Habitat Science is a Fundamental Element in an Ecosystem-Based Fisheries Management Framework: An Update to the Marine Fisheries Habitat Assessment Improvement Plan

The Habitat Assessment Improvement Plan Team:

Rebecca Peters, Anthony R. Marshak, Margaret M. (Peg) Brady, Stephen K. Brown, Kenric Osgood, Correigh Greene, Vincent Guida, Matthew Johnson, Todd Kellison, Robert McConnaughey, Tom Noji, Michael Parke, Chris Rooper, Waldo Wakefield, and Mary Yoklavich

U.S. Department of Commerce
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Executive Summary

The 2010 Marine Fisheries Habitat Assessment Improvement Plan (HAIP) was developed to guide the habitat science activities of the National Marine Fisheries Service (NMFS) and improve the availability of high-quality scientific information detailing the relationships among fishery species and their required habitats. A 2016 program review of the NMFS Office of Science and Technology ecosystem, climate, and habitat science program determined (i.e. action item 7.3.1) that an update of the 2010 HAIP was needed to identify accomplishments, information gaps, and needs in the context of new policies and research approaches in NMFS. Of particular relevance are recent efforts to implement Ecosystem-Based Fisheries Management (EBFM).

While overall progress in implementing the HAIP has been constrained by limited funding, efforts to address its key recommendations have led to an integrated national habitat science program, which has supported habitat research and advanced habitat conservation across the agency. Supported work under this program and the NMFS *Habitat Information for Stock Assessments* funding opportunity continues to increase understanding of the role that habitat plays in various life stages of managed species. As recommended in the HAIP, listings of stocks that would most benefit from habitat assessments have also been developed for each region to prioritize resources in addressing ongoing habitat-related uncertainties in stock assessments and in refining Essential Fish Habitat (EFH) descriptions.

Some success has been achieved with respect to habitat research across all NMFS Fisheries Science Centers; however, more efforts are needed to improve additional stock assessments, refine EFH designations, and to inform ongoing ecosystem-based fisheries management (EBFM) implementation. An internal review of the progress achieved since the HAIP was published identified a number of remaining gaps and emerging habitat science needs in the context of the 2016 NMFS EBFM Policy and Road Map.

Included within the document are a series of recommendations for filling identified post-HAIP habitat science gaps and needs as applied toward enhancing EBFM implementation and strategies to incorporate a broader habitat concentration into NMFS ecosystem science efforts.

As the agency transitions to EBFM, strengthened implementation requires ongoing identification of habitats that are most essential for sustaining living marine resources, and continued support for research to understand how these habitats directly contribute to fisheries productivity. This is especially necessary because habitat is a foundational component of ecosystem processes and a crucial component of EBFM. An integrated focus on the habitat aspects of ecosystem processes and their associated species will lead to a more coherent implementation of an ecosystem approach to management. It will also provide for the most scientifically sound conservation of our managed species, the ecosystems that support them, and the sustainability of our fisheries.

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The authors thank the original Habitat Assessment Improvement Plan co-authors and all working group members past and present for their continued efforts to advance habitat science priorities for NOAA. We also thank Kara Meckley, Christopher Meaney, and Tauna Rankin from the National Marine Fisheries Service Office of Habitat Conservation for their ongoing collaboration and support of NOAA habitat science efforts, and for their input on this technical memo. Additional thanks is expressed to Avi Litwack for his assistance in making this document fully compliant with Section 508 web publishing standards.

Overview

Traditionally fisheries management in the United States, as directed by the Magnuson Stevens Fishery Conservation and Management Act (MSA), maintains stock levels by controlling fishing pressure on single-species fishery populations. More recently, NOAA's National Marine Fisheries Service (NMFS) has made efforts to incorporate habitat, which the MSA explicitly cites as being essential to the long-term sustainability of recreational and commercial fisheries, into its assessments. As NMFS develops and attempts to implement ecosystem approaches to management, fundamental habitat information is needed to improve stock assessments and integrated ecosystem-based management efforts. In 2010, NMFS developed the Marine Fisheries Habitat Assessment Improvement Plan (HAIP) to guide the agency's habitat science activities through a series of personnel and research investments that were needed to improve the availability of high-quality scientific information detailing the relationships among fishery species and their required habitats. Overall progress in implementing the HAIP has been constrained by limited funding for habitat science, though incremental improvements have been made through NMFS Office of Science and Technology (OST) initiatives. A program review of the OST ecosystem, climate, and habitat science program in 2016 determined (i.e. action item 7.3.1) that an update of the 2010 HAIP was needed to identify accomplishments, information gaps, and needs in the context of new policies and research approaches in NMFS. It is clear that while some habitat research has been conducted across all NMFS Science Centers, more comprehensive habitat science efforts are needed to improve additional single-species stock assessments and to inform ecosystem-based fisheries management (EBFM) implementation.

New Policies and Drivers

NMFS is moving forward in transitioning from single species fisheries management to a more holistic ecosystem approach through recommendations in the Ecosystem-Based Fisheries Management (EBFM) Policy,[1] Road Map,[2] and forthcoming update to the NMFS Stock Assessment Improvement Plan (anticipated release in 2018). Moving toward holistic management requires identification of habitats that are most essential for sustaining living marine resources, their vulnerabilities, and understanding how these habitats support productivity.[3] This is necessary because habitat is a crucial component for EBFM (Figure 1).

[1] NMFS. 2016. Ecosystem-Based Fisheries Management Policy of the National Marine Fisheries Service, National Oceanic and Atmospheric Administration. Available: https://www.fisheries.noaa.gov/resource/document/ecosystem-based-fisheries-management-policy.

[2] NMFS. 2016. NMFS Ecosystem-Based Fisheries Management Road Map. Available: https://www.st.nmfs.noaa.gov/Assets/ecosystems/ebfm/EBFM_Road_Map_final.pdf.

[3] Marshak, A.R. and Brown, S.K. 2017. Habitat science is an essential element of Ecosystem-Based Fisheries Management. Fisheries 42(6): 300-300.

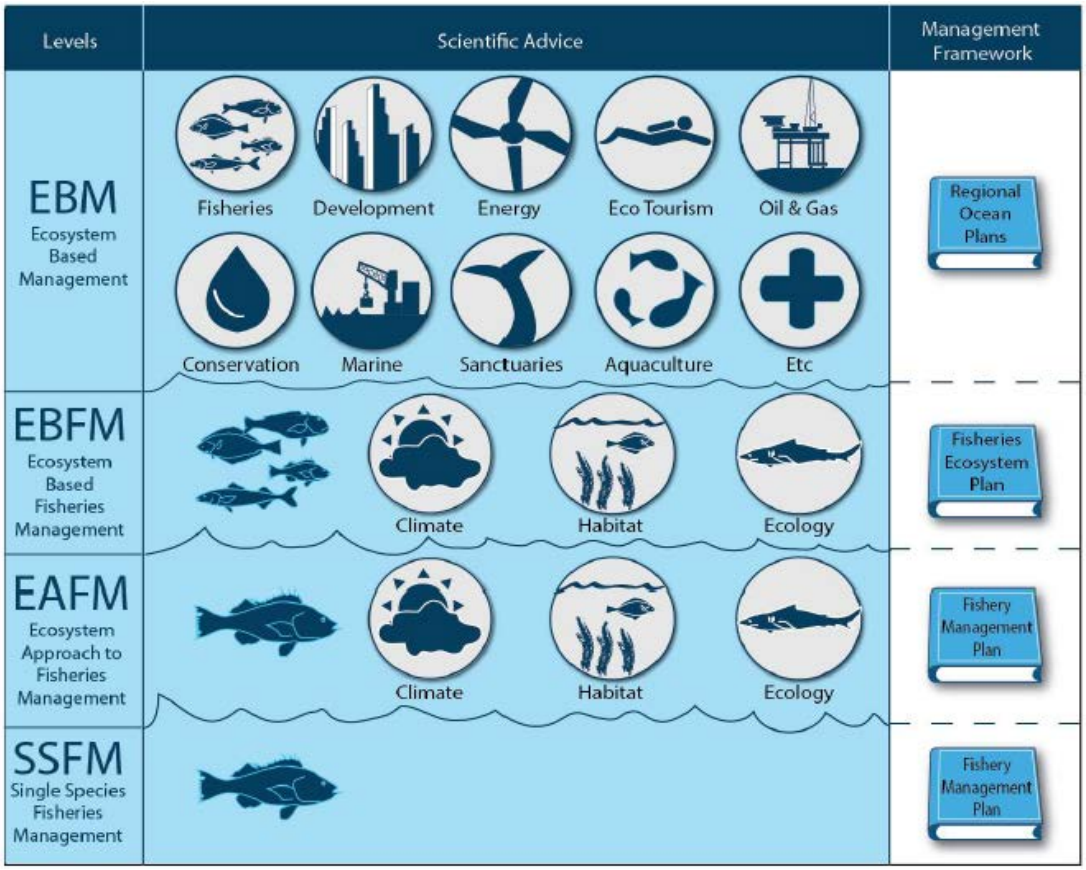

Figure 1: Hierarchical approaches to marine resource management, with each level showing the critical components for a given management strategy.

One type of habitat research that has generated information called for in the HAIP has been the internally funded research from the NMFS *Habitat Information for Stock Assessments* (HISA) opportunity. These studies generate the type of data needed to complement mathematical modeling and move EBFM into practice. The data gained from HISA-funded studies increases our understanding of how habitat influences the abundances of managed species, underpins ecological linkages, and drives marine-ecosystem dynamics. Expansion of these data collection efforts and other fundamental habitat research can strengthen NOAA's ability to move toward holistic assessments of living marine resources, and improve design and analysis of fishery-independent surveys. Additionally, it can allow for reduced uncertainty in stock assessments, enhanced essential fish habitat (EFH) designations, and provide fundamental information needed for accurate ecosystem models.[3] Even though past HAIP recommendations focused mostly on increasing habitat information for single species, many of the accomplishments for each recommendation can support EBFM because of the fundamental nature of the attributes. Future HAIP work should be integrated with other ecosystem science as NMFS moves toward implementing EBFM in consideration of available resources and emerging priorities, as detailed in the Moving Forward section of this document.

Habitat Science: Organizational Updates & Accomplishments

The HAIP included recommendations and a framework to improve habitat science by identifying gaps, recommending steps to improve habitat assessments, and creating an integrated national habitat science program. Below are the three foremost sets of accomplishments since 2010 that encompass multiple recommendations outlined in the 2010 HAIP. Detailed updates of NMFS habitat science accomplishments in context with the nine HAIP recommendations are compiled in **Appendix A**. Improved frameworks within NMFS and across NOAA that enhance coordination and communication of habitat science and conservation efforts, and allow greater leveraging potential to support and advocate for habitat research have additionally emerged post-HAIP.

Accomplishments:

1.) Identified Gaps and Funded Habitat Science Linked to NMFS Mandates

The HAIP identified data gaps in habitat science, particularly the lack of foundational habitat information on species-habitat relationships. To address these concerns, NMFS initiated the following actions:

- Held two National Habitat Assessment Workshops (NHAWs 2010, 2012) that brought together scientists and mangers to identify major gaps in habitat science research;
- Created the Habitat Information for Stock Assessments *(*HISA) internal funding allocation to support short-term, small-scale projects focused on reducing habitat-related uncertainty in stock assessments.
    - Thirty-nine HISA funded projects (totaling $4.1 million) out of 141 submitted proposals have been funded since 2010, and range from studies that determined habitat use of single species to the development of tools that can inform ways to include habitat information into stock assessments or management. (See **Appendix B** for a description of HISA projects, and studies separately supported with NMFS Office of Habitat Conservation (OHC) discretionary funds for "Refine EFH" studies).

Impact: The HISA-funded studies have increased our understanding of the role that habitat plays in various life stages of managed species. Continuation of these types of studies will fill major knowledge gaps on species-habitat dependencies, advance the incorporation of habitat data into stock assessment models, and enhance EBFM implementation.

2.) Habitat Assessment Prioritizations

Due to the high quantity of stocks to manage, the HAIP recommended identifying and prioritizing those stocks in each region[4] that would most benefit from habitat assessments to

[4] NMFS Habitat Assessment Prioritization: http://www.st.nmfs.noaa.gov/ecosystems/habitat/prioritization/index

address habitat-related uncertainties in their stock assessments, and provide higher-level information for characterizing their EFH. The following actions have taken place to prioritize resources for conducting habitat assessments of fishery species:

- Finalized habitat assessment prioritization listings for each of the regions (West Coast[5], Northeast[6], Alaska[7], and Pacific Islands[8]) or produced draft preliminary listings (Southeast) of the relevant stocks under their jurisdictions.
- These identified and prioritized stocks guided the NMFS HISA project selections during the FY17 and FY18 funding cycles, and will continue to guide future agency decisions.

Impact: As NMFS shifts priorities toward EBFM, these listings will enhance its implementation by providing focus on stocks that require fundamental ecosystem information for improved management, and in applying a broader ecosystem focus toward EFH designations of prioritized species. These prioritizations are additionally included as milestones in the EBFM Road Map and forthcoming EBFM regional and headquarters implementation plans.

3.)Improved Coordination and Collaboration between Habitat Science & Management:

Since the publication of the HAIP, NOAA has:

- Formed the National Habitat Leadership Team and developed the Habitat Enterprise Strategic Plan (2016-2020)[9];
- Advanced the National Fish Habitat Partnership (NFHP)[10] - ”Status of Fish Habitats in the United States” five-year habitat assessment efforts, specifically in conducting its national coastal fish habitat assessments and contributing to regional marine habitat assessments;

[5] Blackhart, K. 2014. Habitat assessment prioritization for West Coast stocks. Report of the Northwest and Southwest Regional Habitat Assessment Prioritization Working Groups. Internal Report, NMFS White Paper. Office of Science and Technology, NMFS, NOAA. Silver Spring, MD. 199p. https://www.st.nmfs.noaa.gov/Assets/ecosystems/habitat/pdf/Updated_WestCoast_HAP_Report.pdf

[6] NMFS. 2015. Regional habitat assessment prioritization for northeastern stocks. Report of the Northeast Regional Habitat Assessment Prioritization Working Group. Internal report, NMFS White Paper. Office of Science and Technology, NMFS, NOAA. Silver Spring, MD. 31 p. https://www.st.nmfs.noaa.gov/Assets/ecosystems/habitat/pdf/regional-habitat-assessment-prioritization-for-northeastern-stocks.pdf

[7] McConnaughey, R.A., K.E. Blackhart, M.P. Eagleton, and J. Marsh. 2017 Habitat assessment prioritization for Alaska stocks: Report of the Alaska Regional Habitat Assessment Prioritization Coordination Team. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-361, 102 p. https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-361.pdf

[8] Parke, M., H. Ma, R. Walker, I. Williams, R. Schroeder, B. Richards, and M. Sabater. 2018. Report of the Pacific Islands Habitat Assessment Prioritization Working Group. Internal report, NMFS White Paper. Office of Science and Technology, NMFS, NOAA. Silver Spring, MD. 31 p.

[9] NMFS. 2016. NOAA Fisheries Habitat Enterprise Strategic Plan 2016-2020. https://repository.library.noaa.gov/view/noaa/14994

[10] Crawford, S., Whelan, G., Infante, D.M., Blackhart, K., Daniel, W.M., Fuller, P.L., Birdsong, T., Wieferich, D.J., McClees-Funinan, R., Stedman, S.M., Herreman, K., and Ruhl, P. 2016. Through a Fish's Eye: The Status of Fish Habitats in the United States 2015. National Fish Habitat Partnership. at url http://assessment.fishhabitat.org/

- Created NOAA's Habitat Conservation Team (NHCT), which guides cross-agency habitat conservation and science activities, tracks progress, and explores areas for new research;
- Developed the NOAA Habitat Blueprint[11] from the NHCT, a three-pronged approach for NOAA to think and act strategically across programs in the agency and to partner with organizations toward improving habitat for fisheries, marine life, and coastal communities and in supporting habitat science;
- Established the Council Coordination Committee (CCC) Habitat Working Group and held the National Essential Fish Habitat (EFH) Summit (May 2016);
- Established ten NOAA Habitat Focus Areas (HFAs)[12];
- Developed a National Habitat Policy[13]; and
- Formed the Habitat Science and Ecological Forecasting Technical Team, which used guidance outlined in the 2010 HAIP to develop the Habitat Science and Ecological Forecasting Roadmap[14] that guides the agency on habitat science priorities over the next five years.

Impact: These actions have led to improved coordination and collaboration between the habitat science and management programs throughout NOAA. The formation of the NHCT and its Habitat Science and Ecological Forecasting Technical Team has additionally worked toward addressing habitat science data gaps at a NOAA-wide level, and encouraging further integration of habitat science efforts within and outside of the agency.

Habitat Science: Continued Gaps, Needs, and Next Steps

An internal review of the progress achieved since the release of the HAIP additionally identified a number of gaps and emerging habitat science needs. Recommendations were also provided on how to continue addressing the nine HAIP recommendations and these identified gaps/needs in the context of the EBFM policy/road map. A summary of the gaps/needs and corresponding recommendations follow: (Note: **Appendix C** provides a comparison of the 2010 HAIP recommendations, their progress to date, corresponding gaps/needs that continue, and recommendations for next steps).

Gaps and Emerging Habitat Science Needs:

1. Increased collaboration and integration of NMFS habitat science with other NMFS internal funding opportunities (e.g., those addressing the Stock Assessment Improvement Plan, EBFM Road Map, and the Climate Science Strategy) is needed to support larger-

[11] NOAA Habitat Blueprint: https://www.habitatblueprint.noaa.gov/
[12] NOAA Habitat Focus Areas: https://www.habitatblueprint.noaa.gov/habitat-focus-areas/
[13] NOAA National Habitat Policy: http://www.corporateservices.noaa.gov/ames/administrative_orders/chapter_216/NAO_216-117.pdf
[14] NOAA's Habitat Science and Ecological Forecasting Technical Team's Guidance Document: Support for NOAA's Habitat Conservation Team and the Ecological Forecasting Roadmap. 2016. https://aamboceanservice.blob.core.windows.net/oceanservice-prod/ecoforecasting/HSEF-action-plan.pdf

scale and longer-term projects toward incorporating habitat information into ecosystem-based fisheries management decisions and enhancing NMFS climate science efforts.

Additionally, more funding is required to support continued collection of information on the distribution of benthic habitats, including habitat surveys and multibeam mapping during fishery-independent surveys.

- **Recommendation 1.1:** Continue to work on future budget initiatives.
- **Recommendation 1.2:** Integrate studies that focus on incorporating habitat and other ecosystem metrics into management decisions. Additionally, this information can be used to enhance Integrated Ecosystem Assessments (IEAs) and Ecosystem Status Reports.
- **Recommendation 1.3:** Enhance and continue funding opportunities for work that focuses on collecting habitat data to improve stock assessment models, EFH and Habitat Areas of Particular Concern (HAPC) designations, and ecosystem information. Of particular need is fundamental habitat information for fishery species throughout their life histories, and understanding habitat distributions through mapping and use of acoustic-survey technologies.

2. Habitats associated with regionally prioritized species need to be identified. Resources should be prioritized to investigate EFH requirements for the prioritized species, especially those that are habitat-limited. This information will need to be included into their respective stock assessments. Additionally, resources should be allocated toward determining those habitats that are most important to multiple species of concern.

    - **Recommendation 2.1:** Allocate resources using the regional prioritizations to improve habitat information for those species that would benefit most from increased habitat assessments.
    - **Recommendation 2.2:** Regional science centers and offices should continue to examine regional priorities and identify where investments can be made using the prioritized lists in their region.
    - **Recommendation 2.3:** Apply regional prioritizations to identify taxa and habitats that are most vulnerable to human and natural pressures, as part of broader ecosystem-level risk assessments.
    - **Recommendation 2.4:** Prioritize geographic locations/habitats for future research.

3. Funded projects need to continue to work toward incorporating habitat information into stock assessments and improving EFH information. Additionally, this information can be applied toward focusing on the broader role of habitats in ecosystems and in advancing

our understanding of the inshore-offshore connections for species that rely on nearshore habitats for various life stages.

- **Recommendations under gap 1 will also address this need.**

4. Communication of the utility of the regional habitat assessment prioritization lists among scientists and managers should be improved to increase the use of these listings toward research and management.

    - **Recommendations under gap 2 will also address this need.**

5. A plan should be developed to provide guidance on how to better utilize new technologies (including multibeam echosounders and side scan sonar) to increase collection of habitat data on fishery-independent surveys. Recommendation 1.3, which addresses funding needs to support continued collection of habitat distribution information and multibeam mapping efforts is also applicable toward addressing this gap.

    - **Recommendation 5.1:** Recommendations from the 2017 workshop to improve the use of the ME70 multibeam echosounder aboard NOAA Fishery Science Vessels should be communicated to increase and improve habitat mapping.

    - **Recommendation 5.2:** Continue to develop ways to utilize new technologies to collect habitat information, working more closely with the NMFS Advanced Sampling Technologies Working Group, the NOAA Office of Coast Survey, the NOAA Office of Marine and Aviation Operations, and industrial partners.

6. More engagement is needed among habitat managers in regional offices and fishery management councils, and fishery scientists in the fishery science centers with a focus on incorporating habitat science information into management decisions.

    - **Recommendation 6.1:** Encourage improved communication among scientists and managers, and additional collaboration with partners, like the United States Geological Survey (USGS), Bureau of Ocean Energy Management (BOEM), and the U.S. Army Corps of Engineers (ACOE), to leverage funds to increase collection of foundational habitat information.

    - **Recommendation 6.2:** Fund/expand fishery management council and fishery science center collaborative pilot projects to explore setting habitat objectives for fisheries management.

7. There has not been a NHAW since 2012, nor have initially recommended efforts to create regional NHAWs been carried out.

- **Recommendation 7.1:** Hold additional national and regional NHAWs to address ways to incorporate habitat into EBFM and strengthen communication and collaboration among habitat scientists, ecosystem modelers, and managers within and among regions. Additionally, efforts should be undertaken to increase collaboration with IEA meetings, National Stock Assessment Workshops, and the EBFM workgroup. This recommendation can also be applied toward the above need to engage habitat managers and fishery scientists.

- **Recommendation 7.2:** HAIP members should actively participate in development of regional implementation plans for EBFM and incorporate habitat science milestones into these plans.

8. NMFS scientists should take advantage of existing graduate fellowship programs to mentor graduate students or post docs on habitat science related research.

    - **Recommendation 8.1:** NMFS scientists interested in mentoring graduate students or post docs on habitat science related work can mentor funded students from programs that focus on ecosystem science and modeling such as: NMFS Sea Grant Population and Ecosystem Dynamics Fellowships, National Research Council Research Associated Program, and NOAA Living Marine Resources Cooperative Science Centers.

9. Increased communication and broader application of funded habitat science efforts that provide fundamental ecological information on managed species, enhance stock assessments, and refine EFH designations remains necessary. Successful incorporation of this work into stock assessments and higher-level EFH data can serve as examples for other regions to conduct similar work and address habitat-related uncertainties.

    - **Recommendation 9.1:** Hold workshops, briefings, etc. that improve communication and awareness among NMFS' Offices of Science & Technology and Habitat Conservation with the aim to integrate habitat and stock assessment information. Continue to brief NMFS leadership and NOAA wide committees on progress of habitat science and HAIP-related efforts across the agency.

Moving Forward

Seven years after publication of the HAIP, more foundational habitat information and a greater understanding of the relationship between species and their habitats is still needed to strengthen fisheries science and management. The EBFM Policy and Road Map outline six guiding principles for the successful implementation of EBFM (Figure 2), with main habitat-centric principles being to "advance the understanding of ecosystem processes to improve foundational ecosystem science information" and "prioritize vulnerabilities and risks of ecosystems and their components."

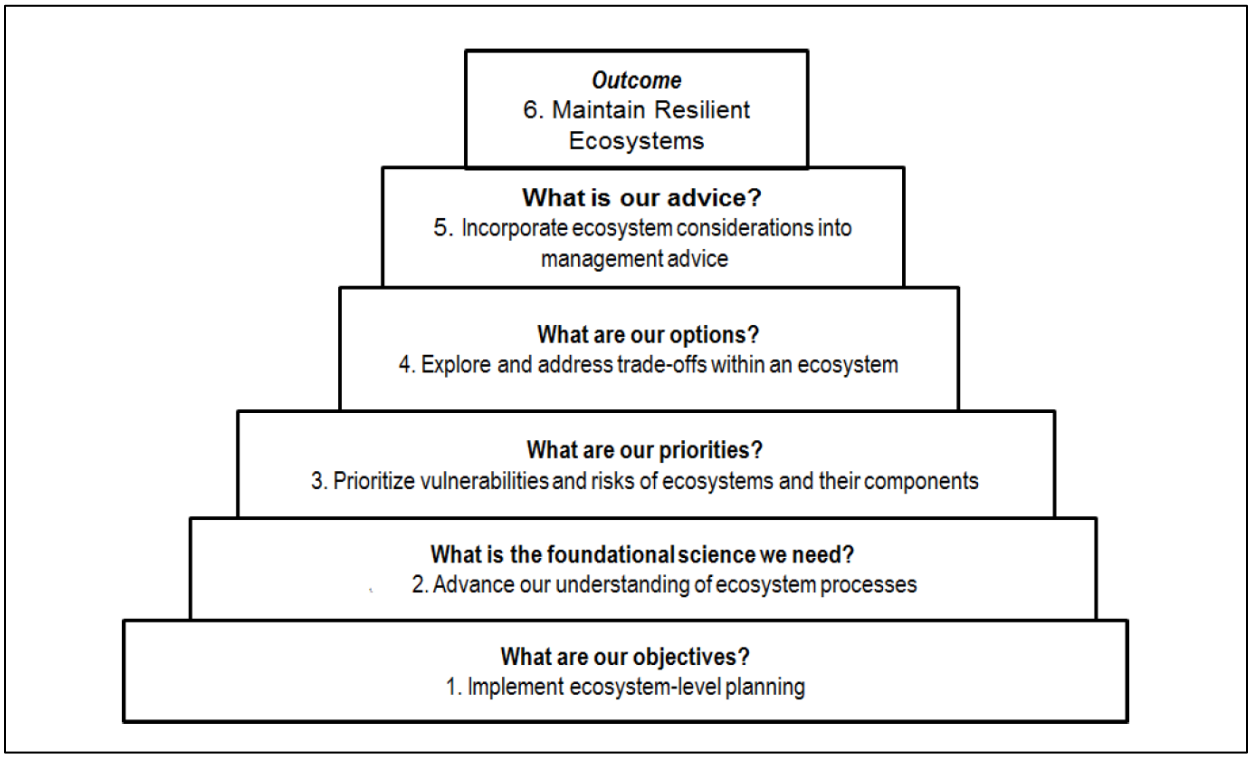

Figure 2: Illustration of the interconnected and interdependent nature of the major EBFM guiding principles. Credit, the NOAA National Marine Fisheries Service Ecosystem-Based Fisheries Management Policy. http://www.nmfs.noaa.gov/op/pds/documents/01/01-120.pdf.

Studies increasing foundational habitat information are crucial to advancing our understanding of ecosystem processes. Each of the past funded HISA and OHC "Refine EFH" studies has advanced our understanding of the role of habitat for species in their respective ecosystems. These collective investigations have led to improved estimates of abundance, greater understanding of climate-change vulnerabilities, and identification of habitat dependencies of managed fishery species. Additionally, these studies provide foundational information for continued efforts that examine the role of habitat in ecosystem responses to human and environmental pressures.

For example, data from HISA-funded studies such as by Doerr and colleagues at the Southeast Fisheries Science Center (SEFSC)[15] that document the effects of climate-mediated changes in habitat conditions on penaeid shrimp production supports an understanding of ecosystem-level consequences of black mangrove displacement of Gulf of Mexico salt marshes. Another study by Hollowed and colleagues at the Alaska Fisheries Science Center and University of Washington used statistical techniques to integrate data on species distribution and interactions, benthic structure, and physical forcing mechanisms to define ecoregions in the eastern Bering Sea[16]. Other studies have increased information on the distribution of available potential habitat for the snapper-grouper complex, which not only expanded the sampling area for fisheries-independent surveys, but also provided foundational benthic characteristics information for the southeast Atlantic[17] and the Gulf of Mexico[18]. These efforts can allow for more precise population estimates, refining of EFH, and improved management strategies for these important species. Without this type of work, information would still be lacking for many regions to move forward with a more holistic framework to examine multispecies interactions within habitats and ecosystem-level responses to emerging climate and anthropogenic factors. Continuing studies that improve benthic and oceanographic mapping, the relationships among these physical phenomenon and living marine resources, enhance EFH designations, and strengthen our understanding of habitat/species-productivity relationships produces the foundational ecosystem science that serves as the backbone of EBFM.

Accomplishing these tasks can be challenging in light of modest resources that are currently allocated for habitat science work. The continuation and advancement of this work is needed for NMFS to achieve its goal of working toward EBFM, especially given that foundational habitat information is a major currency with which to build comprehensive EBFM. Ongoing collaborations with University programs, external agencies and partners, and other NOAA Line Offices, along with executing the new recommendations in this HAIP update, will assist NMFS in its EBFM implementation efforts. An integrated focus on the habitat aspects of ecosystem processes and their associated species will lead to a more coherent implementation of an ecosystem approach to management, and provide for the most scientifically sound conservation of our managed species, the ecosystems that support them, and the sustainability of our fisheries.

[15]Doerr, J. and colleagues. 2016. Marshes to mangroves: examining growth and patterns of habitat use by penaeid shrimp in a changing marsh landscape to inform stock assessments.
https://www.st.nmfs.noaa.gov/ecosystems/habitat/funding/projects/project16-030

[16]Baker, M.R. and A.B. Hollowed. 2014. Delineating ecological regions in marine systems: Integrating physical structure and community composition to inform spatial management in the eastern Bering Sea. Deep-Sea Research II. 109: 215-240.
http://dx.doi.org/10.1016/j.dsr2.2014.03.001

[17] Kellison, T. and colleagues. 2013. Predictive modeling of habitat distribution to support expansion of fishery-independent survey efforts: laying the groundwork to reduce uncertainty in stock assessments.
https://www.st.nmfs.noaa.gov/ecosystems/habitat/funding/projects/project13-014

[18] DeVries, D. and colleagues. 2013. Improving the identification of directed fishing effort when calculating CPUE using the relationship between habitat and reef fish abundance derived from fishery independent surveys.
https://www.st.nmfs.noaa.gov/ecosystems/habitat/funding/projects/project13-013

Appendix A. Progress of the Nine 2010 HAIP Recommendations

1. *NMFS and NOAA should develop new budget and staffing initiatives to fund habitat science that is directly linked to NMFS mandates.*

While defining EFH is an MSA mandate, there is no funding source dedicated to NMFS fisheries habitat science needs. But, FY2010-2018 funding (~$500 thousand per year) has supported short-term, small-scale habitat science studies that advance the goals of the HAIP. Each year resources have been put into the HISA internal funding allocation to support projects that focus on refining fishery-independent surveys and reducing habitat related uncertainty in stock assessments. Since 2010, 39 projects (totaling $4.1 million) have been funded, resulting in improved stock assessments, more precise definitions of EFH, better regional and inter-regional coordination, and a more efficient use of limited resources to support research.

Additionally since 2010, the NMFS Office of Habitat Conservation (OHC) has provided over $5.6 million for research to support the identification, description, and conservation of essential fish habitat for federally managed fisheries. These funds include $4.7M distributed directly to Science Centers to support EFH research and $0.9M in discretionary funding for specific projects to support the data collection, assessment, and analyses necessary to complete required 5-year reviews of EFH information in fishery management plans. Complementing this support, OHC has also provided over $12M in funding through the Deep-Sea Coral Research and Technology Program to generate information of immediate use to regional fishery management councils and other resource managers in conserving structurally complex habitats formed by deep-sea corals and sponges. However, overall funding has been limited for gathering information regarding the nearshore and offshore habitat associations of most fishery species, with knowledge gaps continuing.

NMFS has developed budget initiatives toward creating a more fully and predictably funded habitat science program. In FYs 2016 and 2017, initiatives to support mission-driven applied science and the collection of foundational habitat science data were included in the annual President's Budgets. Such requests have not ultimately been included in the congressional appropriations. However, efforts to advance their higher-level support toward future initiatives are ongoing.

2. *NMFS should develop criteria to prioritize stocks and geographic locations that would benefit from habitat assessments.*

After development of the HAIP, the Habitat Assessment Prioritization Working Group was established to develop a nationally standardized set of criteria and process for prioritizing stocks that would benefit the most from habitat assessments in each region. This process allowed each region to create regional lists of stocks for habitat assessments based on two criteria:

- Stock Assessment Priorities: species whose stock assessments would benefit the most from habitat assessments;
- EFH Science Priorities: stocks that would benefit from habitat assessments to advance EFH designations.

Each region has completed its prioritization process, with listings finalized and available online for the west coast (southwest and northwest), Northeast, Alaska, and Pacific Islands regions. The Southeast region has preliminary listings for its three subregions (Gulf of Mexico, South Atlantic, and Caribbean), and is working to finalize its prioritizations with final reports expected by FY2019. Additionally, for proposals submitted to the FY2017 and FY2018 HISA internal funding allocation, preference was given to project proposals that addressed prioritized species.

Although there has been minimal progress and support for prioritizing geographic locations that are of key importance to fishery species and would benefit from targeted habitat assessments, there is a pilot project funded through OHC to develop a framework and conduct a habitat climate vulnerability assessment in the northeast. Additionally, through the NFHP in its 2010[19] and 2015[20] coastal and estuarine assessments, NMFS has worked toward characterizing conditions and vulnerabilities of inshore fish habitats. These efforts advance the need for geographic prioritizations for habitat assessments, especially as future NFHP assessments become more regionally focused at higher resolutions. Further work by NMFS, other agencies, and fishery management councils to identify priority inshore and offshore habitats of importance to coexisting species are also allowing for the identification of specific geographic locations within which assessments would be most valuable. As climate vulnerability assessments for regional habitats and their associated species continue to emerge, these efforts should also allow for improving the spatial and temporal resolutions needed to identify areas that would most benefit from priority habitat assessments.

3. *NMFS habitat and stock assessment scientists should work together to initiate demonstration projects that incorporate habitat data into stock assessment models, perhaps focusing on well-studied species.*

As indicated above, 39 projects have been funded to date to support reduced habitat related uncertainty in stock assessments. They have been short-term, small-scale projects that have made incremental progress toward refining stock assessments. The full potential of these studies can be realized through larger-scale funding opportunities that would support continued study until their full incorporation into assessments. Although some funded studies have not yet been directly incorporated into stock assessments and management decisions, these projects have still increased understanding of the importance of habitat for many federally managed species, and provided results upon which future studies could build to allow for their incorporation into management decisions. Even with the limited budget, there are examples of HISA funded projects that have been applied toward improving stock assessments and management of federally managed species.

[19]National Fish Habitat Board. 2010. Through a Fish's Eye: The Status of Fish Habitats in the United States 2010. Association of Fish and Wildlife Agencies, Washington, DC. 68p. Available at: http://www.habitat.noaa.gov/pdf/fishhabitatreport.pdf

[20]Crawford, S., Whelan, G., Infante, D.M., Blackhart, K., Daniel, W.M., Fuller, P.L., Birdsong, T., Wieferich, D.J., McClees-Funinan, R., Stedman, S.M., Herreman, K., and Ruhl, P. 2016. Through a Fish's Eye: The Status of Fish Habitats in the United States 2015. National Fish Habitat Partnership. http://assessment.fishhabitat.org/.

One such study that helped in improving the management of one federally managed species was work conducted at the Northeast Fisheries Science Center (NEFSC; funded in FYs 2012[21] and 2014[22]). This work enhanced the stock assessment for Atlantic Butterfish by calibrating survey data based on thermal habitat for use in its assessment models. These results also helped to determine which fishery-independent surveys had best sampled butterfish habitat and the appropriateness of their use in stock assessment models. Results from their work were useful in improving butterfish assessments; allowing the quota to undergo a seven-fold increase, from 3.2 million pounds in 2014 to 22.5 million pounds in 2015[23]. Other work by Shelton et al. (2014)[24] integrated spatial habitat and fisheries effort data to improve estimates of west coast groundfish species. Their work also incorporated habitat variables into models to explore patterns of fish communities along the west coast, and results were incorporated into the California Current Integrated Ecosystem Assessment. Yet other funded studies improved catchability estimates of Alaska snow crab populations that led to an increase in overfishing limits by 64%[25,26], investigated habitat-specific growth rates and productivity of juvenile penaeid shrimp species in the Gulf of Mexico[27], and have addressed research gaps in foundational habitat information to improve understanding of the importance of habitat and development of fishery-independent studies[28].

4. *NMFS should identify and prioritize data inadequacies for stocks and their respective habitats, as relevant to information gaps identified in the HAIP.*

Progress on this recommendation has been made in efforts described above under **the second recommendation** of the 2010 HAIP.

5. *NMFS should increase collection of habitat data on fishery-independent surveys and develop a plan for better utilizing new technologies (e.g. multibeam sonars) aboard the expanding NOAA fleet of Fishery Survey Vessels (FSVs).*

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[21]Manderson, J.P. and colleagues. 2012. Accounting for habitat-dependent observation error in bottom trawl survey indices for pelagic stocks using butterfish (*Peprilus triacanthus*) as a model. Available at: https://www.st.nmfs.noaa.gov/ecosystems/habitat/funding/projects/project12-010

[22]Hare, J. and colleagues. 2014. Physiological ecology and habitat suitability: Combining experiments and surveys to inform stock assessments. Available at: https://www.st.nmfs.noaa.gov/ecosystems/habitat/funding/projects/project14-020

[23]Adams C. F., Miller, T.J., Manderson, J.P., Richardson, D.E., and Smith, B.E. 2015. Butterfish 2014 stock assessment. US Department of Commerce, Northeast Fisheries Science Center Reference Document 15-06. Available at: http://www.nefsc.noaa.gov/publications.

[24]Shelton, A.O., Thorson, J.T., Ward, E.J., and Feist, B.E. 2014. Spatial semiparametric models improve estimates of species abundance and distribution. Canadian Journal of Fisheries and Aquatic Sciences 71(11):1655-1666.

[25]Turnock, B. and Rugolo, L.R. 2011. Stock assessment of eastern Bering Sea snow crab. In North Pacific Fishery Management Council. Stock Assessment and Fishery Evaluation Report for the king and tanner crab fisheries of the Bering Sea and Aleutian Islands Regions. 124 p.

[26]Somerton, D.A., Weinberg, K.L., and Goodman, S.E. 2013. Catchability of snow crab (*Chionoecetes opilio*) by the eastern Bering Sea bottom trawl survey estimated using a catch comparison experiment. Canadian Journal of Fisheries and Aquatic Sciences 70(12): 1699-1708.

[27]Leo, J.P., Minello, T.J., Grant, W.E., and Wang, H.H. 2016. Simulating environmental effects on brown shrimp production in the northern Gulf of Mexico. Ecological Modelling 330: 24-40.

[28]NMFS Office of Science and Technology. Improving the Use of Habitat Information in Stock Assessments. https://www.st.nmfs.noaa.gov/ecosystems/habitat/funding/projects/index

Since publication of the HAIP, improvements have been made to collect habitat data on fishery-independent surveys with the use of new technologies like Underway CTD-Stereo Camera Systems, camera floats, and acoustic technologies. The collection of benthic substrate and oceanographic data during stock abundance surveys through these technological improvements allows for greater spatial and temporal data coverage in understanding species distributions based on habitat availability. Additionally, HISA funded projects have increased information on favorable substrate availability for reef fishes in the U.S. southeast Atlantic and Gulf of Mexico. For example, results from a study conducted at the SEFSC and National Centers for Coastal Ocean Science increased understanding of hardbottom substrate distribution in the southeast Atlantic and facilitated the filling of spatial gaps in the sole regional-scale fishery-independent survey targeting the snapper-grouper complex in the southeast[29]. Another funded study at the SEFSC in Panama City, used side-scan sonar to characterize substrate for reef fish in offshore regions in the Gulf of Mexico, which then informed scientists on the best locations to drop video arrays for surveying reef fish[30] to determine which substrates serve as prime habitat. Other studies have increased understanding of substrate preferences that influence distributions of west coast groundfish, and efforts improved past west coast surveys of sardine and hake (SaKe surveys) by incorporating multibeam scanning and 3D imaging sonar. These advances can lead to better habitat-stratified samplings during surveys and reduce uncertainty in abundance estimates.

Five of NOAA's FSVs have a ME70 Scientific Multibeam Echosounder, which allows for collection of fish and bathymetric data. This technology is used during various surveying programs, including the Southeast Area Monitoring and Assessment Program. The SEFSC Pascagoula Reef Unit and Beaufort Southeast Fishery Independent Survey cruises have been using the ME70 for Gulf and Atlantic Reef fish surveys to identify reef habitat that can later be sampled with trap and camera gear, or to allow for identification of untrawlable habitats in Alaska. Even though this technology has been useful, over the years various issues have arisen when using the ME70 for seafloor mapping. Along with these issues, there is concern over managing different uses of the system among scientists and FSVs, especially when balancing its utility to enumerate fish populations or to characterize benthic substrates. To help overcome these issues, fisheries scientists and experts convened a workshop that brought together ME70 users and specialists together to develop recommendations for more effective use of ME70s for seafloor mapping. This effort will allow the agency to make best use of underutilized existing technologies and apply them toward improving fundamental understanding of fish-habitat associations. Allowing more coordinated opportunities among NOAA and inter-agency interests to leverage ship time and collect co-located habitat data can also increase progress at potentially limited additional cost.

6. *NMFS habitat scientists should engage partners within and outside of NOAA to exchange information about programs and capabilities. Habitat data collection and management*

[29]Kellison, T. and colleagues. 2013. Predictive modeling of habitat distribution to support expansion of fishery-independent survey efforts: laying the groundwork to reduce uncertainty in stock assessments. https://www.st.nmfs.noaa.gov/ecosystems/habitat/funding/projects/project13-014

[30]DeVries, D. and colleagues. 2013. Improving the identification of directed fishing effort when calculating CPUE using the relationship between habitat and reef fish abundance derived from fishery independent surveys. https://www.st.nmfs.noaa.gov/ecosystems/habitat/funding/projects/project13-013

efforts should be coordinated, and data integration applications should be upgraded to improve accessibility and synthesis.

Progress on part of this recommendation has been made through increased engagement within NMFS, and complemented by efforts mentioned below under **the ninth recommendation of the HAIP** to unite with other NOAA Line Offices in broadening the applicability of habitat science and assessments. Since the publication of the HAIP, the OST and OHC participate in regular meetings to discuss advancing habitat science for improving management. Detailed information on the increased partnership between the OST and OHC can be found described above in progress made toward the **first recommendation of the HAIP**. In addition, efforts to align more strongly with the Bureau of Ocean Energy Management (BOEM) in characterization of species-substrate associations and to enhance EFH descriptions are ongoing throughout the U.S. Greater Atlantic region,[31] and joint spatial studies using a jointly funded EFH mapper[32] are working to understand the impacts of dredging on EFH. Other efforts to collaborate with USGS and ACOE in their habitat-related studies and priorities are ongoing, especially through broader engagement through the NHCT and the National Ocean Service.

In the years following publication of the HAIP, there has been a renewed interest from the federal government in improving data availability for the public. NMFS has created InPort, which is an online metadata information system under which all datasets within the agency must be registered. This system stores metadata, explains the accessibility of the data, constraints on its use, and a contact person to acquire the data since the system does not store the raw data. All projects supported from the HISA funding allocation are expected to create records in this system.

7. *NMFS should convene workshops to develop strategies to better incorporate habitat science and assessments into stock assessment and IEA approaches and products.*

Post publication of the HAIP, two NHAWs occurred in 2010[33] and 2012[34]. These workshops included NMFS habitat and stock assessment scientists from the fishery science centers, habitat and fisheries managers from Headquarters and Regional Offices, and restoration scientists and managers. The first NHAW brought together scientists and managers to address mutual interests to create a foundation for cooperative work in building a comprehensive habitat science program. Discussions at this workshop focused on ways to form and fund a habitat science program, align habitat assessments with management priorities, and identify and refine habitat science products and tools for use by management. The second NHAW built upon the first workshop and helped form recommendations that would improve the quality of NMFS habitat science needed to

[31]Hooker, B. 2015. Fishery physical habitat and epibenthic invertebrate baseline data collection. https://www.boem.gov/AT-13-02/

[32]NOAA Habitat Conservation. http://www.habitat.noaa.gov/protection/efh/efhmapper/

[33]Blackhart, K. (ed.) 2010. Proceedings. 11th National Stock Assessment Workshop: Characterization of scientific uncertainty in assessments to improve determination of acceptable biological catches (ABCs); Joint Session of the National Stock and Habitat Assessment Workshops: Incorporating habitat information in stock assessments; and 1st National Habitat Assessment Workshop: Moving towards a national habitat science program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-112, 153 p. https://www.st.nmfs.noaa.gov/Assets/ecosystems/habitat/pdf/NSAW_NHAW_Proceedings_final.pdf

[34]Clarke, L.M. (ed.) 2013. Proceedings of the 2nd National Habitat Assessment Workshop: Habitat Science to Support NOAA's Habitat Blueprint. U.S. Dept. of Commer., NOAA Technical Memorandum NMFS-F/SPO-132, 89 p. https://www.st.nmfs.noaa.gov/Assets/ecosystems/habitat/pdf/NHAWIIProceedings.pdf

improve stock assessments and EFH designations. During this workshop, knowledge gaps were identified, and one identified high priority knowledge gap was the lack of information on the quantitative link between inshore habitat and offshore fisheries production. Both of these workshops were essential to improving habitat science throughout the agency by providing an uncommon opportunity for habitat scientists, stock assessment scientists, and managers to gather and interact, moving toward improved communication among centers, councils, and regional offices. Additionally following the second NHAW, three pilot projects addressing this knowledge gap in the Pacific and Atlantic regions were supported:

- **North Atlantic Pilot Project:** "*Restoring Access to Diadromous Fish Habitat and Linkages to Forage Fish Biomass in the North Atlantic Large Marine Ecosystem*"
  Wes Patrick (NMFS/OSF), Tom Miller (University of Maryland), and JP Walsh (East Carolina University)
  The goal of this project was to predict long-term biological and sociological benefits of restoring diadromous fish habitat. Recent progress in this work includes calculation of the historic ranges and abundances of American shad and river herring, which shows substantial declines from their pristine conditions as a loss of habitat quality and accessibility over time.

- **Mid-Atlantic Pilot Project:** "*Parameterizing the Relationship Between Inshore Habitat Quantity and Quality and Summer Flounder Production*"
  Howard Townsend (NMFS/OHC/NCBO), Tom Ihde (NMFS/OHC/NCBO), David Stevenson (NMFS/GARFO), and John Manderson (NMFS/NEFSC)
  The goal of this project was to provide habitat managers with methods to quantify the cumulative impacts of inshore habitat loss and degradation on the survival and production of juvenile summer flounder. Recent progress in this work includes using the Chesapeake Atlantis Model (CAM) and datasets compiled from the Atlantic States Marine Fisheries Commission Fish Habitat Program to demonstrate the strong impacts of salt marsh loss upon forage fish, broad-scale impacts of habitat change on summer flounder, and ecosystem-wide implications of habitat dynamics.

- **West Coast Pilot Project:** "*Pacific Marine and Estuarine Fish Habitat Partnership Nursery Assessment*"
  PMEP Steering Committee and Assessment Team (Kristan Blackhart, Correigh Greene, Korie Schaefer, John Bragg et al.)
  The goal of this project was to identify key threats and limiting factors to juvenile fish, and describe the role of nearshore habitats to offshore stock recruitment. Recent progress in this work includes inventory and classification of west coast estuaries, a spatial framework to support modeling, and ongoing collection of fish abundance and habitat quality/quantity data. Additionally, west coast wide tier 1 and 2 assessments were conducted to obtain information about existing datasets on juvenile fish use of estuaries and estuarine habitats. Findings from these studies are being applied toward NOAA habitat protection efforts and in refining EFH for west coast species.

All of these projects reinforce the importance of inshore habitat dynamics toward fish productivity and provide methods for quantifying the contributions of habitats toward these productivity estimates and toward enhancing ecosystem models.

As IEAs are being updated, habitat has become an important component in many of these assessments. For example, IEA program sponsored work by Greene et al. (2013)[35] developed ways to incorporate habitat indicators in the California Current IEA. This work helped to provide information on cross-habitat linkages toward ecosystem-based management approaches and refined habitat information on west coast region prioritized species. Additionally, the results of the previously referenced (**see above, progress under the third HAIP Recommendation**) HISA-funded work by Shelton et al. (2014) are being incorporated into the California Current IEA. These projects serve as examples for other regions to begin to work on including habitat indicators into their IEAs and ecosystem status reports.

More recently, in acknowledgement of the twentieth anniversary of the inclusion of EFH in the MSA, habitat scientists and managers from NMFS, along with members of the regional fishery management councils and other partners, participated in the National EFH Summit in May 2016[36]. Even though this summit was not a habitat science specific workshop, it brought scientists and managers together to discuss priority areas of habitat science that are needed in the future to help effectively identify and manage EFH for fisheries species. This three-day workshop broadened the discussion on EFH in the context of climate change, how EFH can support ecosystem-based management, addressed cumulative fishing and non-fishing impacts to EFH, and discussed mechanisms to continue funding high-priority science needs for effective EFH management.

8. *NMFS should establish a habitat assessment fellowship program and provide funds to graduate students and post-doctoral associates of specific sub disciplines that would advance habitat modeling, evaluation, and assessment efforts.*

For continuation and advancement of habitat science within NMFS, the agency must keep supporting the funding of graduate and post-graduate students whose research consists of habitat modeling, evaluation, and assessments to support the goals of the HAIP. Although a dedicated habitat assessment fellowship program has not been started since publication of the HAIP, many graduate students and post docs have conducted research in conjunction with NMFS scientists funded from the HISA program. However, these opportunities have remained limited given constrained resources to support habitat science. Since there are many applicable NOAA funded graduate fellowships available, NMFS must continue to support these programs and scientists with interest in conducting habitat studies who can mentor funded students in advancing habitat scientific research. Some of the programs that exist that focus on ecosystem science and modeling are the NMFS Sea Grant Population and Ecosystem Dynamics Fellowships and the National Research Council (NRC) Research Associate Program. Additionally, the NOAA Living

[35]Greene et al. 2013. Selecting and Evaluating Indicators for Habitats within the California Current Large Marine Ecosystem. https://www.integratedecosystemassessment.noaa.gov/Assets/iea/california/Report/pdf/9.Habitat_2013.pdf

[36]Leaderhouse,T., T. Marshak, L. Latchford, R. Peters, and K. Latanich. 2017. Report from the National Essential Fish Habitat Summit. U.S. Dept. of Commerce, NOAA. NOAA Technical Memorfandum NMFS-OHC-3, 44p. http://spo.nmfs.noaa.gov/sites/default/files/TM-OHC3.pdf

Marine Resources Cooperative Science Centers[37] provide scholarships, internships, and funding resources to train graduate students to conduct research of interest to NMFS. This program has four main research themes. One of those themes includes increasing our understanding on the relationship between habitats and marine populations. Habitat scientists in NMFS can continue to collaborate with these programs to work toward training future habitat scientists.

9. *NMFS should unite with other NOAA Line Offices to develop a NOAA-wide strategic plan for habitat science and assessments in support of the nation's ocean policy priorities for EBFM, CMSP, and the use of IEA's.*

Since 2010, there has been steadily increasing recognition within NOAA of the fundamental importance of habitat science and conservation. The NOAA-wide NHCT was formed to guide cross-line office and cross-agency habitat conservation and science activities, including the initiation of the NOAA Habitat Blueprint[38]. The NOAA Habitat Blueprint was created to provide a framework to strategically coordinate activities within NOAA and increase engagement with outside partners and resources to improve habitat for fisheries, marine life, and coastal communities[39]. The Blueprint developed a three-pronged framework, which consists of: 1) establishment of NOAA HFAs for long-term habitat science and conservation, 2) implementation of a systematic and strategic approach to habitat science to inform effective decision-making, and 3) strengthened policy and legislation to enhance NOAA's ability to achieve meaningful habitat conservation. This framework led to the establishment of NOAA HFAs[40], which are coastal regions around the United States where NOAA offices and their partners can effectively use their resources to conduct long-term habitat science and conservation efforts. There are now ten HFAs around the United States, within which NMFS and other NOAA Line Offices have provided support for habitat science efforts. After development of the NOAA Habitat Blueprint, NOAA developed the National Habitat Policy[41], which established NOAA-wide guideline for using the agency's resources to its fullest extent possible in protecting, maintaining, and restoring habitats.

Under the NHCT, a science sub-team was formed and summarized the priority habitat science needs for NOAA. At the same time, a framework was developed to coordinate ecological forecasting activities within NOAA and across other agencies. With recognition of the need of ecological forecasting to support habitat science, the Ecological Forecasting Roadmap was developed and included habitat as one of its four priorities. The Ecological Forecasting group has now merged with the habitat science sub-team to form the Habitat Science and Ecological Forecasting Technical Team. This team recently developed habitat science priority guidance to advance and promote habitat science across the agency[42].

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[37] NOAA Living Marine Resource Cooperative Science Center: https://www.umes.edu/LMRCSC/
[38] NOAA Habitat Blueprint: https://www.habitatblueprint.noaa.gov/
[39]NOAA Habitat Blueprint Fact Sheet. http://www.habitat.noaa.gov/pdf/habitatblueprint6pfactsheet.pdf
[40] NOAA Habitat Focus Areas: https://www.habitatblueprint.noaa.gov/habitat-focus-areas/
[41] NOAA National Habitat Policy: http://www.corporateservices.noaa.gov/ames/administrative_orders/chapter_216/NAO_216-117.pdf
[42]NOAA's Habitat Science and Ecological Forecasting Technical Team's Guidance Document: Support for NOAA's Habitat Conservation Team and the Ecological Forecasting Roadmap. 2016.
https://aamboceanservice.blob.core.windows.net/oceanservice-prod/ecoforecasting/HSEF-action-plan.pdf

Appendix B. Funded Habitat Science Projects from the NMFS Office of Science and Technology (OST) *Habitat Information for Stock Assessments* Internal Funding Allocation and from the NMFS Office of Habitat Conservation (OHC).

Table 1. OST *Habitat Information for Stock Assessments* Funded Projects 2010-2018.

Year	Region	Title	Lead PI(s)
2010	SW	Relating population abundance of groundfish species to habitats using predictive models and broad-scale seafloor maps	Mary Yoklavich
2010	SE	Habitat Modeling of Atlantic Blue Marlin with SEAPODYM and Satellite Tags	Michael Schirripa
2010	SE/NE	Incorporating sediment and hydrography data assessments for tilefish and lobster	John Quinlan
2011	NE	Detecting an environmental gradient in maturity, spawning rates, and fecundity of inshore winter flounder stocks: does thermal habitat create spatial heterogeneity of life history parameters within stock boundaries?	Richard McBride
2011	SE	Incorporating environmental and habitat characteristics into the brown shrimp stock assessment for the northern Gulf of Mexico	Thomas Minello
2011	NE	Incorporating measures of habitat area into stock assessments: a case study with winter flounder and summer flounder	Jon Hare
2012	PI	Estimation of habitat-stratified catch efficiency of fishery-independent reef fish survey methodologies to improve estimates of stock size	Gerard DiNardo
2012	SE	Estimating habitat related variability in natural mortality of juvenile white shrimp for incorporation into stock assessment models	Lawrence Rozas
2012	NE/SE	Accounting for habitat-dependent observation error in bottom trawl survey indices for pelagic stocks using butterfish (*Peprilus triacanthus*) as a model	John Manderson

Year	Region	Title	Lead PI(s)
2012	SW	Spatially Predictive Modelling and Mapping of Groundfish Species to Advance Stock and Habitat Assessments Relevant to SW Habitat Blueprint Regional Initiative	Mary Yoklavich
2012	AK	Locating essential spawning grounds for red king crab	Chris Long
2012	AK	Defining eco-regions and applying spatial analyses of species abundance, community dynamics and stock substructure to incorporate habitat in SSMs and MSMs	Anne Hollowed
2013	AK	Identifying habitat use by male and female red king crabs during mating season	Chris Long
2013	AK	Evaluating the use of acoustic bottom typing to inform bottom trawl survey catchability models for snow crab in the eastern Bering Sea	Robert McConnaughey
2013	AK	Evaluating Smooth Sheet Bathymetry for Determining Trawlable and Untrawlable Habitats	Wayne Palsson
2013	NW	Integrating spatial habitat and fisheries effort data to improve abundance estimates of west coast groundfish	Andrew Shelton
2013	SE	Predictive modeling of habitat distribution to support expansion of fishery-independent survey efforts: laying the groundwork to reduce uncertainty in stock assessments	Todd Kellison
2013	SE	Improving the identification of directed fishing effort when calculating CPUE using the relationship between habitat and reef fish abundance derived from fishery independent surveys	Doug DeVries
2014	SE	Prioritizing spawning habitats in terms of their relative contribution to recruitment success	John Walter

Year	Region	Title	Lead PI(s)
2014	SE	Estimating habitat-specific variability in growth rates of juvenile penaeid shrimps for incorporation into stock assessment models	Lawrence Rozas
2014	NE	Integrating Habitat Information into Stock Assessments to Maximize Precision: A Case Study Using Data from the Annual Sea Scallop Survey Provided by HabCamV4, an Integrated Habitat Mapping Camera and Acoustics System	Dvora Hart
2014	NE	Physiological ecology and habitat suitability: combining experiments and surveys to inform stock assessments	Jon Hare
2014	SW	Identifying essential spawning habitats for improving assessment and management of the market squid fishery off California.	Emmanis Dorval
2014	SW	Habitat assessment for Pacific Sardine juveniles	Russ Vetter
2015	SE/SW	Incorporating hypoxia-based habitat compression impacts into the stock assessment process for tropical pelagic billfish and tuna	Eric Prince
2015	NW/AK/NE	Distribution and application of a new geostatistical index standardization and habitat modeling tool for stock assessments and essential fish habitat designation in Alaska and Northwest Atlantic regions	Jim Thorson
2015	AK	Improving Stock Assessments for Rockfishes Using Habitat-referenced Acoustic Surveys in the Gulf of Alaska	Chris Wilson
2015	NW	Using habitat-specific, spatial demographic information to improve stock assessments of groundfishes	Jameal Samhouri
2016	AK	Seabed mapping to develop a habitat-based catchability function for the Bristol Bay red kind crab (*Paralithodes camtschaticus*) stock assessment	Robert McConnaughey

Year	Region	Title	Lead PI(s)
2016	SW	Kill ‘em or hide ‘em: where are all the old female rockfish?	Susan Sogard
2016	SE	Marshes to mangroves: examining growth and patterns of habitat use by penaeid shrimp in a changing marsh landscape to inform stock assessments	Jennifer Doerr
2016	SW	Combining high-resolution bathymetry and recreational catch rates to model the spatial distribution of biomass for reef-associated nearshore species	E.J. Dick
2017	AK/NW	Detecting changes in life history traits and distribution shifts in eastern Bering Sea fishes in response to climate change	Chris Rooper, Jim Thorson
2017	AK	Evaluating the effects of habitat quality on YOY sablefish physiological condition to inform estimates of recruitment in the stock assessment	Ron Heintz
2017	NE	Use of a Lagrangian camera float in association with surveys to examine benthic habitats and associated fish: operational test to improving survey-based estimates of abundance	Harvey Walsh
2017	SE	Evaluation of methods of incorporating oceanographic indicators into indices of abundance for stock assessment	Michael Schirippa
2018	AK	Using habitat information to assess Pacific cod life history parameters for stock assessment	Grant Thompson
2018	AK	Accounting for habitat variables to improve abundance indices in Alaska trawl surveys with an emphasis on results from averaging multiple modeling methodologies	Chris Rooper
2018	AK	Seabed mapping to quantify untrawlable habitats and reduce bias in Gulf of Alaska stock assessments	Robert McConnaughey

Table 2. Projects Funded to Refine EFH by NMFS OHC, 2010-2015.

Year	Region	Title	PI(s)
2010	PI	Understanding key habitats of commercial demersal fishes – the Deep Seven Bottomfish complex in Hawaii	Alan Everson
2010	NE	Use of state fisheries independent survey data to refine EFH in estuaries and nearshore coastal waters	Lou Chiarella
2011	SE	Life history summaries and creation of the EcoSpecies Database to provide web-enabled information to support SAFMC habitat management and SEDAR	Pace Wilber
2011-12	NW/SW	Summarize data in support of a 5-year review of EFH for Pacific Coast groundfish	John Stadler, Bryant Chesney, Waldo Wakefield
2012	NE	Conservation of DelMarVa reefs, black sea bass habitats at risk	David Stevenson, Lou Chiarella
2012	AK	Seasonal distribution and habitat use of managed fish species in Upper Cook Inlet, Alaska	Jeanne Hanson, Matt Eagleton
2013	SE	Fish habitat value – salt marsh flooding in TX and LA	Tom Minello
2013	SE	Improve EFH maps for GMFMC managed species	David Dale
2014	SE	Revising SAFMC EFH and HAPC GIS data	Pace Wilber
2014	AK	Gulf of Alaska and Norton Sound bathymetry and substrate compilation	Matt Eagleton
2015	AK	Effects of offshore marine mining activities on Norton Sound Red King crab	John Olson, Robert Foy
2015	NW/SW	Habitat Use Database for the California Current	Waldo Wakefield, Mary Yoklavich, Steve Copps, John Stadler

Appendix C: Examination of gaps/needs for carrying out the 2010 HAIP recommendations, and approaches for continued progress.

2010 HAIP Recommendation	HAIP Progress to Date	Gaps/Needs	2018 Recommendations
NMFS and NOAA should develop new budget and staffing initiatives to fund habitat science that is directly linked to NMFS mandates.	• Initiatives were included in the President's Budgets (FYs 2016 & 2017) to support mission-driven applied science and the collection of foundational habitat science data. Ultimately, these requests were not funded.	**1a.** Increased collaboration and integration of habitat science with internal funding opportunities (e.g., those addressing the Stock Assessment Improvement Plan, EBFM Road Map, and the Climate Science Strategy) is needed to support longer-term projects toward incorporating habitat information into management decisions and enhancing NMFS climate science efforts. **1b.** Funding to support continued collection of information on the distribution of benthic habitats, including habitat surveys and multibeam mapping during fishery-independent surveys.	**1.1.** Continue to work on future budget initiatives. **1.2.** Integrate studies that focus on incorporating habitat and other ecosystem metrics into management decisions, Integrated Ecosystem Assessments (IEAs) and Ecosystem Status Reports. **1.3.** Continue to fund carefully targeted work that focuses on collecting habitat data to improve stock assessment models, EFH and Habitat Areas of Particular Concern (HAPC) designations, and ecosystem information. Of particular need is fundamental habitat information for fishery species throughout their life histories, and understanding habitat distributions through mapping and use of acoustic-survey technologies.

2010 HAIP Recommendation	HAIP Progress to Date	Gaps/Needs	2018 Recommendations
NMFS should develop criteria to prioritize stocks and geographic locations that would benefit from habitat assessments.	• Habitat Assessment Prioritization Working Group (HAPWG) formed. • Nationally standardized set of criteria and process to prioritize stocks in each region that would benefit from habitat assessments to improve stock assessments and advance EFH information. • Each region has finalized or developed preliminary listings. • These listings are currently being used to inform the HISA internal funding allocation, and HISA studies have increased habitat information for 21 high and medium priority listed species.	**2a.** Habitats that are associated with regionally prioritized species have not been fully identified. **2b.** Resources should be prioritized to allow for investigation into the EFH requirements of these species, especially those that are habitat-limited, and the inclusion of this information in their stock assessments. **2c.** Resources should be allocated toward determining those habitats that are most important to multiple species of concern.	**2.1.** Allocate resources using the regional prioritization listings toward research for those species that would benefit most from habitat assessments. **2.2.** Fishery Science Centers and Regional offices should examine regional priorities and identify where investments can be made using the prioritized lists in each region. **2.3.** Prioritizations can be included as a component of a broader ecosystem-level risk assessment to identify taxa and habitats that are most vulnerable to human and natural pressures. **2.4.** Prioritization lists should be examined to work toward prioritizing geographic locations/habitats.
NMFS habitat and stock assessment scientists should work together to initiate demonstration projects that incorporate habitat data into stock assessment models, perhaps focusing on well-studied species.	• ~$500,000 each year has been made available for the *Habitat Information for Stock Assessments* internal funding allocation.	**3a.** Funded projects must continue to work toward incorporating habitat information into stock assessments and improving EFH information.	• See recommendations **1.1** – **1.3**.

2010 HAIP Recommendation	HAIP Progress to Date	Gaps/Needs	2018 Recommendations
	• To date 39 projects have been funded out of 141 submitted proposals.	**3b.** Information should be applied toward focusing on the broader role of habitat in ecosystems and in advancing understanding of inshore-offshore connections for species during life stages.	
NMFS should identify and prioritize data inadequacies for stocks and their respective habitats, as relevant to information gaps identified in the HAIP.	• Prioritization lists mentioned above also support this recommendation.	**4.** Communication of the utility of the regional habitat assessment prioritization lists among scientists and managers should be improved to increase the application of these listings toward research and management.	• See recommendations **2.1** – **2.4**.
NMFS should increase collection of habitat data on fishery-independent surveys and develop a plan for better utilizing new technologies (e.g. multibeam sonars) aboard the expanding NOAA fleet of Fishery Survey Vessels (FSVs).	• Five of the FSVs have a ME70 Scientific Multibeam Echosounder, which allows for collection of fishery and bathymetric data. • Two HISA funded studies supported the increase of habitat data through new technologies (ME70 and side scan sonar). • In November 2017, a two-day workshop was held to bring user and experts of the ME70 together to discuss ways to	**5a.** A plan should be developed to provide guidance on how to better utilize new technologies (including multibeam echosounders and side scan sonar) to increase collection of habitat data on fishery-independent surveys.	**5.1.** Recommendations from the 2017 workshop to improve the use of ME70s aboard NOAA Fishery Science Vessels should be communicated to increase and improve habitat mapping. **5.2.** Continue to develop ways to utilize new technologies to collect habitat information. • See recommendation **1.3**.

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	improve the use of this technology for seafloor mapping. The workshop resulted in short, mid, and long-term recommendations of their more effective use.		
NMFS habitat scientists should engage partners within and outside of NOAA to exchange information about programs and capabilities. Habitat data collection and management efforts should be coordinated, and data integration applications should be upgraded to improve accessibility and synthesis.	• OST and OHC participate in regular meetings to advance habitat science toward improving management. • There have been efforts to work with the Bureau of Ocean Energy Management (BOEM) on characterizing species-substrate associations and to enhance species EFH descriptions. • Through efforts with the NHCT and the National Ocean Service, collaboration has increased between NMFS and the U.S. Geological Survey (USGS) and U.S. Army Corps of Engineers (ACOE) in their habitat-related studies and priorities. • NMFS created InPort to provide an online metadata information system where all	**6.** There needs to be more engagement between habitat managers in regional offices and fishery management councils, and fishery scientists to incorporate habitat science information into management decisions.	**6.1.** Collaborate with partners, like USGS, BOEM and ACOE, to leverage funds to increase collection of foundational habitat information. **6.2.** Fund/expand fishery management council and fishery science center collaborative pilot projects to explore setting habitat objectives for fishery management. • See recommendation **7.1**.

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	datasets within the agency must be registered.		
NMFS should convene regional and national workshops to develop strategies to integrate habitat science and assessments, stock assessments, and IEA's.	• NHAWs were held in 2010 and 2012. These workshops focused forming and funding a habitat science program in NOAA and identified knowledge gaps in habitat science that needed to be filled to improve management of living marine resources. • A National EFH Summit was held in May 2016 to bring together habitat scientists and managers from NMFS, regional management council representatives, and representatives from interested partners to discuss achievements and ways to improve designation of EFH.	**7.** There has not been a NHAW since 2012, nor have initially recommended efforts to create regional NHAWs been carried out.	**7.1.** Hold additional national and regional NHAWs to address ways to incorporate habitat into EBFM and strengthen communication and collaboration among habitat scientists and managers within and among regions. Additionally, efforts should be undertaken to increase collaboration with IEA meetings, National Stock Assessment Workshops, and the EBFM workgroup. **7.2.** HAIP members should actively participate on regional implementation plans for EBFM and incorporate habitat science milestones into these implementation plans.
NMFS should establish a habitat assessment fellowship program and provide funds to graduate students and post-doctoral associates of specific sub disciplines that would advance habitat modeling, evaluation, and assessment efforts.	• Graduate students and post-docs have conducted research in conjunction with NMFS scientists funded from the HISA program. However, funding opportunities have been limited.	**8.** No habitat assessment fellowship program has started since publication of the HAIP, but NMFS scientists should take advantage of existing graduate fellowship programs to mentor graduate students or post docs	**8.1.** NMFS scientists interested in mentoring graduate students or post docs on habitat science related work should mentor funded students from current programs that focus on ecosystem science and modeling such as: NMFS Sea Grant

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		on habitat science related research.	Population and Ecosystem Dynamics Fellowships, National Research Council Research Associated Program, and NOAA Living Marine Resources Cooperative Science Centers.
NMFS should unite with other NOAA Line Offices to develop a NOAA-wide strategic plan for habitat science and assessments in support of the nation's ocean policy priorities for EBFM, CMSP, and the use of IEA's.	• NHCT was formed to guide cross-agency habitat conservation and science activities, which led to the development of the NOAA Habitat Blueprint. • Under the NHCT, there is a science sub-team, which has formed the Habitat Science and Ecological Forecasting Technical Team. This team developed habitat science priority guidance to advance and promote habitat science across the agency.	**9.** Increased communication and broader application of these types of habitat science studies remains necessary and can serve as examples for other regions to conduct similar work and address habitat-related uncertainties.	**9.1.** Hold workshops, briefings, etc. that improve communication and awareness among NMFS' Offices of Science & Technology and Habitat Conservation with the aim to integrate habitat and stock assessment information. Continue to brief NMFS leadership and NOAA wide committees on progress on the HAIP-related and habitat science efforts across the agency.