the acoustic energy over the dominant frequency range of the sound source, and color shading roughly corresponds to the dominant energy band of each source. Dashed lines represent sonars to depict the multifrequency nature of these sounds.

Ongoing/Chronic Activities

Marine Transport and Other Vessel Activity

Watercraft of all kinds produce very loud undersea noise and are the most common sources of anthropogenic noise in coastal waters (Stocker 2002). These sources of noise can be amplified by complex reflected paths due to both surface and seafloor reflections, scattering and reverberating because of the geography and geology of the submerged shoreline and bottom. Watercraft generate sound primarily from propeller action, propulsion machinery, generators, and water flow over the hull (Hildebrand 2005). Combined, the sounds generated from a large container vessel can exceed 190 decibels (dB)[1] at the source (Jasny 1999; see the case study below). Metropolitan areas and ports contain a diverse array of watercraft which constitute the dominant human derived soundscape: commercial and private fishing boats, recreational watercraft, coastal industrial vessels, public transport ferries, military craft, personal watercraft, and many others. Significant underwater sound production can also be generated from bridge automobile traffic, particularly during peak traffic periods.

Additionally, most vessels have sonar systems for navigation, depth sounding, and "fish finding" that may cause acute or episodic noise disturbance. Some commercial fishing boats also deploy various acoustic deterrent devices (pingers) to keep dolphins, seals, and turtles from running afoul of the nets (Stocker 2002). There is little information on the effects of acoustic deterrent devices on fish, however.

Offshore Energy Operations

Renewable energy has been a growing segment of the nation's energy portfolio due to concerns over energy security and environmental change (Dincer 1999; Pimentel et al. 2002; Chow, Kopp & Portney 2003; Valentine 2011). While the United States' renewable energy portfolio has to date been composed almost exclusively of land-based technologies, coastal and marine energy sources in the form of tides, currents, waves and offshore wind have the potential to provide a large amount of predictable energy (Pelc & Fujita 2002). These energy sources, however, are not without impacts to marine fish health, movements, and behavior. Specifically, the noise produced during construction of energy systems that require pile driving and those that produce significant noise during their operation have been documented to cause negative or disruptive physiological and behavioral effects. Of central concern is the impact of offshore wind, an industry that is planned for rapid advancement along the Atlantic coast.

The impacts of offshore wind areas on the marine environment have been widely discussed in recent years, though because the few constructed sites have been in operation for only a short period of time, the actual downstream and long-term effects are still being determined. The impact of noise produced by wind farms can occur during construction, operation, maintenance, and decommissioning. The most noise disturbance is thought to occur during the construction phase when the impact pile driving (for fixed turbines), shipping, and other associated activities (geological and geophysical surveys as discussed

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[1] Note that dB in air and water are different. For more information, visit: How does sound in air differ from sound in water? – Discovery of Sound in the Sea (dosits.org).

in the section below) will impact both animal behavior and survival (Bergstrom et al. 2014). Once wind farms are in operation, marine animals may be impacted by underwater noise from the turbines (Gill 2005). The impact of noise generated by pile driving associated with offshore wind construction is discussed in the section below on acute sources of noise.

During operation, studies have that the noise generated by both the turbines and increased boat traffic for maintenance exceeded the natural sounds typical at similar deep-water locations (Nedwell et al. 2003, Tougaard et al. 2012). Measuring noise at wind farms in the UK documented that the overall sound pressure level was significantly higher during the daytime due to more vessel traffic. The noise levels were found to be higher at low wind speeds, in contrast to the assumption that the turbine-generated noise would be greater with increasing wind speed (Nedwell et al 2003). Turbine operation has been measured between 120 – 142 dB with dominant frequencies at 50, 160, and 200 Hz at wind speeds of 12 m/s (Thomsen et al. 2003). It is estimated that operational noise of wind turbines is within the perception range of cod (*Gadus morhua*) and Atlantic herring (*Clupea harengu*s) up to a distance of approximately 4 km, while for dab (*Limanda limanda*) and Atlantic salmon (*Salmo salar*) up to 1 km.

Oil and Gas Extraction Operations

Mineral extraction in marine waters produces chronic noise disturbance often dominated by vessel noise (the impacts of vessel noise are described above), however noise is also produced by the operation at platforms vary depending on the platform type. A comprehensive study of noise generated by oil and gas extraction found that fixed platforms had lower underwater radiated noise levels than floating platforms, and gravel islands appear to have the lowest source levels of any oil and gas industry activity. Semisubmersible platforms were found to generate the most underwater noise which was highest when thrusters were operating and drilling was occurring. Levels were measured at 20-50+ dB in the frequency range of 20 – 1000 Hz during drilling operations, with the dominant frequencies at 130, 200, 350, and 600 Hz (Spence et al. 2007). On all platform types, noise from large power generation equipment is likely to be a dominant cause of underwater noise, for example from the operation of turbines, compressors, and large pumps (e.g. mud pumps). This noise is thought to be more significant when equipment is hard mounted directly to the platform (Spence et al 2007).

Acute/Episodic Activities

Coastal and Marine Construction

Inshore industrial and construction activities drastically alter the aquatic soundscape and have caused documented mortality and severe behavioral change in fishes and other marine animals. Underwater blasting with explosives is typically used for dredging new navigation channels in rocky substrates; decommissioning and removing bridge structures and dams; and construction of new in-water structures such as gas and oil pipelines, bridges, dams, and wind turbines. The potential for injury and death to fish from underwater explosives has been well-documented (Hubbs and Rechnitzer 1952; Teleki and Chamberlain 1978; Linton et al. 1985; Keevin et al. 1999). Pile driving activities, which

Commented [EC3]: Add sentence about sturgeon in Hudson or pull out ASMFC species from the citations in this paragraph typically occur at frequencies below 1000 Hz, have also led to fish kills (Hastings and Popper 2005). Intensity levels of pile driving have been measured up to 193 dB in certain studies (Hastings and Popper 2005).

Construction of Offshore Wind Farms

Of the studies performed to assess these impacts, construction noise, specifically, pile driving has produced high levels of sound pressure and acoustic particle motion in the water as well as within the seabed (Nedwell et al. 2003, Thomsen et al. 2006, Tougaard et al. 2012)). During pile driving, the broadband peak sound pressure level has been measured at 189 dB at 400 m and a modeled level of 228 dB at 1m with a dominant frequency of 315 Hz, however these levels will depend on the size and diameter of the piles and have been modeled to be higher with larger pile diameters (Thomsen et al. 2006, Tougaard et al. 2012). These noise levels are within the perception ranges of cod (*Gadus morhua*), dab (*Limanda limanda*), Atlantic salmon (*Salmo salar*), and herring (*Clupea harengu*s) at large distances, estimated at up to 80 km from the source (Thomsen et al. 2006). Documented behavioral reactions in cod (*Gadus morhua*) and sole (*Solea solea*) were observed up to tens of kilometers from the source (Andersson 2011). In the same study, noise produced during power production generated noise within specific frequencies which were detectable by sound pressure sensitive fish at a distance of several kilometers, however species sensitive to motion (as opposed to pressure) were found to be affected within tens of meters (Andersson 2011). Close to the source of pile driving, injury and mortality are likely. Mitigation measures for pile driving are discussed in Section VI of this report.

To date, most offshore wind installations have been fixed turbines. Floating offshore wind technology is in its nascent stages and thus there is less known about whether the ongoing noise produced by turbines will be similar to the levels and frequencies measured for fixed turbines. There is some evidence that jacketing monopile turbines reduces the chronic noise from operation (Thomsen et al. 2015), however to date, actual noise levels emitted by floating platforms has not been documented. As this technology advances, there is a need to determine the noise levels and frequencies different floating platform types emit and at what distances.

Geological and Geophysical Surveys

Geological and geophysical (G&G) surveys are performed to gather information about the seafloor including bathymetry, surficial sediment, sub-surface sediment, and the topology of an area. These surveys are performed for a multitude of uses including resource extraction and wind power siting. Not all G&G surveys produce noise that is known to be within the hearing range of marine animals.

Sonar systems are used for a wide variety of civilian and military operations. Active sonar systems send sound energy into the water column. Sonar systems can be classified into low (<1,000 Hz), mid (1,000 – 20,000 Hz), and high frequency (>20,000 Hz).

Low and mid frequency systems emit sound that overlap with the acoustic detection of many marine animals. Sub-bottom profilers are a type of high-resolution seismic system that produce imaging of the seafloor's sub-surface. These can be shallow penetration (2–20 m) or deep penetration systems and operate at a wide range of frequencies (400 – 24,000 Hz) and produce varying levels of peak sound (212-250 dB; Mooney et al. 2020). Seismic airguns are used for a deeper penetration of acoustic sound into the seafloor and are used primarily for oil and gas exploration and siting of offshore cables. Airguns generally produce sound at 200-210dB at a range below 100 Hz. While morbidity has not been associated with airgun exposure, changes in behavior have been observed. Following exposure in a laboratory setting, American lobster (*Homarus americanus*) changed their feeding levels, and physiological changes were also measure.

Studies investigating the effect of full-scale G&G surveys on wild fish populations have shown effects in some cases. Atlantic herring (*Clupea harengus*) schools in the wild were not observed to change their swimming speed, swimming direction, or school size during exposure to a full-scale seismic survey (Pena et al. 2013). However, other studies have found that trawl and long-line fish catches during full-scale G&G surveys decreased within the area of the seismic survey and at ranges of up to 33 kilometers (Engas et al. 1996). When catch rates and behavior were observed to change during seismic surveys, fish were observed to return to the site of the survey within hours or days after the survey completion (Lokkeborg et al. 2012).

High frequency sonar telemetry is associated with vessel positioning, locating, steering, and remotely operated vessel control. Ultrasonic frequencies (generally 200,000 - 400,000 Hz), also known as multibeam echosounders, are used for sonar mapping. These ultrasonic frequencies are generally outside of the known range of acoustic detection by marine animals. Multibeam echosounder surveys collect bathymetry and seafloor hardness information that nautical chart updates, benthic habitat characterizations and fisheries habitat modeling, and surficial sediment analysis.

Oil Drilling and Mining

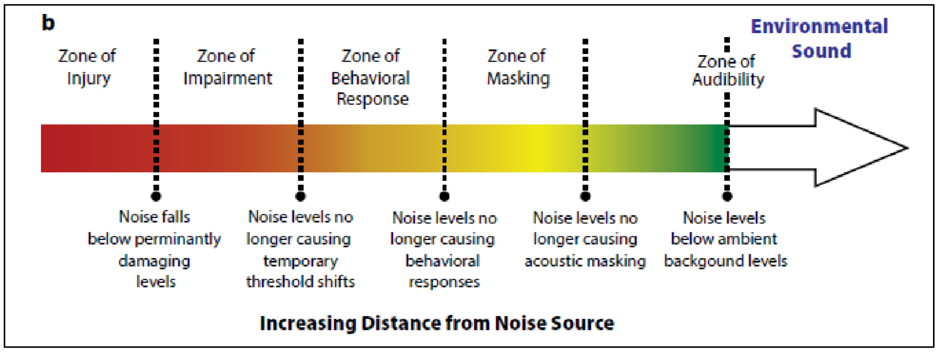
Some of the loudest anthropogenic noises are generated by marine extraction industries such as oil drilling and mineral mining (Stocker 2002). The most common source of sounds is from air guns used to create and read seismic disturbances (Popper and Hastings 2009; Popper et al. 2005, 2014; NOAA 2016; Popper and Hawkins 2016). Air guns are used to generate and direct huge impact noises into the ocean substrate. The sound pressure wave created aids in reflection profiling of underlying substrates for oil and gas exploration. Peak source sound levels typically are 250-255 dB. Following the exploration stage; drilling, coring, and dredging are performed during extraction. Each of these activities also generates loud noises.

IV. Impacts of anthropogenic noise on fishes

Sound energy is transmitted through both sound pressure and water particle motion. Thus, to understand whether and how noises are likely to impact fishes, we need to understand their sensitivity to both sound pressure and particle motion. Fishes as a group have very complex and diverse interactions with sound and how they perceive it. Hearing systems and capabilities vary based on anatomy, including presence of a swim bladder or other gas filled organs and position relative to the inner ear, as well as other factors (Popper and Hawkins 2018). Sensitivity varies by species and among larval, juvenile, and adult stages (Wright et al. 2010). Many species have the same hearing frequency sensitivity that humans do (10 to 20,000 Hz; Tavolga 1960, 1980; Fine et al 1977; Fay et al. 2008; Popper and Hastings 2009; Popper and Fay 2011), and most fish produce sounds below 200,000 Hz (Tavolga 1960, 1980; Fine et al 1977; Fay et al. 2008). Sound frequencies below 100,000 Hz scatter and dissipate least, travel farthest underwater (Wenz 1962; Au and Hastings 2008; Ward 2015), and are the frequencies fish typically use for communication (Bass et al. 1997; Au and Hastings 2008; Popper and Fay 2011). Certain groups of fish, such as the herrings, sardines, and menhaden (clupeids), can detect ultrasound frequencies above 100,000 Hz (Fine et al. 1977b; Nestler et al 1992; Mann et al. 1997, 2001; Narins et al. 2013), however the strongest response has been documented at 40,000 Hz (Wilson et al. 2009).

The frequency at which different species perceive sound is highly variable (Monczak et al. 2017), however for most fishes, sound production and habitat soundscape acoustic signatures are at frequencies below 5,000 Hz (Fish and Mowbray 1970; Zelick et al. 1999; Myrberg and Fuiman 2002). For example, black drum (*Pogonias cromis*) were found to have the highest neurological response to sounds at 82, 166, and 249 Hz (Monczak et al. 2017). This is also the range of frequencies where underwater sound propagates best. Most human-generated chronic noise is also below 5,000 Hz (Richardson et al. 1995; Au and Hastings 2008), which is of concern as fish are very sensitive to intense sounds below 1,000 Hz.

Figure 2. The potential effects of noise with distance from source. Generally, noise and impact on individual animals may be greater closer to the source. Effects change with increasing distance from the source because acoustic signals change, for example decreased dB. Figure from Mooney et al. 2012, modified from Dooling and Blumenrath (2013).



Particle Motion versus Sound Pressure

Describe the difference.

Although there is growing evidence that fish and invertebrates are sensitive to the particle motion caused by underwater noise (Casper and Popper 2010; Mooney et al. 2010; Mueller-Blenkle et al. 2010; Nedelec et al. 2016; Hawkins and Popper 2017; Sole et al. 2017; Popper and Hawkins 2018), it is technically challenging to measure. This difficulty has led to poor assessments of the impacts of particle motion on fish and invertebrates (Popper and Hawkins 2018). There is more information and research on effects of sound pressure in bony fishes and to a lesser extent invertebrates. As such, much of the information discussed below describe the impact of sound pressure.

Physiological Effects

Physiological impacts to fish include damage to ear, nerve, and lateral line tissue that can lead to sound sensing loss or threshold shifts in hearing (Jasny 1999; Heathershaw et al. 2001; Hastings and Popper 2005). Threshold shifts result from exposure to low levels of sound for a relatively long period of time or high levels of sound for shorter periods, which may be temporary or permanent. Recovery from threshold shifts appears to require more time for fish species that vocalize (Amoser and Ladich 2003). Threshold shifts can impact a fish's ability to carry out its life functions. Any organ with a markedly different density to seawater (e.g. swim bladder) may be susceptible to pressure-related impacts. Some of the resulting effects on fish include rupturing of organs and death (Hastings and Popper 2005).

Near field (close proximity) percussion events produced by pile driving and explosions can have a lethal impact on fish through particle motion and sound wave compression. However, the distance from the disturbance and environmental setting (water density, turbulence, etc.) undoubtedly have major influences on potential physiological effects of particle motion and need further study before they can be treated in detail (Kevin et al. 1999; Thomson et al. 2015). The lethality of underwater blasts on fish is dependent upon the intensity of the explosion; however, a number of other variables may play an important role including the size, shape, species, and orientation of the organism to the shock wave; the amount, type, and detonation depth of explosive; water depth; and bottom type (Linton et al. 1985). Fish with swim bladders are the most susceptible to underwater blasts due to the effects of rapid changes in hydrostatic pressures on this gas-filled organ. The kidney, liver, spleen, and sinus structures are other organs typically injured after underwater blasts (Linton et al. 1985). Smaller fish are more likely to be impacted by the shock wave of underwater blasts than are larger fish, and eggs and embryos

Commented [4]: From Eric Montie: Some other important papers to review and include in this section:

McCauley R.D., Fewtrell J., Popper A.N. (2003). High intensity anthropogenic sound damages fish ears. The Journal of the Acoustical Society of America 113:638-642.

Halvorsen MB, Casper BM, Matthews F, Carlson TJ, and Popper AN. (2012). Effects of exposure to pile-driving sounds on the lake sturgeon, Nile tilapia, and hogchoker. Proc. R. Soc. B 279:4705-4714.

tend to be particularly sensitive (Wright 1982). However, early fish larvae tend to be less sensitive to blasts than eggs or post-larval fish, probably because the larval stages do not yet possess swim bladders (Wright 1982). Cephalopods can experience significant trauma to their statocysts, structures necessary for balance and position, at cellular and subcellular levels (André et al. 2011). Additionally, playback of seismic air gun recordings induced delayed development and malformation of New Zealand scallop larvae (de Soto et al. 2013).

Effect of anthropogenic noise on zooplankton is a relatively recent topic of interest. These physiological impacts of noise affect fishes indirectly since many species feed on zooplankton. Abundance of dead larval and adult zooplankton increases two to threefold within one hour after passage of an active seismic air gun; elevated mortality extended at least 1.2 km from the air gun signal (McCauley et al. 2017). Simulations based on the McCauley et al. (2017) findings estimate a 22% reduction of zooplankton population within the survey area and declining to 14% within 15 km and 2% within 150 km (Richardson et al. 2017). In contrast, the copepod *Calanus finmarchicus* was only negatively affected when in close proximity (≤ 10 m) to an active seismic air gun (Fields et al. 2019).

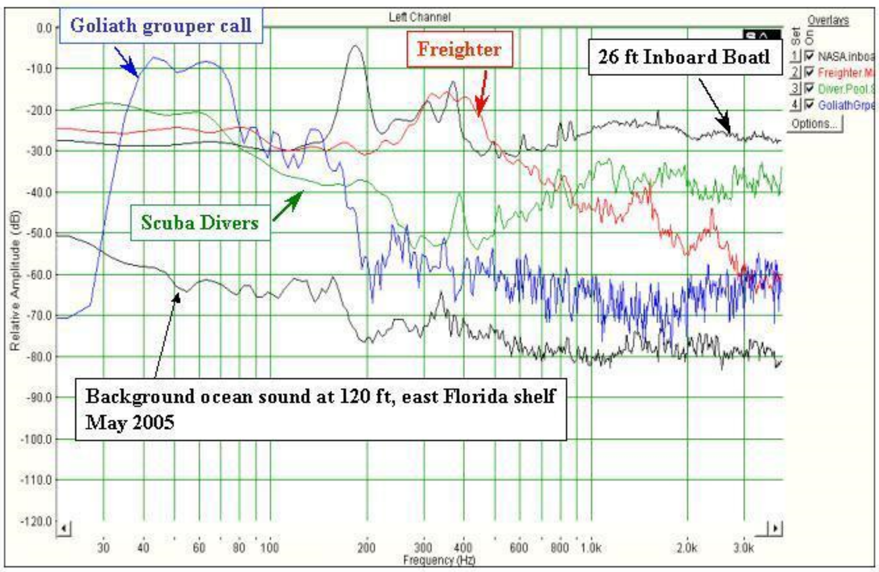


Figure 3. Illustration of the spectrum of various human activity generated and fish (Goliath grouper, *Epinephelus itajara*) sound sources. Note the low frequency sound region where most biologically important sounds are produced (<3 kHz.)

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Behavioral Effects

Anthropogenic noise that falsely trigger fish responses may cause animals to expend energy without benefits (Stocker 2002). Masking biologically significant sounds may compromise feeding, breeding, community bonding, and schooling synchronization. For species in which males broadcast calls to attract females to a spawning location (e.g. oyster toadfish, silver perch, black drum, spotted seatrout, red drum), masking of these acoustic signals by noise may interfere with reproduction through various mechanisms (Smott et al. 2018). Further, the effect of noise on each of these behaviors is compounded when considering that the behaviors are inter-related; for example a change in the ability or desire to feed compounded with reduced communication may lead to a higher reduction in spawning success.

Behavioral response of fishes to noise is varied and dependent on the species sound perception and the characteristics of the source of noise. While not a comprehensive list, the following provide some examples of behavioral responses.

- When exposed to noise from piling installation, Atlantic cod (*Gadus morhua*) initially responded by freezing in place. Following the initial onset of noise, cod and sole (*Solea solea*) increased swimming speed for the duration of the piling installation activity. In contract, other fish species appeared to habituate to the repetitive noise (Andersson 2011).
- Elasmobranch species that are more active swimmers appear to be more sensitive to sound than more sedentary species. Elasmobranchs have been shown to be sound curious, often seeking out the source. Sudden noises that are ~20-30 dB above ambient sound can induce a startle response, but habituation over time has been known to occur (Casper and Popper 2010).
- Turbine and tidal turbine noise can obscure sounds associated with mudflats resulting in delayed metamorphosis of estuarine crabs (Carroll et al. 2017).
- Increased ambient noise created by watercraft activity potentially reduces the ability of marine organisms, particularly larval forms, to receive the appropriate sound cues to settle in critical habitats (Jasny 1999; Scholik and Yan 2002; Hastings and Popper 2005; Stanley et al. 2012; Holles et al. 2013; Simpson et al. 2016; Staaterman et al. 2014, Lillis et al. 2016).

Cumulative Effects

The most chronic and pervasive impacts on regional fish stocks occur when human generated sounds cause behavioral changes that affect critical life history activities required to maintain healthy populations. Several studies have indicated that increased background noise and sudden increases in sound pressure can lead to elevated levels of stress in many fish species (Hastings and Popper 2005). Chronic noise levels ≥123 dB can elicit physiological (weight loss, decreased condition, and elevated and variable heterophil:lymphocyte ratio), behavioral (increased piping and tail adjustments and reduced stationarity), and vocal (increased clicking) stress responses in the lined seahorse (*Hippocampus erectus*) (Anderson et al. 2011). Similarly, scallops exposed to seismic air gun signals resulted in altered physiology (hemolymph biochemistry) and behavior (development of a flinch response and increased recessing reflex) which intensified with repeated exposure (Day et al. 2017).

These examples, as well as others described in this report, demonstrate that noise impacts key life events (e.g. foraging, navigation, and spawning) in many species. This can produce cumulative impacts as many scales. Animals that are exposed to acute noise impacts multiple times, to chronic noise, or most likely to acute impacts followed by chronic noise may have cumulative physiological impacts that in turn reduce their fitness, spawning success, navigation abilities, use of a certain key areas, larval dispersal success, and other impacts. This can lead to population level effects over time if, for example,

Commented [6]: This section needs a little more. There are cumulative impacts from the culmination of multiple sources of noise. But there is also a difference between impacts to individual fish from noise vs. population-level impacts related to effects on important life history events such as spawning. I'm thinking about the case of offshore wind in particular, a fish may be exposed to noise related to construction of one or multiple turbines. Also populations of fish will be exposed to construction of multiple turbines and multiple wind projects over time. If construction noise interferes with, say spawning aggregations over multiple times and locations, then population level effects may result. Effects to individual fish may be less concerning than population-level effects.

Commented [7]: From Eric Montie: Kate provides an important point. As I mentioned previously, masking could severely impact reproduction, which over generations could impact populations. This phenomena could occur in areas where noise is chronic, such as estuaries and coastal oceans near Ports where commercial vessels are constant and loud.

Commented [8]: Again, give Hz range if paper provides one spawning success or aggregations are interrupted on a multi-generational scale. This phenomena could occur in areas where noise is chronic, such as estuaries and coastal oceans near ports with repeated in-water coastal construction, ubiquitous vessel traffic, or offshore areas where seismic surveys, construction, vessel traffic, and operational noise result in years of noise interruption in an area.

Effects on Biogenic Habitats

Alteration of the soundscape has the potential to impact biogenic fish habitats. Oyster larval settlement increased in the presence of oyster reef habitat sounds (Lillis et al. 2013). In response to sediment vibrations blue mussel respiration rates decreased resulting in altered valve gape, oxygen demand, and waste removal (Roberts et al. 2015). Unlike shellfish, Scleractinian corals appear resistant to soft tissue and skeletal damage after repeated exposure to a 3D seismic survey (Heyward et al. 2018). Seagrass meadows, which provide not only a structural habitat for species to forage and avoid predators, but also act as an acoustic refuge for prey species including fishes by attenuating high frequency sounds (100,000 Hz) such as those used by bottlenose dolphin (Wilson et al. 2013), may be impacted by noise. Submerged aquatic vegetation exposed to low frequency sounds (50-400 Hz at 157 ± 5 dB re 1 μPa^2) can develop physical damage to root and rhizome cellular structures; specifically amyloplasts responsible for starch production and storage, gravity sensing, and vibration reception; as well as fungal symbionts (Solé et al. 2021).

Effects on Fisheries Catch Rates

Anthropogenic noise has been demonstrated to affect catch rates. Several studies indicate that catch rates of fishes decreased in areas exposed to seismic air gun blasts (Engås et al. 1996; Hastings and Popper 2005, Paxton et al. 2017); abundance and catch rates for cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) did not return to pre-disturbance levels during the five-day monitoring period (Engås et al. 1996). These results imply that fish relocate to areas beyond the impact zone (area of highest sound intensity), which have been corroborated with visual studies on fish abundance before and after seismic surveys (Paxton et al. 2017). One study indicated that catch rates increased 30-50 km away from the noise source, showing that redistribution of fish populations can occur over broad areas (Hastings and Popper 2005). Seismic surveys may have positive, no change, or negative effect on fishery catch rates due to variable responses among fish species such as no response, dispersal, avoidance, and decreased responsiveness to bait (Carroll et al. 2017). While fish abundance can decrease due to increased anthropogenic noise, such as from wind farm operation, it is unclear the extent to which the increased noise from wind farm operation affects individual behaviors (Mooney et al. 2020).

Commented [9]: We could definitely cite a personal communication here from Capt. Monty Hawkins, if we wanted to do so, based on his personal observations for Black Sea Bass.

Commented [10]: Monty's observations are specific to sub-bottom profiler sound. We would need to make that distinction regarding sound source. I do not recall seeing an papers provided that assess sub-bottom profiler sound effects. Not sure we want to include anecdotal observations. I am not discounting Monty's observations which are compelling, but the correlation has not been studied (at least in that specific example).

- Resulting impacts to fisheries
    - Loss of fish on fishing grounds and resultant redistribution of fishing effort, increasing costs and possibly interactions with other types of fishing or other activities
    - Also reference direct biological impacts to fish tissues, etc., although I think we want to keep our focus on effects related to habitat
    - Potential local/regional population effects (tied to repeated reproduction impacts)

V. Case Studies: the importance of sound to species managed by ASMFC

Case Study 1: Ultrasound may impact clupeid spawning migration

As noted above, fishes are impacted by sound both physiologically and behaviorally. Physiological responses are somewhat consistent across families. However, behavioral responses can vary depending on species-specific hearing and sensitivity to sound. Within the family Clupeidae, the subfamily Alosinae (alewife, blueback herring, menhaden, shad) have evolved the ability to hear in the ultrasound range of frequencies (25,000 – 180,000 Hz) Mann et al. 1997). The ability may have evolved as an avoidance mechanism to hear echolocating predatory toothed whales (Narins et al. 2013).

Alewife responded to high frequency pulsed sound at 110,000 – 150,000 Hz above 157 dB (Dunning et al. 1992), while menhaden can detect sound at 40,000 – 80,000 Hz (Mann et al. 2001)--all within the range of ultrasonic frequency. Ultrasound pulses have been used to deter alosines from power plant intakes (Narins et al. 2013).

Because sound intensity above the clupeid sensitivity threshold of 145 dB and within the ultrasound range could impact behavior of the fish, there is concern that certain anthropogenic activities, for example, the use of Acoustic Deterrent Devices for marine mammals near pile driving activities, could impact spawning migration (Boyle & New 2018).

Case Study 2: Long-term monitoring of human interference with biological sound production in Horseshore Reef, East Florida

Long term deployment of hydrophones in East Florida freshwater tributaries, estuaries, and continental shelf reef formations was used to isolate specific fish spawning sites for long term monitoring and continuous acoustic assessment (Gilmore 2002; Gilmore et al. 2003). The hydrophone array allowed for monitoring the impact of single freighter engine/propeller noise on subtropical reef fish. A complex, high relief (2-8 m) rock reef formation known locally as "Horseshoe Reef" was chosen for a multiple day deployment of three "Passive Acoustic Monitoring Systems" (PAMS) (Gilmore et al. 2003). PAMS were deployed on July 9, 2004 for a period of 72 hrs to continuously record all sounds between 10 and 20,000 Hz (Gilmore et al. 2003). The monitoring system documented vessel noise interference with biological sounds (Figures 2 & 3) on a mid-continental shelf reef where fishery species are known to spawn: groupers (Goliath grouper, *Epinephelus itajara*; gag, *Mycteroperca microlepis*; scamp, *M. phenax*; red grouper, *Epinephelus morio*), black sea bass, *Centropristis striatus*, and various snappers (red, *Lutjanus campechanus*; mutton, *L. analis*; and lane, *L. synagris)*. Each of these species uses acoustic signals during mating events (Mann 2006; Mann et al. 1997, 2007, 2009, 2010; Locascio and Mann 2005, 2008, 2011). What is the conclusion?

Case Study 3: Add another regarding wind turbine installation and/or operation from Block Island Studies

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Commented [12]: Here or above in section III it would be good to define the difference between passive and active acoustics.

Commented [13]: This paragraph leaves the reader hanging. Vessel noise interfered with biological sounds. The species use signals during mating. What is the conclusion? (I don't know enough to add the right text) Vessel noise may interfere with mating events, possibly decreasing successful reproduction? or More research is needed to understand potential population level effects of vessel noise?

Commented [14]: From Eric Montie: Yes, what are the conclusions? Was this a soundscape study that defined the different sound-producing fish? Did the freighter noise disrupt fish sound production?

Soundscape studies are excellent to perform. They define organisms that produce sound and explain their temporal patterns. Then, anthropogenic noise events can be counted and quantified. By comparing quieter vs noisy sites and in collaboration with fishery-independent surveys, we can then begin to understand how noise may impact fish populations. Some examples of soundscape studies that we've performed and that could be cited include:

Monczak A., McKinney B., Mueller C., Montie E.W. (2020). What's all that racket! Soundscapes, phenology, and biodiversity in estuaries. PLoS ONE 15(9): e0236874. https://doi. org/10.1371/journal.pone.0236874

Mueller C, Monczak A, Soueidan J, McKinney B, Smott S, Mills T, Ji Y, Montie E.W. (2020). Sound characterization and fine-scale spatial mapping of an estuarine soundscape in the southeastern USA. Marine Ecology Progress Series 645:1-23

Monczak A., Mueller C., Miller M.E., Ji Y., Borgianini S.A., Montie E.W. (2019). Sound patterns of snapping shrimp, fish, and dolphins in an estuarine soundscape of the southeastern USA. Marine Ecology Progress Series 609:49-68.

Monczak, A., Berry A., Kehrer C., Montie E.W. (2017). Long-term acoustic monitoring of fish calling provides baseline estimates of reproductive timelines in the May River estuary, southeastern USA. Marine Ecology Progress Series 581, 1-19.

Add another for G&G impacts

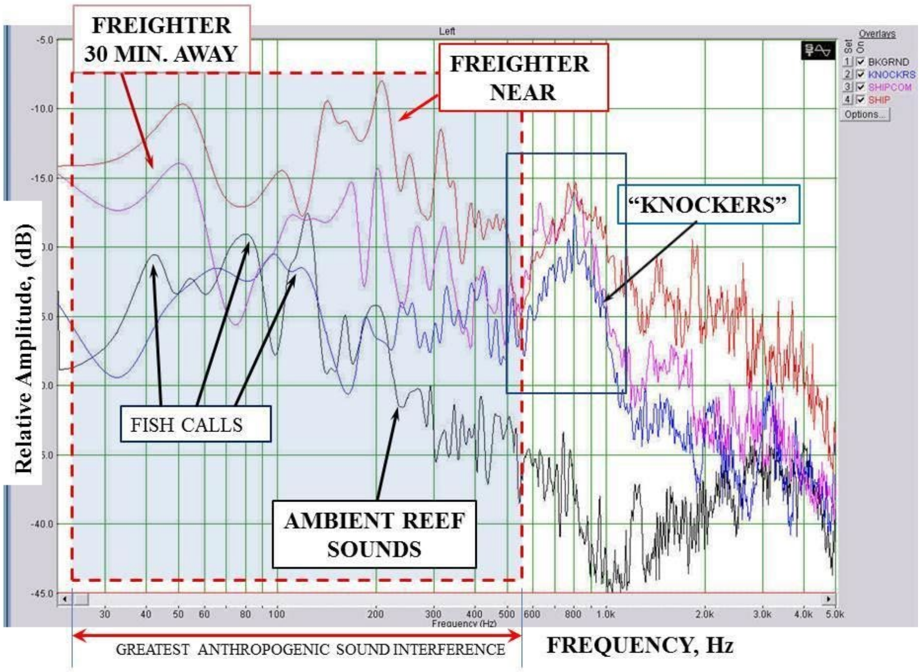

Figure 4 (Case Study 2). Spectral curves for diurnal ambient reef sounds produced on Horseshoe Reef, Florida (black curve) are compared to nocturnal biological sounds produced by an unidentified organism, labeled as "knockers", whose acoustic pulses center around 1,000 Hz, and fish calls (grouper/snapper) below 300 Hz (blue curve) with an approaching freighter 30 min away (purple curve), and same vessel nearby (red curve). Note that the greatest anthropogenic interference is below 600 Hz.

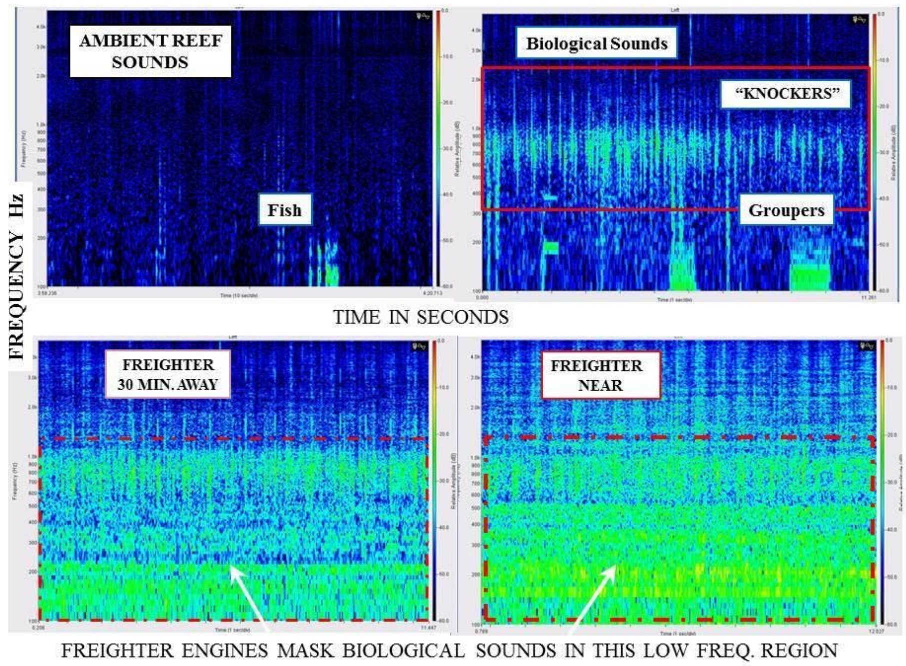

Figure 5 (Case Study 2). Horseshoe Reef, Florida sonogram depicting the same acoustic signals presented in Figure 2, revealing the greatest anthropogenic interference is from highly energetic sounds, engine and propeller noise below 600 Hz.

VI. Mitigation

Several measures could be implemented to mitigate anthropogenic acoustic impacts. New technologies are available to reduce vessel noise making them less acoustically intrusive. As technology allows, use of alternative propeller design and propulsion systems such as diesel-electric hybrid, electric motors, LNG pumps, and rotor sails that are quieter than internal combustion engines can be employed. Ship generators are also a substantial source of underwater noise. Insulated or sound proofed ship hulls may be necessary in major shipping industries to further reduce acoustic impacts. When in port, vessels should connect to on-shore power systems when possible.

Commented [15]: From Eric Montie: This is all great to do, but it is challenging to measure source levels of commercial vessels in shallow water environments. See the following paper:

Ainslie M.A., Martin S.B., Trounce K.B., Hannay D.E., Eickmeier J.M., Deveau T.J., Lucke K., MacGillivray A.O., Nolet V., Borys P. (2022). International harmonization of procedures for measuring and analyzing of vessel underwater radiated noise. Marine Pollution Bulletin 174:113124.

Regulations and permitting, informed by biological information and marine spatial planning, can be used to manage location and timing of when damaging sounds are generated. Acoustic transects can be used to isolate and map specific sites based on sound production of fishery aggregations (Gilmore 1994, 1996, 2002; Luczkovich et al. 1999; Rountree et al. 2003) as well as the broader ambient soundscape (Chou et al. 2021). For example, critical spawning and aggregation sites can be designated as off limits to vessels,

Commented [16]: From Eric Montie: Understanding the temporal rhythms of fish sounds associated with reproductive activity is key. Then, as stated, more informed management can follow. See the soundscape papers cited above as specific examples for Southeastern estuaries.

dredging, seismic, construction, and other sound generating activities at night which is when spawning chorus events typically occur. These sites can be remotely monitored with vessel tracking technologies, currently in use, allowing for violating vessels to be identified.

Alternate seismic survey methods including higher sensitivity hydrophones, benthic stationary fiber-optic receivers, parabolic reflectors, and non-impulsive, very low frequency marine vibroseis are being studied (Chou et al. 2021).

Construction that requires pilings or some form of foundation can benefit from installation technologies such as pulse prolongation, vibropiling, foundation drilling, gravity base foundation, suction bucket jacket, mono bucket foundation, and floating foundation (Koschinski and Lüdemann 2020). When possible, one or more sound dampening measures such as bubble curtains, isolation casings, hydro sound dampers, dewatered cofferdams, and double/mandrel piles should be used (Koschinski and Lüdemann 2020). Multiple sound exposure level metrics such as cumulative, peak, single-strike, and number of strikes should be considered when evaluating the potential effect of pile driving and other impulsive sounds and establishing allowable exposure criteria (Halvorsen et al. 2011). Furthermore, deterrence strategies such as soft-start and ramp-up are intended to scare away mobile species as noise levels are gradually increased to levels that are damaging (Andersson 2011 and Chou et al. 2021).

Commented [17]: Do we have any examples of where a "noise exclusion window" has been put in place to protect a spawning aggregation or spawning behavior? Would be good to cite if we do have one or more examples.

Commented [18]: that create less noise interference? that have less of an impact on fish?

Commented [19]: spelling?

VII. Data gaps and research needs

Commented [20]: Go through Popper and Hawkins 2019 for an overview of data gaps.

There are still many unknowns about the impact of anthropogenic noise on the physiology and behavior of fishes. Some of these include species-specific effects, the impact on fishing catch rates, synergistic impacts of multiple sources of anthropogenic noise, and many other questions. The following topics have been identified by researchers in the field and the ASMFC Habitat Committee as important data gaps and research that is needed to inform our understanding of anthropogenic noise on ASMFC species and their management.

- There is little long-term data on the effect of chronic, cumulative, anthropogenic sounds from watercraft and wind turbine generators on the behavior of invertebrates and fish, particularly at spawning sites (Hawkins and Popper 2016, 2017) and monitoring programs should be developed.

- Effects from various types of anthropogenic noise including duration of and recovery from noise should be studied to determine if population level impacts exist which could affect fisheries catch rates (Carroll et al. 2017).

- Anthropogenic noise may act in combination with other non-noise stressors to affect a biological response or outcome (Carroll et al. 2017). Synergistic effect of noise and non-noise stressors should be examined.

- Sounds important to biological processes may be masked by anthropogenic sounds and the consequences of this disruption should be studied (Carroll et al. 2017 and Hawkins et al. 2015).

- Identify the noise exposure limits and acoustic impact thresholds for various life history stages of species (Chou et al. 2021).

- Subtle and long-term effects on behavior or physiology could result from persistent exposure to certain noise levels leading to an impact on the survival of fish populations (Jasny 1999; Hastings and Popper 2005). It is important to conduct integrated laboratory, behavioral, and physiological experiments under a variety of acoustic conditions, and coordinate these lab studies with field studies using the same organism. This is of critical importance as chronic sound has the potential to directly impact periodic spawning events at specific locations.

- Long-term acoustic listening stations should be deployed at spawning sites where significant human activities occur to determine if mitigation measures are needed. Identifying and mapping these critical areas to create management areas limiting human generated noise~~sound~~ is also needed.

- More information on the impacts and importance of sound to fish larvae and eggs, as well as invertebrates at all life stages, is needed.

- Impact of noise exposure on fish habitat development, specifically reef formation and submerged aquatic vegetation beds, is poorly understood and in need of study.

- Mining the tens of thousands of hours of long duration historical recording data made by various aquatic bioacoustic investigators whose literature contributes to this review should be conducted to further identify and characterize potential human acoustic interference.

- Several important data collection needs to resolve include standardization of terminology and measurement of sound exposure (Carroll et al. 2017 and Hawkins et al. 2015), a methodology for measuring particle motion in the field (Hawkins et al. 2015, Popper and Hawkins 2018), determination of appropriate particle motion metrics, improvement of particle motion sensors and mounting systems, and standards for particle motion and sound pressure sensors (Popper and Hawkins 2018).

- Improved understanding of how sound pressure and particle motion effects may differ for and among species and life history stages (Popper and Hawkins 2018).

Commented [21]: From Eric Montie: There is also the possibility of adaptation and the Lombard Effect.

Commented [22]: From Eric Montie: Hard to do on a large spatial scale. First, you need to identify the spawning sites which can be challenging for both inshore and offshore species. For fish species in which courtship calls are integral in reproduction, the best approach is defining temporal rhythms of chorusing. Then, you can perform more in depth spatial studies focusing on these time periods with gliders or other autonomous vehicles.

Commented [23]: From Eric Montie: Machine learning techniques are needed. It takes our Team a very long-time to review acoustic files. Nonetheless, when describing a new soundscape, you need to manually review acoustic files to understand the different sound-producing organisms and build a training dataset.

Commented [24]: I paraphrased some of the Popper & Hawkins 2018 recommendations (double check me, see references for DOI to search paper).

Commented [25]: Should also add to this section research into 1) technologies that perform the same functions but with reduced noise impact (as referenced above by Chou et al. 2021) and 2) roadblocks to implementing changes to existing acoustically-damaging practices.

For more information, the NYSERDA/RWSE working group wrote an extensive document on research and monitoring related to sound and vibration effects on fishes and invertebrates.[2]

VIII. Additional information

Commented [26]: Can link to other webpages, reports, etc.

Commented [27]: Popper has a good web site for which we can include a link.

The Discovery of Sound in the Sea website, https://dosits.org/ introduces users to the science and uses of Sound in the Sea. There are several major sections on the site such as The Science of Sound in the Sea, People and Sound in the Sea, and Animals and Sound in the Sea. This page focuses on resources for decision makers.

IX. Literature Cited

Commented [28]: This has not been checked yet.

Commented [29]: Lisa, one way to perhaps proceed is to separate Literature Cited from a Bibliography of other references which our readers may find useful, but which we didn't cite. I'd be willing to assist you in ferreting out which ones go where. Just let me know. I also can check my hard drive acoustic literature files against what we have included here, and then add any we missed to the Bibliography, if you want.

Commented [30]: I made a first pass at standardizing format and adding DOIs where possible. I made comments where there is an issue with the reference that I was not able to resolve with certainty. Yes, there are literature cited that are not referenced in the document which needs to be resolved.

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Habitat Hotline Atlantic 2022
Theme: Promoting Resilience in Vegetated Coastal Habitats
Lead: Kent Smith
Articles due September 15th, 2022

	Draft Completed	Photos	Feature Articles	Contributor	Status
1			Chair Introduction	New chair	
2	yes	Yes – clip from article	The Possible Future Fate of Eelgrass in the Northwest Atlantic under Climate Change	Phil Colarusso	
3	Yes	Yes	How Do We Increase the Thermal Tolerance of Eelgrass in the Face of Warming Ocean Temperatures?	Phil Colarusso	
4			Reducing nitrogen in NY	Alexa Fournier/Eric Schneider	
5			Summary of Yale article 'planning and funding natural infrastructure along CT's coast'	Robert LaFrance	
6			Light attenuation for SAV	Jimmy to contact Dr. Hall	
7			Tying impacts of degraded habitats on our managed fish species	Michelle Bachman/Eric Schneider	
8	Yes	Figures in text	Importance of water quality to seagrasses in the IRL	Kent Smith	
	Draft Completed	**Photos**	**Sidebars**	**Contributor**	**Status**
9	Yes	No	SAV Policy update	Lisa Havel	
10	Yes	Figure in doc	Habitat Committee climate change document	Lisa Havel	
11			FHOC updates	Lisa Havel	
	Draft Completed	**Photos**	**Updates on 2022 activities** 2-3 paragraphs	**Contributor**	**Status**
12	Yes	Does not have	Maine	Claire Enterline	

		separate photo			
13	Yes	2	New Hampshire	Josh Carloni	
14	Yes	3	Massachusetts	Mark Rousseau	
15			Rhode Island	Eric Schneider	
16			Connecticut	Robert LaFrance	
17	Yes	yes	New York	Alexa Fournier	
18			New Jersey	Russ Babb	
19			Pennsylvania	Dave Dippold	
20			Delaware	Zina Hense	
21	Yes	no	Maryland	Marek Topolski	
22			Virginia	Rachael Peabody	
23	Yes	yes	North Carolina	Jimmy Johnson	
24			South Carolina	Sharleen Johnson/assign another staff?	
25			Georgia	Paul Medders	
26			Florida	Kent Smith	
27	Yes	No	ACFHP	Lisa Havel	
28	Yes	No	NEFMC	Michelle Bachman	
29	N/A combined with 28	No	MAFMC	Jessica Coakley	
30			NOAA Fisheries	Lou Chiarella/Ginny Faye/Cindy Cooksey	
31			USFWS	Tripp Boltin	
32	Yes	Screenshot in text	EPA	Phil Colarusso	
33			NCCF	Wilson Laney	
34			TNC	Kate Wilke	
-			GMRI	Graham Sherwood	

Articles

- Be sure to include the author's name and affiliation for each submission.
- Ideal length is one page (2 pages max), including photos.

- Photos are highly encouraged, so please submit high-resolution images with your draft and include credit/source and captions. **Please attach photos separately; do not embed them in the document.**

2022 Updates

- Please keep state updates short, and feel free to include links.
- The updates should link to the theme, but if you have other important updates you can include those as well.
- Photos optional, but encouraged. **Please attach photos in email separately, do not embed them in the document. Provide photo credits and captions.**

Audience

- Please write for a general audience. Feedback from ASMFC Communications staff: the general public (not just managers) is interested in reading about coastal marine habitat activities. *Habitat Hotline* is also used as an outreach tool to promote fish habitat conservation and management activities.

Submission

Please send drafts to Lisa Havel Lhavel@asmfc.org.

- Articles and updates due on September 15th.

Fish Habitat of Concern Designations for Fish and Shellfish Species Managed by the Atlantic States Marine Fisheries Commission

Month XX, 2022

Prepared by the ASMFC Habitat Committee and Habitat Program Coordinator

Introduction

The Atlantic States Marine Fisheries Commission (Commission or ASMFC) serves as a deliberative body that coordinates the conservation and management of the Atlantic coastal states' shared fishery resources for protection and sustainable use. The Commission's Habitat Committee functions to promote and support cooperative interstate conservation, restoration, and protection of vital habitats for Commission-managed species. One of these functions includes the development of recommendations for Habitat Areas of Particular Concern (HAPC) for each species. The Commission renamed HAPCs 'Fish Habitats of Concern' (FHOC) in October 2017 to distinguish the Commission term from the federal term defined by the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson Act). FHOCs are a subset of fish habitat that are particularly ecologically important, sensitive, vulnerable to development threats, and/or rare. FHOCs are defined based on the same criteria as federally designated HAPCs, but since species managed only by the Commission do not fall under the Magnuson Act, their habitats are not afforded federal legal protection and no consultation with the National Marine Fisheries Service (NMFS) is required. Defining HAPC and FHOC for federally- and Commission-managed species, respectively, is intended to focus conservation efforts on specific habitats that are most ecologically important, vulnerable, and/or necessary to support each life stage of a species.

Goals

This report has two primary goals:

1. To describe the regulatory and policy context for habitat descriptions in Commission Fishery Management Plans;
2. To draft text descriptions of FHOC for species managed only by the Commission, plus Atlantic sturgeon. Atlantic sturgeon management will become the responsibility of the Commission once it is declared recovered. Given that the Commission wishes to affirm NMFS's designation of Critical Habitat (CH) for the species, the Habitat Committee elected to includes the species in this document.

Commission Policy on Habitat Descriptions in Fishery Management Plans

The Commission recognizes the importance of habitat conservation as a critical component of fisheries management and that thriving habitats produce abundant fish populations. While the Atlantic Coastal Fisheries Cooperative Management Act does not grant the Commission regulatory authority over habitat of Commission-managed species, the Commission does require habitat descriptions be included as part of each Commission Fishery Management Plan (FMP) in recognition of the critical role habitat plays in fisheries production and ecosystem function.

Guidance and process for the development of habitat sections to be included in FMPs is outlined in the ASMFC's Habitat Committee Guidance Document (2013).

The basic elements of an FMP's habitat section include:

1. Description of the Habitat;
2. Identification and Distribution of Habitat and HAPC (*since re-named FHOC*);

3. Present Condition of Habitats and HAPCs (*since re-named FHOC*);
4. Recommendations and/or Requirements for Fish Habitat Conservation/Restoration; and Information Needs/Recommendations for Future Habitat Research.

This document focuses on designations under Section 2: Identification and Distribution of Habitat and HAPC (*since re-named FHOC*), and under Section 3: Present Condition of Habitats and HAPCs (*since re-named FHOC*) where appropriate.

Commission-managed species are not subject to requirements imposed by the Magnuson Act which mandate designation of Essential Fish Habitat (EFH) and evaluation of federally-permitted projects that may impact that habitat[1]. However, the NMFS and U.S Fish and Wildlife Service (USFWS) do have obligations to consult on a broader array of trust resources under the Fish and Wildlife Coordination Act, which includes Commission-managed species.

Guidelines for Identifying Fish Habitat of Concern, formerly known as HAPCs
The Commission's guidelines for identifying FHOCs (formerly HAPCs) in FMPs are stated in the box below. The subsections were combined to create the current designations.

The text is taken from Appendix 3 to the Habitat Committee Guidance (2013, pp. 30-31). *Note: "Habitat Area of Particular Concern" has been changed to "Fish Habitat of Concern" in the text below where appropriate.*

1.4.1.2: Identification and Distribution of Fish Habitat of Concern

The intent of this subsection is to identify habitat areas or [fish] habitat area of concern that are unequivocally essential to the species in all their life stages, since all used habitats have already been identified in Subsection 1.4.1.1.

Habitat Areas of Particular Concern, or HAPCs, are areas within EFH that may be designated according to the Essential Fish Habitat Final Rule (2002) based on one or more of the following considerations: (i) the importance of the ecological function provided by the habitat, (ii) the extent to which the habitat is sensitive to human-induced environmental degradation, (iii) whether, and to what extent, development activities are, or will be, stressing the habitat type, or (iv) the rarity of the habitat type. Descriptions of EFH are not currently being included in FMPs prepared for species solely under Commission management. The definition of FHOC is therefore modified to be areas within the species' habitat that satisfy one or more of the aforementioned criteria. ***When an FHOC is described for a species solely under the management of the Commission, the designation does not have any regulatory authority. Please refer to the ASMFC HAPC document for a list of species under Commission management only and description of the corresponding HAPC (ASMFC 2013b)[2].***

[1] Federal agencies proposing or authorizing projects within EFH areas are required to consult with NMFS to determine the impact of those projects on EFH. This EFH consultation is required only for federally managed species, not for species solely under the management authority of the Commissions. Regulatory guidelines for EFH consultations can be found at 50 C.F.R. §600.905 2015.

[2] The referenced document is referring to this current document (ASMFC 2022).

A FHOC is a subset of the "habitats" described in Subsection 1.4.1.1, and could include spawning habitat (e.g., particular river miles or river reaches for striped bass populations), nursery habitat for larvae, juveniles and subadults, and/or some amount of foraging habitat for mature adults. FHOC are geographic locations which are particularly critical to the survival of a species. Determination of the amount of habitats (spawning, nursery, subadult, adult residence, and adult migration routes) described in Subsection 1.4.1.1 that should be classified as FHOC may be difficult.

Examples of FHOC include: any habitat necessary for the species during the developmental stage at which the production of the species is most directly affected; spawning sites for anadromous species; benthic areas where herring eggs are deposited; primary nursery areas; submerged aquatic vegetation in instances when species are determined to be "dependent" upon it; and inlets such as those located between the Atlantic Ocean and bays or sounds, which are the only areas available for providing ingress by larvae spawned offshore to their estuarine nursery areas.

The extent of habitats or FHOC for a species may depend on factors such as habitat bottlenecks, the current stock size and/or the stock size for which a species Management Board and Technical Committee establishes targets, etc. Given the current state of knowledge with regard to the relationship between habitat and production of individual species, this information may not be available for many species.

If known, the historical extent of FHOC should also be included in this subsection, in order to establish a basis for Subsection 1.4.1.3. Use of GIS is encouraged to depict the historical and current extent of HAPCs, and determine the amount of loss/degradation, which will assist in targeting areas for potential restoration.

1.4.1.3: Present Condition of Habitats and Fish Habitat of Concern

This subsection should include, to the extent the information is available, quantitative information on the amount of habitat and FHOC that are presently available for the species, and information on current habitat quality. Reasons for reduction in areal extent (either current or historical), should be addressed, for example, "dam construction has eliminated twenty percent of historical spawning habitat" (ASMFC, 2008), "forage habitat bottleneck has reduced the young-of-year populations by thirty percent", or "fishing gear continues to disturb fifty percent of the forage habitat", etc.

Any habitats or FHOC that have diminished over time due to habitat bottlenecks should be incorporated to the extent information is available. Habitat bottlenecks can occur due to natural disasters, fishing disturbance, impacts of development, or other complex processes that can cause habitat shifts. This subsection can further address options to reverse or restore current known habitat bottlenecks. All current threats to the species' habitat should be discussed in this subsection. If known, relative impacts from these activities should be identified and prioritized. For example, addressing hydrological alterations and their impacts are a high priority for anadromous species. These may include freshwater inflow/diversions; changes in flows due to hydropower, flood control, channel modifications, or surface/aquifer withdrawals; and saltwater flow or salinity changes due to reductions in freshwater inflows or deepening of navigation channels, which facilitate upstream salinity increases. Threats should also be assessed for their effect on the ability to recreationally and commercially harvest, consume, and market the species (e.g., heavy metals or chemical contamination which results in the posting of consumption advisories, or prohibition of commercial fisheries for a species, e.g. striped bass in the Hudson River, NY).

This subsection will serve as a basis for the development of recommended or required actions to protect the species' habitat, which will be outlined in Section 4.4. For example, the effectiveness of water quality standards should be reviewed in this subsection. If they are ineffective or inappropriate at protecting water quality at a level appropriate to assure the productivity and health of the species, then a recommendation should be included under the recommendations section (Section 4.4) for improvement of water quality standards.

Purpose of this Report

Although habitat information is required for each FMP, the amount of information compiled for each species varies, as does the extent of the underlying habitat-related science. Also, FMPs are written and amended as management needs arise, and the frequency of updates is not consistent between plans. Consequently, FHOC designations range from non-existent to specific and recent. This report was initiated to assess the current FHOC designations and make updates, clarifications, and improvements where possible.

The Habitat Committee drafted text descriptions of FHOC for each Commission-managed species drawing on information from the current description of FHOC in the FMPs, species fact sheets, other ASMFC publications, and current literature. Descriptions were reviewed and modified by the species technical committees for accuracy and approval.

FHOC will not be designated for species managed jointly with the Councils, instead deferring to federal designations for EFH and HAPCs. FHOCs will be designated on a case by case basis for ASMFC species which may be listed under the Endangered Species Act (the presumption being that ASMFC would still be responsible for management of the species, once it is declared recovered).

As FMPs and other Commission documents are updated, 'Habitat Areas of Particular Concern (HAPC)' will be replaced with 'Fish Habitats of Concern (FHOC)' as appropriate.

American Eel Fish Habitats of Concern

Although no current anthropogenic threats to the functional health of the Sargasso Sea have been reported (aside from climate change), it is a FHOC for spawning adults and eggs because this is where reproduction for the panmictic population occurs exclusively. *Sargassum* seaweed was being harvested in U.S. waters by surface trawling primarily by one company, but such harvest has ceased. Historically, the harvesting of *Sargassum* began in 1976, but only occurred in the Sargasso Sea since 1987. Since 1976, approximately 44,800 dry pounds of *Sargassum* were harvested, 33,500 pounds of which were from the Sargasso Sea (SAFMC 1998). It is unknown whether this harvest had a direct or indirect influence on American eel mortality. Harvesting *Sargassum* was eliminated in the South Atlantic Exclusive Economic Zone and state waters on January 1, 2001, through a management plan adopted by the South Atlantic Fishery Management Council (SAFMC 1998). The extent of eel bycatch in these operations was not documented.

The drift of leptocephalus larvae from the Sargasso Sea towards the Atlantic coast may be impacted by changes in ocean currents. Such changes have been predicted to be possible due to climate change (Knights 2003, Caesar et al. 2018, Thornalley et al. 2018, Peng et al. 2022). The potential impact on the drift of larvae is unknown at this time, but the predicted weakening and positioning of the Gulf Stream (Ezer 2015, Rypina et al. 2016) may reduce larval transport to coastal and fresh waters. Currents, primary production, and potential influence of toxins transferred from the adults to the eggs influence the success of hatch, larval migration, feeding, and growth.

Glass eel survival (growth, distribution, and abundance) on the continental shelf is probably impacted by a variety of activities. Channel dredging, shoreline alterations, and overboard dredged material disposal are common throughout the Atlantic coast, but currently the effects on glass eels are unknown. Additionally, these activities, along with impacts from mobile fishing gear, may damage American eel benthic habitat. However, the significance of this impact also remains unknown. Changes in salinity in embayments, as a result of dredging projects, could alter American eel distribution.

Elver and yellow eel abundance is impacted by physical changes in the coastal and tributary habitats. Lost wetlands or access to wetlands and lost access to the upper reaches of tributaries have significantly decreased the availability of these important habitats with wetland loss estimated at 54% (Tiner 1984) and Atlantic coastal tributary access loss or restriction to American eel nursery habitats estimated at 84% (Busch et. al 1998).

Habitat factors are probably impacting the abundance and survival of elver, yellow, and silver eel life stages. The nearshore, embayments, and tributaries provide important feeding and habitat for growth. The availability of these habitats influences the density of the eels and may influence the determination of sex. Therefore, since females may be more common in lower density settings (Vladykov 1966; Columbo and Rossi 1978; Liew 1982; Holmgren and Mosegaard 1996; Roncrati et al. 1997; Krueger and Oliveira 1999) it is crucial that the quantity and quality of these habitats be protected and restored (including upstream access). The blockage or restriction to upstream migration caused by dams reduces or restricts the amount of available habitat to support eel distribution and growth, and therefore tributary headwaters are a particular FHOC. Fish that succeeded to reach upstream areas may also face significant stresses during downstream migration. For example, if eel have to pass through turbines, mortality rates can range from 10 – 60% (J. McCleave, U. of Maine, personal communication) and the amount of injury is not well documented. In the future, it is possible that “fish-friendly” turbines which provide much higher survival rates for American eels may greatly reduce this source of mortality (Peter Sturke and Corey Chamberlain, Dominion Energy, personal communication).

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American Lobster Fish Habitats of Concern

There has been widespread increase in the area and duration of stressful water temperatures (>20°C) throughout Southern New England inshore waters (ASMFC 2010, ASMFC 2020). This loss of optimal thermal habitat in inshore waters throughout this region has caused the stock to contract into deeper waters. Furthermore, young-of-year recruitment throughout historically productive inshore areas have shown dramatic declines throughout the past two decades are now at sustained low levels. Much of the Southern New England fishery has moved to deeper offshore areas in this region. The contraction of thermal habitat in Southern New England to rising ocean temperatures is a major concern for this species. The Gulf of Maine is still within the optimal temperature range for American lobster, though it is warming at unprecedented rates and there have been recent declines in young-of-year recruitment and older juvenile indices in recent years (ASMFC 2015, ASMFC 2020). Though the Gulf of Maine/Georges Bank stock is still near a time series high level of reference abundance, declines in recruitment and other older life stage indices have prompted ASMFC to consider management changes to protect spawning stock biomass. The Gulf of Maine will be monitored closely over the coming years to detect population changes, though other than concerns of recent declines, continues to be in generally good condition. In contrast, the Southern New England population is at historic low levels and a major concern is lack of optimal thermal habitat for all life stages.

Other American lobster FHOCs include gravel, cobble, boulder, and embedded rock for young-of-year, juvenile, and adult life stages. Areas where these habitats are limited and in close proximity to offshore shoals are susceptible to various types of anthropogenic impact. American lobster metamorphose through four larval stages before settling to the bottom. Research has shown they need shelter providing habitat to protect them from predators during this vulnerable time (Wahle and Steneck 1991, Wahle and Incze 1997). These shallow water cobble/boulder areas are critical to protect from coastal development. Furthermore, egg-bearing female lobsters tend to aggregate in offshore and nearshore shoal areas (Campbell 1990, Carloni and Watson 2018, Jury et al. 2019). This likely provide access to warm water for brooding eggs and close proximity to deep offshore areas for releasing larvae. Areas such as Grand Manan, Canada; Monhegan Island, Maine; Isles of Shoals, Maine/New Hampshire; and Georges Bank have all documented large aggregations of female reproductive lobsters. These areas need to be taken into consideration with any coastal development.

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Atlantic Croaker Fish Habitats of Concern

FHOCs for juvenile Atlantic croaker include low salinity estuarine habitats along the Atlantic coast in early spring, to higher salinity estuarine habitats in summer and early fall, in areas with mud and detrital bottoms rich in benthic prey and dissolved oxygen (DO) levels consistently higher than 2.0 mg/L. Estuaries such as Pamlico Sound and Chesapeake Bay serve as important nursery and spawning areas (Schloesser and Fabrizio 2018). Adult Atlantic croaker are also dependent upon estuarine habitat in spring through fall, in areas with salinities ranging from 3-27 ppt and DO greater than 2.0 mg/L, but are less limited than juveniles by bottom substrate type due to an ontogenetic diet shift.

Along the Atlantic coast, juvenile Atlantic croaker are typically found in estuaries. Young-of-year less than 50 mm total length (TL) inhabit low salinity or upriver areas (Haven 1957; Dahlberg, 1972; Chao and Musick 1977; White and Chittenden 1977; Miller et al. 2003). Juveniles are positively correlated with mud bottoms that have large amounts of detritus and high amounts of benthic prey (Cowan and Birdsong 1985). Juveniles migrate downstream as they develop; by late fall, most juveniles emigrate out of the estuaries to coastal ocean habitats (Miglarese et al. 1982). In spring (after spending winter in the coastal ocean) through fall, adult Atlantic croaker are found in estuaries over muddy and sandy substrates, seagrass beds, and near oyster, coral and sponge reefs (White and Chittenden 1977; TSNL 1982).

Studies have shown that Atlantic croaker are virtually absent from waters with DO levels less than 2.0 mg/L, suggesting they are very sensitive to the amount of DO present (Eby and Crowder 2002). This can become a factor that limits habitat quantity and quality in the warmer summer months in estuarine systems that experience nutrient enrichment and eutrophication issues. Bottom-tending fishing gear may also impact Atlantic croaker FHOCs (Able et al. 2017, Odell et al. 2017).

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Atlantic Menhaden Fish Habitats of Concern

Estuarine-subtidal and riverine-tidal systems are FHOCs for larval and early juvenile life stages of Atlantic menhaden. Atlantic menhaden production is heavily dependent on estuarine-subtidal and riverine-tidal systems (constrained to the upstream limit of the tidal zone) and the water quality of those systems is threatened by climate change, toxicants, nutrient pollution, and altered freshwater flows. A further threat to estuarine water quality is lower DO associated with increasing average annual temperatures due to climate change. Both the Neuse River Estuary and Chesapeake Bay have been prone to hypoxic or anoxic conditions during summer (Cooper and Brush 1991), resulting in significant episodic mortality of juvenile Atlantic menhaden, particularly in the Neuse (Carpenter and Dubbs 2012).

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Atlantic Striped Bass Fish Habitats of Concern

Adult striped bass are highly concentrated and most vulnerable to exploitation in their offshore wintering grounds (historically from the Outer Banks of North Carolina northward through Virginia and Maryland waters, but in recent years shifting more northward and further offshore) and riverine spawning areas (for the Atlantic migratory stock, most major coastal rivers from the Roanoke in North Carolina through the Kennebec in Maine). While exploitation of striped bass aggregations impacts the spawning stock, the determinant factor in striped bass abundance (year class strength) is the survival of their eggs and larvae. For this reason, spawning areas are a FHOC for striped bass.

Striped bass spawn in freshwater or nearly freshwater of Atlantic Coast rivers and estuaries. Such sites provide the critical ecological function of reproduction; are sensitive to anthropogenic impacts such as dam emplacement, nutrient and sediment loading, and pollution; are susceptible to navigational dredging and other coastal development activities; and are relatively small in extent and extremely rare in comparison to the areal extent of other migratory striped bass habitats. According to Hill et al. (1989) and citations within: striped bass spawn above the tide in mid-February in Florida but in the St. Lawrence River they spawn in June or July. The bass spawn in turbid areas as far upstream as 320 km from the tidal zone. The tributaries of the Chesapeake Bay are the primary spawning areas for migratory striped bass, but other major areas include the Hudson River, Delaware Bay, and the Roanoke River. Spawning is triggered by increased water temperature. Spawning occurs between 10 and 23°C, but optimal temperature for spawning is between 17 and 19°C.

A temperature range of 17-19°C is important for egg survival as well as for maintaining appropriate DO levels (Bain and Bain 1982). Minimum water velocities of 30 cm/s are needed to keep the eggs suspended, and fluctuations in the water velocity cause changes in the size of the oil globule surrounding the eggs (Albrecht 1964). Without the buoyancy, the eggs sink to the bottom, where the sediment may smother them. It is possible for the eggs to hatch if the sediment is coarse and not sticky or muddy, but survival is limited (Bayless 1968). Eggs hatch from about 30 hours at 22°C to about 80 hours at 11°C (Hill et al. 1989).

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Atlantic Sturgeon Fish Habitats of Concern

The FHOCs for Atlantic sturgeon include the NMFS CH designations for the five discrete population segments (DPS) which comprise the species range. The designations can be found here: https://www.fisheries.noaa.gov/action/critical-habitat-designation-atlantic-sturgeon. The designations include the reaches of Atlantic Coast rivers where spawning migrations, egg deposition, and larval and early juvenile nursery habitats occur. Threats to these habitats are multiple and include altered river flows and thermal regimes due to hydropower operations, water withdrawals, and increased incidence of storms owing to climate change; low DO, ocean acidification, altered salinity due to navigational dredging, and ship strikes, among others.

Information regarding Atlantic sturgeon use of spawning reaches at a finer scale has increased since CH designation in 2017 as a result of ongoing long-term studies using acoustic telemetry of sexually mature Atlantic sturgeon (e.g., see Breece et al. 2021, for the Hudson River population; Hager et al. 2020 for the York River population in Virginia; and additional information is currently being gathered for North Carolina rivers under a NMFS Section 6 grant, see McCargo et al. 2019). These studies may allow further refinement of Atlantic sturgeon FHOC beyond what is presently designated as CH by NMFS.

When the initial CH designations were made, the NMFS indicated that they believed they did not have enough data to designate estuarine or offshore habitats where sturgeon aggregations occurred as CH for reasons that were not unequivocally associated with particular physical or biological features. Specifically, they stated, “We cannot designate critical habitat based on the presence of the species alone. Therefore, while we acknowledge there is literature that identifies aggregation areas where Atlantic sturgeon are generally found, it does not provide specificity as to the purpose of the aggregations or the features that support those purposes. Therefore, we do not believe it provides the information we need to meet the statutory and regulatory requirements to designate critical habitat” [Federal Register / Vol. 82, No. 158 / Thursday, August 17, 2017 / Rules and Regulations, Page 39172].

While we do not disagree with the NMFS conclusions with respect to sturgeon aggregations and CH designation(s), the Commission believes that sufficient justification and data currently exist to designate habitats FHOC for ASMFC purposes, in particular Atlantic sturgeon nursery habitats within estuaries outside of the current NMFS CH designations, where fishery-independent sampling has persistently shown juveniles to be present. Most natal rivers discharge into estuaries, and these areas, part of the migratory pathway for juveniles to the ocean, are of significance for juveniles as they migrate from their birthplace. The NMFS CH designations in most cases already include the estuarine portions of many rivers (i.e., Haverstraw Bay as documented as a significant Atlantic sturgeon nursery area, see Pendleton and Adams 2021; and the Delaware River estuary, see Hale et al. 2016); however, we believe additional estuarine areas further downstream merit FHOC status, based on the persistent and documented presence of juvenile Atlantic sturgeon within them and their importance as part of the migratory pathway.

Our recommendations are based in large measure on the comprehensive review of Atlantic sturgeon life history by Hilton et al. (2016), supplemented by additional published information and in some cases unpublished data (specific references cited below). We also rely on the review by Dunton et al. (2010) of Atlantic sturgeon within the Northwest Atlantic Ocean as derived from five fishery-independent surveys. In particular, they note: "Our analysis of habitat preferences indicated that depth was the primary environmental characteristic defining the Atlantic sturgeon distribution. Thus, essential habitat for juvenile marine migrant Atlantic sturgeon can broadly be defined as coastal waters <20 m depth, and it is concentrated in areas adjacent to estuaries such as the Hudson River–NY Bight, Delaware Bay, Chesapeake Bay, Cape Hatteras, and Kennebec River. This narrow band of shallow water appears to represent an important habitat corridor and potential migration path."

These estuarine FHOC areas which were not included within the NMFS CH designations include (from north to south): Long Island Sound (Dunton et al. 2010, citing Bain et al. 2000 and Savoy and Pacileo 2003); Delaware Bay (Dunton et al. 2010; Brundage and O'Herron 2009; Breece et al. 2018); Chesapeake Bay (Musick 2005; Greenlee et al. 2017), including the Nanticoke River-Marshyhope Creek estuary (see Secor et al. 2022); western Albemarle Sound (based on a decades-long time series documenting young-of-year production and subadult habitat use, from captures in the NCDMF fishery-independent striped bass gill net survey, NCDMF unpublished data; and Armstrong 2003); Pamlico Sound (Atlantic sturgeon use also documented through NCDMF fishery-independent unpublished data); and Winyah Bay (Collins et al. 2000, Simpson et al. 2015, Crane 2021). Such estuarine areas are important not only as nursery habitat for juveniles produced within natal rivers tributary to these estuaries, but also for juveniles and subadults which may migrate into them from other spawning populations (e.g., see Waldman et al. 2013).

Finally, several long-term fishery-independent data time series (Laney et al. 2007 and unpublished data; Dunton et al. 2010), as well as analysis of fishery-dependent data derived from observation of Atlantic sturgeon bycatch (e.g., see Stein et al. 2004, ASMFC 2007, and NMFS 2022) have consistently documented aggregation sites for subadult and adult Atlantic sturgeon in the nearshore marine environment. In the spring and fall, juveniles are found off the Rockaways and Sandy Hook (Dunton et al. 2010, 2015, unpublished acoustic data). We believe these areas also merit designation as FHOC. Stein et al. (2004) mapped multiple areas from Cape Hatteras northward. Dunton et al. (2010) also mapped multiple sites. Analysis of the complete time series (1988-2016) of data from Atlantic sturgeon captures during the Cooperative Winter Tagging Cruises (see Laney et al. 2007) by Wickliffe et al. (2019) further documents the Atlantic sturgeon "hot spots" in the nearshore Atlantic Ocean off NC and VA. Such aggregation sites are not only used by sturgeon from nearby natal rivers, but are also frequented by sturgeon from other DPSs as well (Wirgin et al. 2015, Kazyak et al. 2021). "Hot spots" should be designated FHOCs once specific locations are identified.

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Black Drum Fish Habitats of Concern

Black drum are habitat generalists, so no FHOCs are designated at this time. At various life stages they can be found in the following habitats: tidal freshwater, estuarine emergent vegetated wetlands (flooded salt marshes, brackish marshes, and tidal creeks), estuarine scrub/shrub (mangrove fringe), submerged rooted vascular plants (seagrasses), oyster reefs and shell banks, unconsolidated bottom (soft sediments), ocean high salinity surf zones, and artificial reefs. The estuarine system as a whole serves as the species' primary nursery area. In the future, we may elect to specify documented spawning sites as FHOC for black drum, should acoustic surveys be able to accurately pinpoint such habitats (e.g., see Rice et al. 2016).

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Cobia Fish Habitats of Concern

Important habitats for cobia include estuarine and nearshore spawning areas and live reefs and artificial structure. Good water quality in high salinity sounds in South Carolina and Virginia where spawning aggregations occur and eggs and larvae develop are critical for the sub-population of cobia that spawn inshore. Oceanic spawning sites off Virginia to Georgia may extend from just outside inlets and sounds to the Gulf Stream (Brown-Peterson et al. 2001). Offshore spawning was determined through the presence of eggs and larvae, thus exact locations are not known but cobia often associate with structure provided by live reefs, artificial reefs, oil platforms, and navigation markers.

Designation of FHOCs should be considered for Port Royal Sound, St. Helena Sound, Beaufort Inlet, Barden's Inlet, Hatteras Inlet, Pamlico Sound, and the mouth and lower portion of the Chesapeake Bay, especially for the months of April through June, when extensive eggs and larvae have been documented (Lefebvre and Denson 2012). Movement data show that cobia can exhibit site fidelity to spawning areas, returning to the same sites across multiple years. Four genetically distinct groups of cobia are found along the Atlantic coast, two of which are associated with spawning inshore in South Carolina and inshore Virginia/North Carolina (Darden et al. 2018), further supporting the areas listed above. Additional locations could be considered as potential FHOCs in the future as research on cobia spawning habitat and movements expands.

As for many species, protection of spawning habitat can help to ensure population viability. Seasonal cobia migrations that occur along coasts, and between inshore and offshore waters, are driven by water temperature; thus, interannual variation in water temperature, and climate change, could affect the timing of spawning and recruitment (Crear 2021). Protection of spawning habitat is warranted in areas subject to urbanization, eutrophication, and dredging. In the Chesapeake Bay, one of the spawning sites of cobia, nutrients along with warmer water has led to more frequent and severe hypoxic events (e.g., Hagy et al. 2004).

Along the Atlantic coast, cobia are divided into two stocks at the Florida/Georgia border (GMFMC 2014) with a mixing zone from southern Georgia to Cape Canaveral FL (Darden et al. 2014, Perkinson et al. 2019). The east coast of Florida is considered a migratory zone and is managed by the Gulf of Mexico Fishery Management Council. Hence, Florida is not considered in habitats of concern for the ASFMC.

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Horseshoe Crab Fish Habitats of Concern

Habitat requirements change throughout the horseshoe crab life cycle, extending from intertidal beach fronts and tidal flats in coastal embayments for eggs and larvae, to the edge of the continental shelf for adults. The distribution of high quality spawning beaches, which are exposed to minimal human disturbance, presents a potential bottleneck to reproductive success for this species. Beach areas that provide spawning habitat are Fish Habitats of Concern for adult horseshoe crabs. Spawning adults prefer sandy beaches in low wave energy areas, usually within bays and coves. The ideal beach habitat for spawning horseshoe crabs includes a sufficient depth of porous, well-oxygenated sediments to provide a suitable environment for egg survival and development, although nest depth and location on the beach vary among the Atlantic states depending on local habitats available for spawning. Spawning beach characteristics can vary along the coast, with beaches in Florida typically having a finer grain size and larger area of tidal inundation and saturated zones. This causes the sediment to hold more water, though these beaches have also shown to hold oxygen farther from the water line than in Delaware (Penn and Brockman 1994).

Juvenile horseshoe crabs use nearshore, shallow water, and intertidal flats as they develop. Larger juveniles and adults use deep water habitats to forage for food, but these are not considered Fish Habitats of Concern. Of these habitats, the beaches are the most critical (Shuster 1996). Optimal spawning beaches may be a limiting reproductive factor for the horseshoe crab population.

The densest concentrations of horseshoe crabs in New Jersey occur on small sandy beaches surrounded by salt marshes or bulkheaded areas (Loveland et al. 1996). The spawning beaches within Delaware Bay are critical habitat because they support the highest density of spawning horseshoe crabs along the U.S. Atlantic Coast. Prime spawning beaches within the Delaware Bay consist of sand beaches between Maurice River and the Cape May Canal in New Jersey and between Bowers Beach and Lewes in Delaware (Shuster 1996). Horseshoe crab eggs play an important ecological role in the food web for migrating shorebirds and the Delaware Bay is an important stopover location for the threatened red knot. Good spawning habitat is widely distributed throughout Maryland's Chesapeake and coastal bays, including tributaries. In South Carolina and Georgia, horseshoe crabs spawn in substantial numbers on a variety of substrates including sandy beaches, salt marshes, and coarse-grained oyster shell. These sites are also known stopover locations for red knot. While viability of eggs deposited in salt marshes are slightly reduced compared to the sandy beaches, horseshoe crabs apparently use these habitats for spawning frequently in South Carolina (Kendrick et al. 2021). Florida has less dense concentrations of horseshoe crabs but there are still prominent spawning populations on both the Atlantic and Gulf Coasts. The Indian River Lagoon has the highest densities of horseshoe crabs in Florida.

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Jonah Crab Fish Habitats of Concern

Currently there is not enough information available to designation Jonah crab FHOC.

Northern Shrimp Fish Habitats of Concern

Deep, muddy basins (generally 90-180 m, but found down to 300 m) in the southwestern region of the Gulf of Maine act as cold-water refuges (4-6°C) for adult shrimp during periods when most water in the Gulf reaches sub-optimal temperatures and are therefore a FHOC. Sub-optimal temperatures are considered over 8°C, with temperatures over 12°C being considered highly stressful for northern shrimp and potentially causing mortality if exposed to these temperatures over longer time periods (ASMFC 2017, Richards and Hunter 2021). Temperature serves as a habitat bottleneck for this species (Apollonio 1986).

Nearshore water provides habitat for larval and juvenile stages of northern shrimp, however the specific habitat requirements and spatial distribution are not well known (ASMFC 2017).

See Figure 10 in Amendment 3 of the northern shrimp FMP (ASMFC 2017) and Figure 6 in Richards and Hunter 2021, showing temperature regimes and shrimp populations respectively, further than 10 miles from shore. Also see “Offshore Habitat Preferences” in Apollonio et al. 1986, p. 18 for general discussion.

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Red Drum Fish Habitats of Concern

Red drum FHOCs vary based on life stage. FHOCs for early juveniles include protected marsh (tidal fresh, brackish, and salt water) and tidal creek habitat (Peters and McMichael 1987; Wenner, 1992; FWCC 2008). Subadults, while they can use a wide range of estuary habitats, exhibit highest abundances and apparent productivity in association with submerged aquatic vegetation, oyster reef, tidal creeks, and marsh (tidally fresh, brackish, and salt) habitats (Pafford et al. 1990; Wenner 1992; Adams and Tremain 2000). Highest concentrations tend to be found in areas with dense reefs and/or shell hash in association with tidally flooded marsh habitat where these habitats exist. FHOCs for adults include inlets, channels, sounds, outer bars, and within estuaries in some areas (e.g. Indian River Lagoon, FL), due to their importance for red drum spawning activity (Murphy and Taylor 1990; Johnson and Funicelli 1991; Reyier et al. 2011).

A species' nursery areas are indisputably essential to its continuing existence. Nursery areas for red drum can be found throughout estuaries. Larvae and early juveniles seemingly prefer shallow waters of varying salinities that offer a certain degree of protection. Such areas include coastal marshes, shallow tidal creeks, bays, tidal flats of varying substrate, tidal impoundments, and seagrass beds (Pattillo et al. 1997; Holt et al. 1983; Rooker and Holt 1997, Rooker et al. 1998; Levin et al. 2001). Since red drum larvae and juveniles are ubiquitous in such environments, it is impossible to designate specific areas as deserving more protection than others. Moreover, these areas are not only nursery areas for red drum, but they fulfill the same role for numerous other resident and estuarine-dependent species of fish and invertebrates, especially other sciaenids. Similarly, subadult red drum habitat extends over a broad geographic range and adheres to the criteria that define HAPCs and FHOCs. Subadult red drum are found throughout tidal creeks and channels of southeastern estuaries. The subadults utilize submerged aquatic vegetation, tidal creeks, oyster reefs as well as tidally fresh, brackish, and salt marsh (Pafford et al. 1990; Wenner 1992; Adams and Tremain 2000). The entire estuarine system, from the lower salinity reaches of rivers to the mouth of inlets, is vital to the continuing existence of this species.

While there is currently no supporting evidence to suggest a particular habitat type limits red drum populations, it should be noted again that seagrass beds are vitally important for newly settled individuals, and oyster reefs, tidal creeks, and coastal rivers are of critical importance to red drum during the juvenile and subadult life stages. Data from Georgia's Marine Sportfish Health Survey indicate over 80% of juvenile red drum in Georgia waters are associated with shell habitats. Changes in water flow and conditions due to watershed activities may also limit recruitment of larvae at a local scale.

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River herring and Shad: Alewife (*Alosa aestivalis*), Blueback Herring (*Alosa pseudoharengus*), American Shad (*Alosa sapidissima*), and Hickory Shad (*Alosa mediocris*) Fish Habitats of Concern

NOTE: Due to the dearth of information on FHOCs for alosine species, this information is applicable to American shad, hickory shad, alewife, and blueback herring combined. Information about one alosine species may be applicable to other alosine species and is offered for comparison purposes only. Certainly, more information should be obtained at individual FHOCs for each of the four alosine species.

Metapopulation structure, meaning groups of the same species that are spatially separate, but may interact at some level, is evident in river herring. Metapopulation structure is important because individuals may be locally adapted. Adults frequently return to their natal rivers for spawning but some limited straying occurs between rivers (Jones 2006, ASMFC 2009). Critical life history stages for American shad, hickory shad, alewife, and blueback herring, are the egg, prolarva (yolk-sac or pre-feeding larva), post-larva (feeding larva), and early juvenile (through the first month after transformation) (Klauda et al. 1991a, b). Spawning grounds and nursery habitat where these critical life stages grow and mature broadly includes freshwater ponds, rivers, tributaries, and inlets. The substrate preferred for spawning varies greatly and can include gravel, detritus, and submerged aquatic vegetation. Blueback herring prefer swifter moving waters than alewives do (ASMFC 2009). Nursery areas include freshwater and semi-brackish waters. Access to these spawning and nursery habitats may be blocked or impeded by dams or other barriers. Juvenile alosines, which leave the coastal bays and estuaries prior to reaching adulthood, also use the nearshore Atlantic Ocean as a nursery area (ASMFC 1999).

See Greene et al. 2009 for tables that detail environmental, temporal, and spatial values/factors affecting the distribution of alewife, blueback herring, American shad, and hickory shad.

Habitat quantity

Thousands of kilometers of historic anadromous alosine habitat have been lost due to development of dams and other obstructions to migration. In the 19th century, organic pollution from factories created zones of hypoxia or anoxia near large cities (Burdick 1954, Talbot 1954, Chittenden 1969). Gradual loss of spawning and nursery habitat quantity and quality and overharvesting are thought to be the major causative factors for population declines of American shad, hickory shad, alewife, and blueback herring (ASMFC 1999).

It is likely that American shad spawned in all rivers and tributaries throughout the species' range on the Atlantic coast prior to dam construction in this country (Colette and Klein-MacPhee 2002). While precise estimates are not possible, it is speculated that at least 130 rivers supported historical runs; now there are fewer than 70 systems that support spawning. Individual spawning runs may have numbered in the hundreds of thousands. It is estimated that runs have been reduced to less than 10% of historic sizes. The 2020 American Shad Benchmark Stock Assessment Summary reported that the percentage of historic riverine habitat that is currently unobstructed varies from 4-100% in 23 river systems from Maine to Florida, with 12 systems at 75% or less unobstructed and seven river systems at 50% or less unobstructed (see table in ASMFC 2020a). One recent estimate of river kilometers unavailable for spawning is 4.36 x 10^3 compared to the original extent of the runs. This is an increase in available habitat as compared with estimates from earlier years, with losses estimated at 5.28 x 10^3 in 1898 and 4.49 x 10^3 in 1960. The increase in available habitat has largely been due to restoration efforts and enforcement of pollutant abatement laws (Limburg et al. 2003).

Some states have general characterizations of the degree of habitat loss, but few studies have actually quantified impacts in terms of the area of habitat lost or degraded (ASMFC 1999). It has been noted that dams built during the 1800's and early to mid-1900's on several major tributaries to the Chesapeake Bay have substantially reduced the amount of spawning habitat available to American shad (Atran et al. 1983, CEC 1988), and likely contributed to long-term stock declines (Mansueti and Kolb 1953). North Carolina characterized river herring habitat loss as "considerable" from wetland drainage, stream channelization, stream blockage, and oxygen-consuming stream effluent (NCDENR 2000). Sixteen state and cooperative river basin habitat plans that provide greater local detail on American shad habitat and are available at http://www.asmfc.org/species/shad-river-herring.

Some attempts have been made to quantify existing or historical areas of anadromous alosine habitat, including spawning reaches. Most recently, the American shad benchmark assessed and compared the amount of currently available habitat for American shad in Atlantic coast rivers to historic habitat availability (ASMFC 2020b). See section 2.7.2 for a description of this analysis. Results are presented for individual systems in each system stock section (Section 3), and overall coastwide results are provided in section 4.4.2. Previously, Maine estimated that the American shad habitat area in the Androscoggin River is 2,111 acres. In the Kennebec River, Maine, from Augusta to the lower dam in Madison, including the Sebasticook and Sandy rivers, and Seven Mile and Wesserunsett streams, there is an estimated 6,510 acres of American shad habitat and 24,606 acres of river herring habitat. Lary (1999) identified an estimated 1,877 acres of suitable habitat for American shad and 6,133 acres for alewife between Jetty and the Hiram Dam along the Saco River, Maine. Above the Boshers Dam on the James River, Virginia, habitat availability was estimated in terms of the number of spawning fish that the main-stem area could support annually, which was estimated at 1,000,000 shad and 10,000,000 river herring (Weaver et al. 2003).

Although many stock sizes of alosine species are decreasing or remain at historically low levels, some stock sizes are increasing. It has not been determined if adequate spawning, nursery, and adult habitat presently exist to sustain stocks at recovered levels (ASMFC 1999).

Habitat quality

Concern that the decline in anadromous alosine populations is related to habitat degradation has been alluded to in past evaluations of these stocks (Mansueti and Kolb 1953, Walburg and Nichols 1967). This degradation of alosine habitat is largely the result of human activities. However, it has not been possible to rigorously quantify the magnitude of degradation or its contribution to impacting populations (ASMFC 1999).

Of the habitats used by American shad, spawning habitat has been most affected. Loss due to water quality degradation is evident in the northeast Atlantic coast estuaries. In most alosine spawning and nursery areas, water quality problems have been gradual and poorly defined; it has not been possible to link those declines to changes in alosine stock size. In cases where there have been drastic declines in alosine stocks, such as in the Chesapeake Bay in Maryland, water quality problems have been implicated, but not conclusively demonstrated to have been the single or major causative factor (ASMFC 1999).

Toxic materials, such as heavy metals and various organic chemicals (i.e., insecticides, solvents, herbicides), occur in anadromous alosine spawning and nursery areas and are believed to be potentially harmful to aquatic life, but have been poorly monitored. Similarly, pollution in nearly all of the estuarine waters along the East Coast has certainly increased over the past 30 years, due to industrial, residential, and agricultural development in the watersheds (ASMFC 1999).

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Spot Fish Habitats of Concern

FHOCs for larval spot include brackish and saltwater marsh as well as submerged aquatic vegetation in mesohaline and polyhaline waters. From Delaware to Florida, primary nursery habitat for juveniles includes low salinity bays and tidal marsh creeks with mud and detrital bottoms that contain their epifaunal and infaunal prey. Seagrass habitats, where present, appear to be most important for young-of-year spot in early spring. In the Chesapeake Bay and North Carolina, juveniles can be found in eelgrass. FHOCs for adult spot include tidal creeks and estuarine bays with mud and detrital substrates which support abundant prey (epifauna and benthic infauna). Bottom-tending fishing gear may impact spot FHOCs (Odell et al. 2017).

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Spotted Seatrout Fish Habitats of Concern

Submerged aquatic vegetation, salt marsh, and oyster reefs, especially where submerged aquatic vegetation is not available, are FHOCs for spotted seatrout. Seagrass beds provide important habitat for both juvenile and adult spotted seatrout, but are in decline along much of the Atlantic coast (Orth et al. 2006; Waycott et al. 2009; Adams et al. 2019; Morris et al. 2022). Salt marsh and oyster reef habitats provide FHOCs for juvenile and adult spotted seatrout, particularly in areas where submerged aquatic vegetation naturally does not occur. These habitats are also in decline, and are under continuing threats due to coastal development, sea level rise, and ocean acidification. Spawning takes place on or near seagrass beds, as well as sandy banks, natural sand, shell reefs, near the mouths of inlets, and off the beach (Daniel 1988; Brown-Peterson and Warren 2002). Environmental conditions in spawning areas may affect growth and mortality of egg and larvae, as sudden salinity reductions cause spotted seatrout eggs to sink, thus reducing dispersal and survival (Holt and Holt 2002).

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Tautog Fish Habitats of Concern

All structured habitats that are used by juvenile and adult tautog (e.g., outcrops, rock piles, boulders, shells, reef, hard and soft corals, and sea whips), as well as inlets adjacent to estuaries serving as important refuge and spawning sites are FHOCs. Submerged aquatic vegetation is a FHOC for larvae, young-of-year, and juveniles.

Weakfish Fish Habitats of Concern

Important habitats for weakfish include estuarine and oceanic nursery and spawning areas distributed along the coast from Maine through Florida. The principal spawning area is from North Carolina to Montauk, NY (Hogarth et al. 1995), although extensive spawning and presence of juveniles has been observed in the bays and inlets of Georgia and South Carolina (D. Whitaker, South Carolina Department of Natural Resources, personal communication) as well as in nearshore areas off North Carolina and Virginia (ASMFC and USFWS, unpublished data; Osborne 2018).

Spawning sites include coastal bays, sounds, and the nearshore Atlantic Ocean. Nursery areas include the upper and lower portions of the rivers and their associated bays and estuaries, as well as nearshore areas in the Atlantic Ocean. While disturbance to a nursery area will affect the overall coastal weakfish population it would be expected to have the greatest impact on the specific sub-population and the local fisheries that depend on it. There is evidence that indicates that weakfish engage in natal homing (Thorrold et al. 2001). Natural geochemical signatures in otoliths indicated that spawning site fidelity ranged from 60 to 81%, comparable to estimates of natal homing in birds and anadromous fishes (Thorrold et al. 2001). That being the case, estuaries with significant concentrations of weakfish juveniles should be designated as FHOCs (i.e., Pamlico Sound in North Carolina; see Barbieri 2016). Egg and larval habitats include the nearshore waters as well as the bays, estuaries, and sounds to which they are transported by currents or in which they hatch.

Juvenile weakfish inhabit the deeper waters of bays, estuaries, and sounds, including their tributary rivers. They also use the nearshore Atlantic Ocean as a nursery area (Osborne 2018). In North Carolina and other states, they are associated with sand or sand/seagrass bottom. In Chesapeake and Delaware Bays, they migrate to the Atlantic Ocean by December.

Adult weakfish reside in both estuarine and nearshore Atlantic Ocean habitats. Warming of coastal waters in the spring keys migration inshore and northward from the wintering grounds to bays, estuaries and sounds. Larger fish move inshore first and tend to congregate in the northern part of the range. Catch data from commercial fisheries in Chesapeake and Delaware Bays and Pamlico Sound indicate that the larger fish are followed by smaller weakfish in summer. Shortly after their initial spring appearance, weakfish return to the larger bays and nearshore ocean to spawn. In northern areas, a greater portion of the adults spends the summer in the ocean rather than estuaries. Weakfish form aggregations and move offshore as temperatures decline in the fall. They move generally offshore and southward. The Continental Shelf from Chesapeake Bay to Cape Lookout, North Carolina, appears to be the major wintering ground. Winter trawl data indicate that most weakfish were caught between

Ocracoke Inlet and Bodie Island, NC, at depths of 18-55 m (59-180 ft). Some weakfish may remain in inshore waters from North Carolina southward.

The quality of weakfish habitats has been compromised largely by impacts from human activities. It is generally assumed that estuarine weakfish habitats have undergone some degree of loss and degradation; however, there are few studies that quantify impacts in terms of the area of habitat lost or degraded. Estuarine nursery habitat is impacted by bottom-tending gear (Odell et al. 2017).

Loss due to water quality degradation is evident in the northeast Atlantic coast estuaries. The New York Bight is one example of an area that has regularly received deposits of contaminated dredged material, sewage sludge and industrial wastes. These deposits have contributed to oxygen depletion and the creation of large masses of anoxic waters during the summer months.

Some habitat losses have likely occurred due to the intense coastal development that has occurred during the last several decades, although no quantification has been done. Losses and/or degradation have likely resulted from dredging and filling activities that have both eliminated shallow water nursery habitat and negatively impacted weakfish spawning activity. Further functional losses have likely occurred due to water quality degradation resulting from point and non-point source discharges. Intensive conversion of coastal wetlands to agricultural use also is likely to have contributed to functional loss of weakfish nursery area habitat.

Other functional loss of riverine and estuarine areas may have resulted from changes in water discharge patterns resulting from withdrawals or flow regulation. Estuarine nursery areas for weakfish, as well as adult spawning and pre-spawning staging areas, may be affected by prolonged extreme conditions resulting from inland water management practices.

Power plant cooling facilities continue to impact weakfish populations. In recent rules regarding these facilities, the Environmental Protection Agency estimates that the number of total weakfish age 1 equivalents lost as a result of entrainment at all transition zone cooling water intake structures in the Delaware Bay is over 2.2 million individuals. Other threats stem from the continued alteration of freshwater flows and discharge patterns to spawning, nursery, and adult habitats in rivers and estuaries. Threats in the form of increased mortality resulting from placement of additional municipal water intakes in spawning and nursery areas will occur, although the impacts may be mitigated to some degree with proper screening.

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BY COMMITTEE MEMBER

Member	Species Assignments
Russ Babb	spiny dogfish, black drum
Michelle Bachman	Atlantic herring
Josh Carloni	Jonah crab, American lobster
Lou Chiarella	coastal sharks
Jessica Coakley	summer flounder, scup
Dave Dippold	American eel
Claire Enterline	Northern shrimp, Atlantic herring
Ginny Fay	spotted seatrout
Alexa Fournier	weakfish AND tautog
Jimmy Johnson	red drum AND weakfish
Wilson Laney	striped bass, American eel, shad and river herring
Robert LaFrance	horseshoe crab, menhaden
Paul Medders	spotted seatrout AND red drum
Rachael Peabody/Tiffany Birge	shad and river herring
Mark Rousseau	horseshoe crab
Sharleen Johnson	spot AND Atlantic croaker
Eric Schneider	winter flounder, Atlantic sturgeon
Graham Sherwood	Northern shrimp, Atlantic herring
Kent Smith	Spanish mackerel, cobia
Zina Hense	tautog
Marek Topolski	black sea bass, striped bass
Kate Wilke	bluefish, menhaden

BY SPECIES

Species	Member
American eel	Wilson Laney AND Dave Dippold
American lobster	Josh Carloni
Atlantic croaker	Sharleen Johnson
Atlantic herring	Michelle Bachman, Graham Sherwood, Claire Enterline
Atlantic sturgeon	Eric Schneider
black drum	Russ Babb
black sea bass	Marek Topolski
bluefish	Kate Wilke
coastal sharks	Lou Chiarella
cobia	Kent Smith
horseshoe crab	Mark Rousseau AND Robert LaFrance
Jonah crab	Josh Carloni
menhaden	Kate Wilke AND Robert LaFrance
Northern shrimp	Graham Sherwood AND Claire Enterline
red drum	Jimmy Johnson AND Paul Medders
scup	Jessica Coakley
shad & river herring	Wilson Laney AND Rachael Peabody/Tiffany Birge
Spanish mackerel	Kent Smith
spiny dogfish	Russ Babb
spot	Sharleen Johnson
spotted seatrout	Ginny Fay AND Paul Medders
striped bass	Marek Topolski AND Wilson Laney
summer flounder	Jessica Coakley
tautog	Alexa Fournier AND Zina Hense
weakfish	Jimmy Johnson AND Alexa Fournier
winter flounder	Eric Schneider