

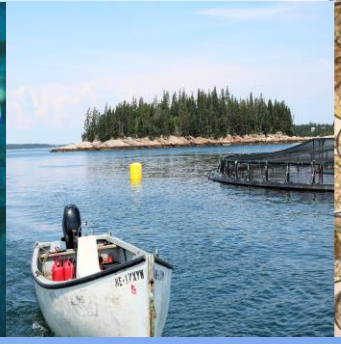
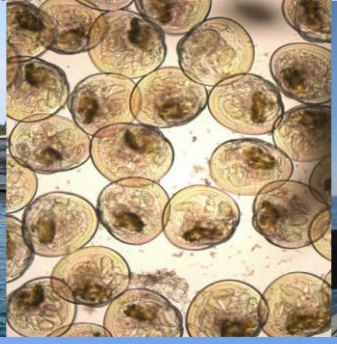

# Introduction

This document is a summary of the formal peer review of the aquaculture science conducted at NOAA's Fisheries Science Centers during 2016 and 2017. The document serves several purposes:

- Provides a brief overview of how the Aquaculture Science Program review was conducted.
- Summarizes the key issues reviewers identified during the review; and
- Presents individual Fisheries Science Center and a national-level response for those issues identified during the review.

Historically, all NOAA Fisheries Science Centers and the Office of Science and Technology (OST) have individually conducted reviews of elements of their science programs on an ad hoc basis. NOAA Fisheries added the Science Program Reviews[1] in FY 2013 as the overarching and systematic, national approach to peer review that ensures the NOAA Fisheries science enterprise is being properly conducted. This approach complements NOAA's Science Advisory Board and its Ecosystem Science and Management Working Group, which provide overarching thematic reviews of NOAA science by adding advice geared toward specific topics relevant to the NOAA science portfolio. Through continued use of this agency-wide peer-review process, NOAA Fisheries will more effectively maintain a high level of scientific quality, advance its science nationally, and provide guidance for future science investments.

Scientific integrity is a fundamental element of the process by which NOAA delivers the best available science and earns the public's trust in our science and management. To this end, NOAA drafted a policy to uphold scientific integrity principles contained in the President's March 9, 2009, Memorandum and in the December 17, 2010, Memorandum on Scientific Integrity[2] from the Office of Science and Technology Policy. Peer review is an essential element of this policy and these reviews are an opportunity for scientific exchange, maintaining and improving standards, improving performance, and increasing scientific credibility.
NOAA's Office of Aquaculture coordinated this review owing to the direct connection between the sustainable development goals of the Office and its active management of funding of NOAA labs for aquaculture science products. As a cross line office effort, this review covers all NOAA Fisheries Science Centers and one National Ocean Service Science Center. For the purposes of this report they will all be referred to as Science Centers.

## The Aquaculture Science Review

The Science Centers, Office of Science and Technology and Office of Aquaculture staff, developed a general review process and Terms of Reference (Appendix I) for the review. An Aquaculture Science Committee (ASC, Appendix II) coordinated the review, and results were communicated to NOAA Fisheries administrators. This team included

[1] http://www.st.nmfs.noaa.gov/science-program-review/
[2] http://nrc.noaa.gov/ScientificIntegrityCommons.aspx

members from each organization under review and was responsible for refining the Terms of Reference to meet their specific needs.

This review was conducted to ensure NOAA achieves its statutory mandates and implements agency policies effectively. The review included elements of aquaculture science that intersect with other NOAA mission areas, such as sustainable fisheries (defined by NOAA Fisheries to include commercial and recreational fishing and aquaculture), protected resources, and habitat conservation. This review was conducted to:

- Evaluate the quality, relevance, and performance of research and development supported by NOAA and conducted at NOAA Science Centers and Laboratories (supported by a variety of NOAA budget lines and external funding);
- Strategically position NOAA to plan and conduct effective aquaculture research and development activities; and
- Align science activities to implement NOAA Fisheries' Office of Aquaculture Strategic Plan[3].

This science review was focused on NOAA Science Centers' research conducted with internal funds, although it includes the partnerships and links the Science Centers have with externally funded research programs where appropriate.

Two meetings, one on the east coast and one on the west coast, were conducted for a period of four days each. The two meetings were scheduled in July 2016 as follows:

- East Coast Review – July 19-22, Northeast Fisheries Science Center, Milford, CT
- West Coast Review – July 26-29, Northwest Fisheries Science Center, Seattle, WA

The Scientific Review Panel included 7 independent scientists from diverse regions with familiarity with marine aquaculture. Panels included:

| Name | Role | Organization |
|---|---|---|
| **Dr. David Straus** | Chair | USDA Agriculture Research Service Harry K. Dupree - Stuttgart National Aquaculture Research Center |
| **Dr. Bill Walton** | Member | Auburn University Shellfish Laboratory |
| **Dr. Bob Rheault** | Member | East Coast Shellfish Growers Association |
| **Dr. Cheng-Sheng Lee** | Member | Center for Subtropical Aquaculture |
| **Dr. Chuck Weirich** | Member | North Carolina Sea Grant |
| **Dr. Doug Lipton** | Member | NOAA, Office of Science and Technology |
| **Dr. Mike Tringali** | Member | Florida Fish and Wildlife Conservation Commission |

NOAA Fisheries requires that the panel Chair is not a NOAA Fisheries employee but encourages them to be a federal scientist external to NOAA. David Straus from USDA's Agriculture Research Service served as Chair. Doug Lipton, NOAA Fisheries' Chief Economist, served as a NOAA representative on the review panel. The remainder of the panel was from industry, academia and government agencies.

[3]http://www.nmfs.noaa.gov/aquaculture/docs/aquaculture_docs/noaa_fisheries_marine_aquaculture_strategic_plan_fy_2016-2020.pdf

The Science Centers, Laboratories, and Offices provided briefing materials and background documents to the Panelists to facilitate the independent review. Two links were provided for pre-reading by the panel at least 10 days prior to the review, including the NOAA Aquaculture Strategic Plan and the Aquaculture Research Story Map[4]. The Aquaculture Strategic Plan provides context and budget numbers for the agency's aquaculture science endeavors. The story map covers the breadth of NOAA's internal aquaculture research program. It is designed to allow the viewer to skim over all projects or go into further depth on any specific project, if desired, and it provided the best opportunity to overview the breadth NOAA's internal aquaculture science. Subsets of these projects were covered in greater depth during the in-person reviews, and all presentations were provided to the Panel following the sessions where they were presented (see agenda summary in Appendix III).

Each in-person review was conducted over a four-day period. Review agendas typically began on Day 1 with background presentations on national and regional aquaculture science vision and strategies. These talks were followed on Days 1 and 2 by presentations by Science Center leadership on the perspectives, roles, and responsibilities of individual Science Centers and then by staff on the various fish and shellfish aquaculture programs and projects at the Science Centers (e.g., nutrition and alternative feeds, hatchery technologies, breeding and genetics, seafood safety, coastal planning, policy and management, stock enhancement, *etc.*). Tours of Science Center laboratories and aquaculture facilities concluded most days. Presentations or tours ended by mid-afternoon to allow the Panel time for discussion. Day 3 was reserved for all day review work by the Panel, and Day 4 focused on discussion by the Panel and Center Directors of the Panel's assessment.

Each Panelist and the Chair produced a succinct report detailing their individual observations and recommendations for the themes provided within the Terms of Reference (Appendix I). Individual reports are required for NOAA to comply with the Federal Advisory Committee Act (FACA). Draft reports were submitted to the Review Coordinator at the close of each review, with final individual reports submitted to the Review Coordinator and the Panel Chair approximately one week after the final review concluded. The Panel Chair summarized the program review proceedings for submission to the Review Coordinator approximately one week after receiving the individual Panelist reports. The Review Coordinator sent reports to the Aquaculture Science Committee, Science Centers, Office of Science and Technology, and Office of Aquaculture leadership for written response. The full text of responses from individual Science Centers are in Appendix IV.

All final reports, responses and background information (e.g., Chair's summary report, Directors' responses, and individual Panelists' reports) were made available for public review at the conclusion of the review process via the Office of Aquaculture[5] and Office of Science and Technology[6] program review websites.

[4] http://www.nmfs.noaa.gov/storymap/aquaculture/aquaculture_research.html

[5] https://sites.google.com/a/noaa.gov/nmfs-aquaculture-science/

[6] http://www.st.nmfs.noaa.gov/science-program-review/program-review-reports/index

# Summary Findings

## Overall National NOAA Aquaculture Program

The Review Panel was provided the Terms of Reference, the NOAA Story Map, and the NOAA Strategic Plan as background materials before convening. Several reviewers familiar with NOAA sought out additional sources, including the National Ocean Policy Implementation Plan, the White House Office of Science and Technology Policy Interagency Working Group on Aquaculture, the June 2014 International Our Ocean Conference, and the Aquaculture Policies of Department of Commerce and NOAA. Most reviewers were familiar with general aspects of NOAA's Aquaculture Research Program, however, reviewers observed that they were not familiar with the acronyms used during presentations and request that in the future presenters should be mindful of their non-NOAA and non-federal audiences. With this suggestion in mind, this document is written with a minimum of acronyms.

***Recommendations from the Panel:***

As noted in the sections below about work at specific Science Centers, the Review Panel was impressed with the quality and results of the science produced, especially given the limited budget, staff resources, and infrastructure available to the Aquaculture Program. Presentations were effective in providing the review team, with in-depth information about selected programs. The Panel thought the story map was an excellent summary of the agency's aquaculture science work and a platform for outreach and communication of the breath of aquaculture science at NOAA and encouraged its further development and expansion as an outreach tool. The Panel also commended the Internal Competitive Aquaculture Funds grant program (ICAF) for its flexibility (funds science, outreach, development and infrastructure for aquaculture at NOAA labs) and for providing a means to regularly develop and adjust priorities.

The Review Panel found that NOAA Science Centers have been adjusting their activities in recent years to meet the aquaculture mission, objectives, and priorities of the agency. The panel heard presentations from science center staff about current work and notable recent achievements such as the following:

- Development and application of GIS/siting, water quality, and genetics/escapes models to assist federal and state agencies in the review of aquaculture permit applications.
- Research on the interactions of shellfish farming and aquatic vegetation and endangered species.
- Use of fish processing trimmings, algae, and plants in fish feeds that have helped to reduce the percentage of wild capture fish (in the form of fish meal and fish oil) in aquaculture feeds.
- Maintenance of a national marine microalgae collection, distribution of algae starters to shellfish hatcheries, and the development of probiotics for shellfish hatcheries—all critical to the commercial and restoration shellfish industry.

- Development of marine fish, shellfish and algae culture and hatchery methods and genetics analysis (sablefish, yellowtail, oysters, mussels and seaweeds)
- Use of aquaculture for wild species recovery or enhancement (abalone, oysters, crab, salmon and others)
- Development of tools to improve the safety of aquaculture produced seafood (*Vibrios* and harmful algae blooms)

In addition to expanding the type of research above to all regions, the Panel also highlighted the need for development of new areas of research in:

- Disease modeling and health management
- Social and economic impact analysis.

Review Panel noted that the budget, staffing, and infrastructure resources available to the NOAA Aquaculture Program are insufficient to meet the agency's current mandates and priorities, as well as to meet national needs and federal priorities and guidance to increase domestic seafood production, double U.S. seafood consumption, create jobs especially in coastal fishing communities, use aquaculture (hatcheries) to restore species and habitats, and maintain healthy oceans. The following comment about the Northeast Center's Milford lab illustrates a common and reoccurring theme articulated by all the reviewers about the majority of labs reviewed:

*"It is absolutely clear that the Milford Lab has been hampered by budget declines and loss of staff. The facilities are operational and the staff is doing very strong work with what they have. That said, the lab's infrastructure is in need of improvement. More critically, perhaps, there is a dire need to address the staff shortages. The lab is currently understaffed, and a large number of retirements are looming. The lab's capacity to function in the future without at least replacement hires appears to be at risk."*

While the comment above was about the Northeast Center, similar comments made the same point about the Northwest and other Centers. The Panel found that the Northwest, Northeast and to a lesser extent, the Southwest Fisheries Science Centers have minimally-viable aquaculture research programs (relative to agency and national needs), however, the Southeast Fisheries Science Center, Alaska Fisheries Science Center and the Pacific Islands Science Center are below the minimally-viable level. There is a need for scientific support in all regions for multiple organism types (finfish, shellfish and seaweeds). The recently approved Fisheries Management Plan for Aquaculture in the Gulf of Mexico, and a similar plan developing in the Western Pacific make the Southeast and Pacific Islands regions among the most active areas for development of marine fish aquaculture. Recent Alaskan interest in shellfish and seaweed aquaculture has increased the need for aquaculture science support in Alaska. State and regional shellfish initiatives, inspired by the National Shellfish Initiative, are sparking increased needs for shellfish science in all regions as this industry expands.

Although the review team pointed out the need for science support in all regions, the Panel also stated that NOAA should not reduce funding to its aquaculture research programs in the Northeast, Northwest and Southwest regions, or NCCOS which are already under resourced[7]. The Panel noted that demand for scientific information exceeds NOAA's ability to supply it and that expertise is concentrated by geography, scientific expertise and organism focus (shellfish, finfish, algae). In a flat budget, and without expertise at NOAA Science Centers in some regions, the Panel suggested using the relatively stronger programs in the Northwest, Northeast and Southwest Centers and NCCOS to address needs outside their regions. The NOS/NCCOS program was given as an example of a Science Center doing a good job of serving key national needs. In addition, the Panel suggested that Centers in all regions or the Office of Aquaculture could work with NOAA's extramural aquaculture grants programs to develop coordinated regional support at academic institutions outside of NOAA Science Centers.

The Panel highlighted the fact that collaborations among the NOAA East and West Coast Science Centers should be encouraged. The Panel suggested that future reviews allow all NOAA aquaculture scientists to attend to share information, find out more about programs throughout NOAA, and form collaborations. The Reviewers also noted that within NOAA, the degree of interaction between entities conducting aquaculture research was not clear. To enhance future communication and development of collaborations, the Panel suggested that a travel program or regular meeting be put in place to allow NOAA aquaculture researchers from various regions throughout the country to interact and exchange ideas and information.

The Panel suggested a Senior Scientist be assigned to aquaculture research at each Science Center to raise the profile of aquaculture in the agency, serve as a bridge to Regional Aquaculture Coordinators, and align internal and external aquaculture research to focus on regional needs. The review team also suggested that an advisory panel from industry, Sea Grant and outside research centers, if not already functioning, could benefit all the NOAA labs. Moreover, Sea Grant agents should be involved with specific projects, so that the labs can take advantage of their role and expertise in technology transfer.

The Panel encouraged greater outreach to stakeholders through development of workshops and dissemination of newsletters to promote and transfer research results. It was suggested that the Science Centers utilize Sea Grant resources to assist in this area. Many domestic institutions and agencies conducting aquaculture research host workshops every year or two to promote and transfer research results to stakeholders. The panel highlighted the Milford Aquaculture Seminar as a good example that could be encouraged and replicated in other regions. Newsletters and webinars were also suggested as ways that Science Centers can keep stakeholders updated on current events.

The Panel also recommended that efforts be increased towards establishing additional Cooperative Research and Development Agreements (CRADA) to bring in more resources and focus research. CRADAs should be developed before commencing research to identify

[7] This was reinforced in the FY17 Congressional CJS Budget which stated "*The Committee is concerned by reports that NMFS fisheries science centers are cutting resources and staff positions dedicated to aquaculture research. NOAA is expected to maintain viable financial and personnel resources at the Northeast and Northwest Fisheries Science Centers, including refraining from cutting aquaculture funding or staff resources and expeditiously filling open positions.*" It is important to note that flat budgets equate to a reduction in funding for science. Over time the cost of operations increases (power, maintenance, service contracts, etc). Thus, the funds available for aquaculture science decrease. The Congressional language is thus unsustainable without budget increases.

deliverables. To begin, the Panel suggests developing a workshop (with several successful USDA/ARS aquaculture CRADA holders) to promote formation of CRADAs more broadly within the NOAA Aquaculture program.

Finally, staffing and retirements were a recurring topic among the Science Centers, and the reviewers suggest investigating the possibility of using the Federal Government's new initiative on "Phased Retirement."

***Response from the Office of Aquaculture:***

The Office of Aquaculture looks forward to implementation of many of the suggestions given by the Review Panel. Three overarching issues and recommendations cut across all programs, topics and Centers.

1) *Budget Issues*: Many panel recommendations require additional staff and other resources to maintain existing efforts as well as expand efforts to additional priorities. Much of the ongoing work is long term and requires substantial consistent funding from year to year to achieve goals related to development of new species for marine aquaculture all the way to commercialization. Dependence on temporary funds to sustain programs and facilities makes it challenging to manage long term efforts because temp funds are inherently unstable and distributed late in the fiscal year.
2) *Stakeholder involvement* - The panel suggests more communication/involvement/outreach with industry, regulators and other stakeholders particularly in setting priorities. While annual workshops and outreach through seminars, conferences are helpful for communication it does not ensure NOAA will work on specific stakeholder priorities. How do we hold ourselves accountable? We will develop a process that ensures that stakeholders are consulted when developing national and regional priorities on a regular basis.
3) *Strategic planning and coordination among Centers*- Coordination of annual Science Center research planning/ prioritization with the national efforts to prioritize NMFS AQ research is needed. This will require a process for increased communication among Science Centers, regulators and with industry

In addition to creating better efficiency and communication, the Panel suggestions will help to better align Science Center activities to meet, support, and implement the objectives and tasks outlined in the Aquaculture Program Strategic Plan, the NOAA Fisheries annual strategy, and the DOC/NOAA aquaculture policies. The aquaculture program priorities are: a) improving regulatory efficiency, b) developing science tools for management, c) technology development and transfer, and d) creating an informed public. Science has a role to play in meeting all these goals and suggestions provided by the Review Panel will assist NOAA in meeting them. To capture the suggestions from this review and provide a way forward we will work with Science Centers and other parts of the wider NOAA aquaculture program to develop a Strategic Aquaculture Science Plan.

Because of limited resources and high demand for science products, we should continue focus on high priorities identified by stakeholders and partners, and in areas where Science Centers provide maximum value. NOAA's Science Centers provide unique infrastructure and professional personnel at a scale, experience level and time horizon that is larger and more resource secure than most academic institutions. Science Centers also have the ability

to work on issues that are "inherently governmental" or that use restricted data sets. However, the need for aquaculture science is large and exceeds our ability to provide it. The budget tagged for internal aquaculture science in FY17 was less than $8M. The Office of Aquaculture will continue to evaluate and articulate the unique role of NOAA's Science Centers in sustainable development and management of marine aquaculture. Some examples of science tasks we identify as needed for smart management and industry development are:

- Create and deploy siting and regional planning data, tools and models.
- Develop and operationalize prediction models for water and benthic quality, genetics, seafood and human health, and aquatic organism health management.
- Understand the habitat implications of aquaculture operations, and develop mitigation measures.
- Ensure interactions among endangered species and aquaculture operations are low risk.
- Develop and deploy economic, market, and social impact analyses and tools.
- Develop and deploy aquaculture techniques to restore or enhance wild populations, create or preserve critical habitats, and support important wild commercial and recreational species.
- Develop and deploy aquaculture technology to increase the variety of species cultured, improve efficiency of production, maximize seafood quality and improve environmental performance of marine aquaculture.
- Understand ocean conditions that affect aquaculture production (eutrophication, acidification, temperature changes, salinity, *etc.*) and develop mitigation approaches.
- Discover and apply science information on human health impacts of aquaculture products caused by ocean conditions, feeds, and/or production system.

In addition to coordinating development of a Strategic Aquaculture Science Plan (SASP), the NOAA Aquaculture Program will use the suggestions from the review panel to explore the development of a National Marine Aquaculture Initiative. The Initiative will include a) streamlining regulations and permitting, b) developing regional partnerships to facilitate deployment and operation of commercial scale facilities, and c) invest in research, development, technology transfer, and extension. The Program has been successful in the past using initiatives (Shellfish Initiative, Feeds Initiative, *etc.*) to align and focus resources from multiple sources (federal and non-federal) to effect change. We will address the subject areas the Panel found lacking, (Disease modelling and health management; and, Social and Economic impact analysis) using initiatives to develop and structure research in these areas.

We agree that the issues of geographic coverage, species coverage (seaweed, shellfish and finfish), and discipline coverage (genetics, physiology, nutrition, health, microbiology, engineering. *etc*) among the Science Centers is insufficient to meet the demands for marine aquaculture science in the US. Although NOAA and NOAA Fisheries priorities have put

increased emphasis on marine aquaculture in recent years, budget and staffing resources for aquaculture did not increase from FY10 to FY16 to implement the stated agency priorities. Congress did increase the NOAA aquaculture budget line from $6.3M in FY16 to $9.3M in FY17, then to $15M in FY18, largely to increase partnerships with industry through external grants designed to increase commercial production[8]. Due to Congressional language tied to the budget, only a part of the increases can be used at NOAA Science Centers to support those commercial endeavors. The challenge is meeting the stated requirements Congress has mandated to direct funds toward industry partners while also supporting the costs associated with the NOAA side of these partnerships. In addition, from FY10 to FY17, Even the aquaculture programs in the Northwest and Northeast Fisheries Science Centers are seriously underfunded relative to mission needs, and staffing levels at the two aquaculture flagship Centers have declined during the past six years. They are in danger of losing the critical mass needed to maintain existing services and research. During that time, labor and other fixed costs have risen, leaving less money available to conduct research (supplies, equipment, travel, *etc.*). The Office of Aquaculture will draft budget options/requirements as part of an action plan to implement a potential national marine aquaculture initiative in FY19 and later years.

The Office of Aquaculture agrees that an increased focus on national coordination will better inform a bi-coastal review in the future. The Office will continue to fund complementary research at both the Northeast and Northwest Centers to encourage bicoastal synergies focused on key issues of national importance (e.g. Shellfish and Habitat interactions). The Office of Aquaculture will also restart a regular national webinar series to increase national communication among Centers, and explore the options and costs for an All NOAA Aquaculture meeting on a regular basis.

The Office of Aquaculture agrees that having Senior Scientists in each Center would raise the stature of aquaculture in the Centers, however it is also clear from the responses below that most Centers do not have the resources to do this. We will continue to explore maintaining the Aquaculture Science Committee that was formed to facilitate this review. While this does not have the stature of a Senior Scientist in each Center, it may help to accomplish much of the same thing. Coordination with Sea Grant and USDA is already taking place and will be expanded at both the state and national level.

An external advisory panel, the Aquaculture Task Force[9], to NOAA's Marine Fisheries Advisory Committee (MAFAC) was formed in 2015. Using this group to provide public advice to NOAA's aquaculture science program will be explored. USDA, for example,

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[8] Specific language from FY17 budget is as follows: *Regional Pilots in Sustainable Aquaculture-The Committee notes that more than ninety percent of seafood consumed in the United States is imported, that more than half of imported seafood is from overseas aquaculture, and that, while possessing the largest exclusive economic zone in the world, the United States ranks only fifteenth in aquaculture production. To address this major lost opportunity for job creation in coastal communities and to encourage the development of a domestic seafood supply, the NMFS Aquaculture Office is directed to conduct regional pilot programs for partnerships between the seafood industry and community partners that can develop, validate, and deploy economically and environmentally sustainable aquatic farming techniques and regional business practices to grow U.S. domestic seafood production…. To maximize the impact of these* ***pilot grants****, NMFS is encouraged to give priority consideration to promising but less commercially developed technologies, such as those targeting shellfish, seaweed, and other relative newcomers to the domestic aquaculture industry. $2,000,000 is included in NMFS Aquaculture budget for this purpose.*

[9] http://www.nmfs.noaa.gov/ocs/mafac/Task%20Forces/NEW%20Nominees%20Aquaculture%20Task%20Force.html

convenes a stakeholder meeting every five years to review the results of USDA's internal and extramural aquaculture programs; and then to gather recommendations for work to be conducted during the next five years. Public input through MAFAC combined with a public input process similar to what USDA uses, and periodic advice from state Sea Grant directors would provide several diverse avenues for greater public engagement with NOAA's Aquaculture Program. It will also be critical to solicit input from regulatory decision makers at NOAA and other agencies dealing with aquaculture permitting and management.

The Office of Aquaculture newsletters regularly feature the aquaculture science undertaken at the Science Centers and will continue to do so. The Office website is in the process of being updated and we will incorporate the Panel's recommendations in the new site and make greater use of the story map. We will explore the option of adding an open webinar series (or set of series) targeted on key marine aquaculture needs and featuring NOAA science center researchers.

The use of CRADAs at NOAA fisheries and the ease of their development was largely pioneered by the Office of Aquaculture and the growing numbers of agreements prove it has been successful. We will continue this effort.

Staff and management have been made aware of the opportunity for Phased Retirement. Indeed, the Northeast Center explored the possibility of using Phased Retirement in its staffing plan and the Northwest Center has successfully used the program. We recognize that it is a tool that retirees and management may consider and may be mutually beneficial however exploring retirements without the ability to replace staff erodes capability and does not help NOAA address its current bandwidth limitations in aquaculture research.

***Action Items:***

- Develop a strategic research plan taking into account the limitations of budget and proliferation of need for marine aquaculture science in all regions.
- Propose a National Marine Aquaculture Initiative to attract resources and foster coordinated action.
- Explore opportunities to improve 1) Disease modelling and health management; and 2) Social and Economic impact analysis using initiatives to develop and structure multi-Center research in these areas.
- Facilitate collaborative research among the Centers and to provide national and regional guidance on interactions between commercial aquaculture and a) habitat, and b) protected resources to facilitate regulatory streamlining and effective management.
- Restart the national NOAA Aquaculture Science Webinar Series to enhance national collaboration, and explore use of new webinar series to advance sub-topic issues of aquaculture (seaweeds, shellfish, finfish for example)
- Consider an All NOAA Aquaculture meeting, perhaps as a stand alone or in association with one of the major national aquaculture meetings – perhaps at Aquaculture America.

- Survey NOAA aquaculture staff on the structure and budget for travel grants to allow scientists to attend an All NOAA or other Aquaculture meeting.
- Develop a clear charter for and establish the Aquaculture Science Committee to increase coordination among regions.
- Link NCCOS's GIS/siting and water quality modeling work with fisheries, oceanography, and environmental data produced by other NOAA science centers.
- Explore better use of MAFAC for aquaculture science input.
- Continue to integrate with extramural science grant and extension programs such as Sea Grant, SK and programs from NOAA's Technology Transfer Office (SBIR) .
- Add more science stories to the Office of Aquaculture newsletter and rewrite the web site.
- Facilitate Centers working with industry, academia, and other groups via expanded training and inreach on Cooperative Research and Development Agreements and/or Material Transfer Agreements. Educate stakeholders of the opportunity to work with National Labs.

### National Centers for Coastal Ocean Science (NCCOS)

The Review Panel indicated that the National Ocean Service's National Centers for Coastal Ocean Science (NCCOS) is a tremendous asset to NOAA aquaculture, and its staff and leadership should be commended. The Panel was impressed by the tools that the aquaculture group at NCCOS's Beaufort, N.C. Laboratory has delivered to stakeholders to help with regulatory processes and that it has done so on a very limited budget. The NCCOS performs modeling/mapping needed by the regulators, is well-suited for its mission, and maintains high productivity. The Reviewers felt that NCCOS skills would continue to be needed as coastal aquaculture grows in the future.

#### *Recommendations from the Panel:*

The Review Panel requests that the NCCOS continue to conduct beneficial services to stakeholders and publish key reports.

#### *NCCOS Response:*

NCCOS will work to continue to provide products and services as resources allow that empower coastal managers to make science-based decisions regarding coastal resource stewardship and aquaculture industry development. NCCOS has established Coastal Aquaculture Siting and Sustainability as a priority research area under Marine Spatial Ecology, we will consider adding disease modeling to our suite of modeling approaches for coastal aquaculture, and we consider economic and social science a priority. We will work to leverage and apply NCCOS resources towards these areas of need and plan to hire an additional full-time marine ecologist to work on aquaculture in 2017. NCCOS has also increased its online footprint through the recent release of the Coastal Aquaculture Planning Portal[10] (CAPP), which provides over 20 tools for coastal aquaculture planning and siting. NCCOS will be posting an additional 25 tools in 2018.

[10] https://coastalscience.noaa.gov/research/marine-spatial-ecology/coastal-aquaculture-planning-portal-capp/

***Action Items:***

- Provide products and services as resources allow that empower coastal managers to make science-based decisions regarding coastal resource stewardship and aquaculture industry development.
- Work collaboratively with other Centers to provide national guidance on habitat and commercial aquaculture interactions.
- Work with the Office of Aquaculture and other Centers to add disease modeling to suite of modeling approaches for coastal aquaculture
- Hire an additional full-time marine ecologist to work on aquaculture.
- Update and maintain Coastal Aquaculture Planning Portal suite of tools for coastal aquaculture planning and siting.

## Northeast Fisheries Science Center (NEFSC)

The Review Panel was impressed by the breadth and quality of research at the Milford Laboratory. The Milford Lab's productivity was shown in their presentations and publication record. In terms of inreach and outreach, the Panel noted that the annual Milford Aquaculture Seminar and the phytoplankton workshop are good ways to connect with stakeholders, and efforts to collaborate with state governments and industry are commendable. Milford also does a great job of teaching, training, and mentoring interns, students, and post-docs. However, staff attrition and soft funding need to be addressed. All Reviewers commented on addressing forthcoming retirements, the need to maintain institutional memory, the need to invest in facilities, and the lack of finfish research due to staffing reductions.

***Recommendations from the Panel:***

Funding and staffing shortages should be addressed immediately to keep the NEFSC at the forefront and preserve institutional memory. In particular, the future of the Milford Aquaculture Lab program can determine how significant a role NOAA can play in US aquaculture, particularly on the East Coast. Additional funding and staffing are required to fulfill their current priorities. Many work spaces are not being used because of decreased numbers of staff, including parts of the microalgae lab, finfish lab, and outdoor greenhouses/tanks. Outside researchers should be encouraged to come to the lab. A combined investment in upgraded facilities and new scientists would ensure the U.S. taxpayer is getting a high return on investment.

The Review Panel recommends that the NEFSC continue to engage in the microalgal work but should reevaluate the shellfish genetics project. Reviewers believe that the value of national labs is their ability to conduct long term research and maintain long term facilities. For example, the microalgal research and services project is a long-term commitment and more suitable for NOAA as opposed to short-term projects sponsored by universities or private industry. The Panel pointed out, that the value of the scallop genetics and breeding project is questionable. Shellfish genetics efforts should be directed to address species currently being produced or current needs. *Vibrio* research should be expanded with a

dedicated scientist, and genetic improvement redirected to high value bivalves. The Milford shellfish hatchery and microalgal production techniques trainings have been successful at transferring this technology to many different aquaculture operations around the country. In addition, the Milford Lab should consider returning to finfish research and start using the outdoor greenhouse facility.

***Response from the Northeast Fisheries Science Center:***
The NESFC is reviewing short and long-term staffing needs and is committed to supporting aquaculture science; we will work with our leadership such that those needs are accurately communicated. The NEFSC values the work conducted in Milford and recognizes its aging infrastructure. Revitalization of the facility is part of the NEFSC's Facilities Strategic Plan but is contingent upon adequate funding and is restricted to not increasing the facility footprint. Promoting cooperation with staff in Sandy Hook, NJ, and other locations in the NEFSC will help address maintaining a diverse and ambitious aquaculture research portfolio.

We agree with the recommendation to revitalize aquaculture finfish research and are exploring the possibility of developing a finfish aquaculture research capacity at Sandy Hook, NJ, in collaboration with our experts in Milford. This research could focus on caged culture and/or enhancement of natural stocks, depending upon resources and potential collaborators. One topic to consider at the Northeast Aquaculture Conference and Exposition 2019 meeting and/or the Milford Aquaculture Seminar 2019, both of which are hosted or co-hosted by the Milford Lab, may be the role of finfish aquaculture in the Northeast.

We are creating a staffing plan to continue micro-algal work, and we are evaluating the level of effort on our genetics research on shellfish to improve its relevance, possibly reducing or eliminating it, and transfer effort to other species of interest. We will consider redirection of current shellfish genetics efforts on scallops to mussels and oysters. The NEFSC will need to hire a new *Vibrio* expert or form necessary collaborations with experts to restore this research capacity and address the need for robust management of human and aquatic animal health issues.

Our success in shellfish hatchery techniques and microalgal production is communicated through publications and extensive outreach and education activities such as an annual course in microalgae culturing. We will also review and update the shellfish hatchery culture manual, as needed. We are exploring options for additional resources or funds to expand on these efforts. We will also continue research on development of probiotics and the effects of ocean acidification on blue mussels, and oysters. We will explore appropriate finfish species for the Northeast region and develop a finfish research plan in line with agency goals.

We agree that the facility in Milford is underutilized. We will consider increased usage of cooperative agreements like CRADAs to promote engagement with outside researchers. Along these lines, we have discussed with the USDA in Kingston, RI, the possibility of space sharing in Milford. We also have allowed the University of Connecticut macroalgae research group to set up a rearing capacity in Milford. Each of these has the potential to lead to a long-term collaboration at the lab. The long-term success of both will require additional investment in infrastructure. We also will encourage staff to consider

collaborations with industry, academic, agency and NGO partners and have already initiated discussions with the National Fish and Wildlife Foundation.

The NEFSC will consider creation of a newsletter and increased submissions of articles to Sea Grant, the Office of Aquaculture newsletter and other media outlets (e.g., East Coast Shellfish Growers Association Newsletter). Publicizing activities in the Northeast Center is important, and our online Spotlight series aims to do this. Milford staff members are engaged with the popular media and have been featured in numerous newspapers, journals, video, radio and television in recent years. Key staff from the NEFSC aquaculture program met with Sea Grant representatives from all states in the Northeast in 2017 to discuss how to better coordinate our activities, identify regional research needs and collaborations, leverage our respective strengths, and improve outreach and educational activities. Invitations to the seminars will be distributed to key representatives of regulatory agencies, and we will create a distribution list of key stakeholders, to whom notifications of publications of particular interest will be communicated.

***Action Items:***

- Work collaboratively with the NEFSC and NCCOS to provide national guidance on habitat and aquaculture interactions.
- Review short and long-term staffing needs, including creating a staffing plan to continue microalgal work.
- Revitalize aquaculture finfish research and develop a finfish aquaculture research capacity at Sandy Hook, NJ.
- Hire an animal or human health scientist or form necessary collaborations to restore capacity for *Vibrio* research, continue research on the development of probiotics, and continue research on the effects of ocean acidification on shellfish and finfish.
- Evaluate the genetics research on shellfish to determine its value, possibly reducing, redirecting, or eliminating it.
- Review and update the shellfish hatchery culture manual, as needed.
- Explore options for additional resources or funds and collaborations to expand on the above research efforts, including CRADAs.
- Improve outreach and educational opportunities and engage stakeholders by holding seminars, creating a newsletter, increasing submission of articles to Sea Grant and other print media outlets (trade magazines, newspapers, journals), and continuing to work with the popular media (video, radio, online, and television).

## Northwest Fisheries Science Center (NWFSC)

The NWFSC is involved with many research projects that are extremely valuable to their present and future stakeholders and appears to have a good track record of successes. The NWFSC represents a very good value to the NOAA Aquaculture Program, especially with the shellfish and sablefish research projects and work involving the Environmental

Sampling Processor. Shellfish research focusing on the Olympia oyster is important for stock restoration and may encourage industry diversification. Similarly, the sablefish culture project has the potential to be instrumental in the development of a domestic industry for the species.

***Recommendations from the Panel:***

The Review Panel recommends that the NWFSC develop a research program to support the regional commercial shellfish industry; invest in facility maintenance (i.e., net-pens and docks); focus on affordable tools for harmful algal bloom research; focus on predicting risk of *Vibrio*; develop a research program for macroalgae production and utilization; and transfer technologies developed regarding sablefish reproduction, larviculture, and juvenile production to the industry to optimize research output.

Other specific research recommendations include:

- Developing diets specific for sablefish and partner with industry to evaluate growout diets. Sablefish sex-control work should continue to receive strong support, as well.

- Correlating Environmental Sample Processor data with other measured parameters and looking for less expensive testing methods.

- Initiating research on existing commercially important shellfish species. Moreover, shellfish/eelgrass interactions research is relevant to regulatory and industry and should be expanded.

- Protecting technologies developed for finfish aquaculture and working towards establishing a viable industry.

- Continue investigating the potential of sea cucumbers and macro-algae for aquaculture development.

- Finalizing needed decision support tools (e.g., genetics and habitat) toward regulatory efficiency and target development of additional management tools in other areas.

The Panel suggests hosting an annual workshop to promote and transfer these and other research results to stakeholders. Science Centers should seek extramural funding, especially through CRADAs.

Finally, there is need to be proactive regarding staffing shortages. The NWFSC should hire scientists dedicated to shellfish research to advance restoration and aquaculture production of commercially important species. Many research questions about sablefish production could be addressed with more manpower and facilities not devoted solely to mass production of juveniles.

***Response from the Northwest Fisheries Science Center:***
We concur with the Panel's observation that the NWFSC is fulfilling mandates and addressing stakeholder needs. This fulfillment has been achieved by coordinating with the Office of Aquaculture in headquarters, the Aquaculture Coordinator of the West Coast Regional Office (WCRO), and stakeholders in industry, local governments, and tribes. All of our research programs have regular research planning meetings where progress, problems, and research directions are discussed. Some of these meetings also include stakeholders and external partners.

The NWFSC aquaculture research program is broad and diverse. Over the last five years, the NWFSC has broadened the subject area of its mandates from a focus primarily on finfish aquaculture to include shellfish, macroalgae, and sea cucumber. However, with increasing costs and flat budgets it is not clear that the current breadth of species and subjects is sustainable. The research program is requiring more prioritization, and this is underway, but the challenge is how to involve the industry in ensuring priorities match with industry needs, and also coordinate with the broader NWFSC activity prioritization process that occurs annually. The Panel's recommendations are very helpful and its guidance timely.

Sablefish culture technology has been developed to the stage that it is ready for industry to adopt sablefish as a new aquaculture species. Transferring sablefish culture technologies to a developing U.S. industry is a high priority. The vision for sablefish culture in the future is to further refine culture science and technology and provide an economic and marketing analysis for entrepreneurs to consider for establishing a sablefish industry in the US. In FY17 NWFSC scientists have partnered with the Jamestown S'klallam tribe and University of Washington to transfer technology for sablefish grow out to the tribe. The non-NOAA portion of this project is funded by a grant from the National Sea Grant Program. In parallel NOAA Office of Aquaculture funded an economic analysis of sablefish aquaculture and the NOAA portion of the project. Success would not have been possible without both parts and coordinated funding. A primary focus of NWFSC research on sablefish aquaculture will be on refining rearing protocols for sablefish embryos, larvae, and juveniles on live feeds and development of methods for sterilization of sablefish to reduce genetic risks of escapes from net-pens to native populations. In FY17, NWFSC staff in collaboration with scientists from the University of Maryland (who were awarded a grant from Maryland Sea Grant) tested a novel technology for reproductive sterilization of sablefish. Developing a domestic net-pen industry with local tribes is encouraging from the standpoint of the tribes wanting to culture native sablefish rather than exotic Atlantic salmon. However, the 30+ year old floating net-pen structure at the Manchester lab has outlived its projected life span by about one decade and was dismantled in FY18 for safety reasons. Since the net-pen complex at Manchester is the only one in the US devoted to research, the loss of the wooden net-pens will severely limit the types of finfish research the US will be able to conduct. Additional facilities needs due to aging infrastructure (chillers, heat exchangers, pumps) are being addressed. However, infrastructure costs at the Manchester Research Station will continue to impact the overall funding available for aquaculture research. Because the net-pens are unique infrastructure nationally, their loss impacts the NOAA's and our partners ability to conduct many types of marine finfish aquaculture research focused on offshore development.

A second priority will be to expand research efforts on commercially important shellfish species. Although there is considerable activity in the shellfish facility involving NOAA's

partners, these efforts would be greatly enhanced by hiring a NOAA researcher with primary responsibility of working on commercially important species. Work on shellfish pathogens and toxins will continue to be supported.

Additional ongoing work includes populating the OMEGA model with the following species and sites: almaco jack (*Seriola rivoliana*) in Hawaii, the Gulf of California, and the Gulf of Mexico; red drum (*Sciaenops ocellatus*) in the Gulf of Mexico; and red snapper (*Lutjanus campechanus*) in the Gulf of Mexico. Work is also continuing on shellfish-eelgrass interactions in Puget Sound. Sea cucumber and macroalgae culture will be supported as funds and staff are available.

The NWFSC is fortunate to have a research staff that use cutting-edge techniques and approaches in biology, including genomics, genetics, epigenetics, bioinformatics, as well as traditional sub-disciplines in physiology, nutrition, immunology, and microbiology. However, staffing and succession planning continue to be problematic with difficulties in hiring in the agency. Staff continue to seek extramural funding and have three CRADAs in place and one in development; working with stakeholders, including industry, is one way to assure that useful science is pursued and the roles and responsibilities of government and our partners are formally defined.

The NWFSC is also expanding efforts to collaborate with other Science Centers, especially with the SWFSC with recent collaboration on genetics, bioinformatics, and algal culture. Expansion of communication and collaboration between the NWFSC and NEFSC is anticipated for shellfish technology, shellfish-eelgrass studies, and other topics. The Aquaculture Review was a great opportunity for face-to-face communication among researchers within NOAA's West Coast (Northwest and Southwest) Science Centers and has already led to follow-up visits of bench-level researchers from the Northwest and Southwest Science Centers. Scientists at the two Science Centers also share collaboration with external partners. However, more work needs to be done to improve collaboration and communication among NOAA labs, especially with our closest center in the SWFSC.

Lastly, the NWFSC continues to emphasize quality science and peer-review publication. The recommendation of hosting an annual workshop to promote research among stakeholders is under consideration. Communications and scientific staff coordinate participation in education and outreach including scientific publications, outreach materials, press releases, videos, participation at regional and national scientific meetings, social media, websites, open houses, and direct contact with stakeholders. Additional communication of NWFSC research results is through websites and newsletters of NOAA's Office of Aquaculture. The NWFSC works with Sea Grant researchers and extension agents in western states as well as with the National Sea Grant Office. There is also opportunity to improve communication of research results from different Centers as part of a NOAA-wide update of websites.

***Action Items:***

- Continue seeking guidance from the groups inside and outside of NOAA with regard to future directions of the Northwest Center aquaculture research.
- Develop a prioritized research strategy and continue evaluating aquaculture research progress and plans.

- Host an annual workshop is being considered in addition to continuing participation in a wide range of outreach efforts, including participation at national and regional meetings (e.g., Aquaculture America, Shellfish Growers Conference), press releases, videos, and brochures, among other media outlets.
- Fill a shellfish research position with expertise in genetics, epigenetics, genomics and adaptation that was approved in the FY17 Northwest Center hiring plan.
- Work collaboratively with the NEFSC and NCCOS to provide national guidance on habitat and aquaculture interactions.
- Conduct an economics and marketing study of sablefish aquaculture funded in FY17.
- Conduct a sensitivity analysis of the OMEGA model, which should help inform managers about the relative importance of the various genetic and ecological impacts evaluated in the model.

### Southwest Fisheries Science Center

The SWFSC has a growing track record of success given its recent start to aquaculture program development. It has established excellent research programs in the areas of yellowtail physiology and genetics, as well as abalone genetics.

***Recommendations from the Panel:***

Having a Senior Scientist with expertise in aquaculture in the Director's office shows a commitment to aquaculture research as the program developed. However, due to the current low level of industry development in the southwest region, the finfish research program has developed some of its current collaborations with institutions and industry in Mexico, including U.S. institutions and companies working in Mexico. The Review Panel recommends that the SWFSC focus on finfish aquaculture research to support domestic industry development, keep working on abalone restoration and production aquaculture, and communicate research to stakeholders. Facilitating the permitting process for offshore finfish aquaculture in the U.S. is important, and the technology developed for yellowtail culture should be applied to closely related species suitable for aquaculture in the Gulf of Mexico when these regulatory hurdles are satisfied. Thus, the Panel suggests researchers continue identification of yellowtail qualitative traits and genetic improvement through selection, while concurrently protecting technologies developed for finfish aquaculture and working more within the US. Finally, work must continue on white abalone to develop technologies for restoration and aquaculture.

***Response from the Southwest Fisheries Science Center:***

The Southwest Center will continue to pursue the science needed by industry, federal and state agencies to enable the aquaculture industry to develop. Regarding abalone, we will continue to leverage the intersecting goals of NOAA's Protected Resources and Aquaculture Programs to improve methods and outcomes of Endangered Species Act (ESA) mandated restoration of abalone as well as improvements for commercial abalone culture; a genetic and genomic approach for developing breeding programs and out-planting strategies provides a firmer foundation to restoration. Our aquaculture efforts will continue to focus on one potential offshore commercial species, yellowtail, as well as the

recovery of endangered abalone. We do not anticipate adding new taxa at this time, but realize that industry and protected resource interests can change and we will strive to be responsive to those changes. We anticipate these efforts and the SWFSC's facilities will support NMFS' goals for warm water aquaculture species in the future.

SWFSC scientists currently collaborate with other government, industry and academic partners on individual projects; the benefits of larger and longer-term relationships will be key for stable and sustained growth of aquaculture research. Lines of communication between NOAA scientists, regional NOAA offices and industry partners need to be strengthened. For example, as aquaculture permitting and siting discussions continue to grow, there will be an increasing need to coordinate efforts between West Coast Regional Office (WCRO), SWFSC, and NCCOS to provide clear guidance to industry that recognizes the rewards for food security as well as the risks to habitat and protected resources. Building on the opportunity the review gave us to connect with the other West Coast Centers, the SWFSC has a better understanding of the expertise within the agency, especially at the NWFSC, and we will strive to establish stronger collaborations and coordinate in areas such as hiring. Finally, the SWFSC has experienced increased interest in aquaculture from constituents, as well as interest from industry, NGO and academic interest sectors in accessing new infrastructure assets such as the experimental aquarium and genetics laboratory. Funded academic partners are encouraged to collaborate with the SWFSC to make use of seawater facilities, the genetics laboratory or environmental data.

We appreciate the Panel's specific comments on research to understand the natural genetic variation and genetic differences among *Seriola* populations worldwide, and we will continue to characterize the genetics of wild populations and hope to guide the conversation regarding trait improvement and the risks of escapement. To this end, the SWFSC hosted the first *Seriola* Genomics Workshop in 2016 and a second in early 2018. We will continue to support these efforts to share information and communicate results across an array of *Seriola* science issues.

The Reviewers also identified the key point of intellectual property protection and collaboration with Mexico (and other countries), but different countries make progress in different areas (e.g., yellowtail) and collaboration is key to rapid advancement of the industry worldwide. It would be worthwhile to discuss intellectual property considerations with other agencies, or moving research advancements to fee-for-service US aquaculture genomics companies. The SWFSC and the Office of Aquaculture have discussed establishing capacity for economics research focused on aquaculture issues at the SWFSC. This new capacity would have a national focus and could address intellectual property and transboundary science issues as well as more traditional economic impact studies.

The SWFSC's Aquaculture Program is really just beginning. An advantage of the program is that it is has occurred as an extension of fisheries research rather than created *de-novo*. Researchers automatically consider aquaculture in the context of maintaining and preserving natural genetic variability and the health and well-being of wild fisheries and habitat. As the Panel noted, it is an opportune time to consider how to communicate research results. The first building block should be continued enhancement of the communication between the WCRO and the NW and SWFSC. The second building block should be better communication with constituents. Regulatory issues such as site evaluation, protected resources issues such as restoration of ESA listed abalone species,

and commercial interests have different but overlapping national and international constituencies.

Occasionally, there is also the need to focus on specific areas in depth. first In addition to the 2016 and 2018 *Seriola* Genomics Workshops, the SWFSC participated in the first Binational Abalone Workshop in Mexico in 2016, and routinely participates in and hosts a number of wider ranging annual bilateral meetings. Lastly, consumer interest in the pros and cons of domestic aquaculture must also be addressed.

***Action Items:***

- Build the capacity to rear large quantities of larval and juvenile white abalone and assist in white abalone outplanting efforts as soon as permits and sufficient captive born abalone are available.

- Hold workshops to inform international partners of the risk of moving genetically different yellowtail populations between eco-regions and work to identify and select for genetic traits that can improve aquaculture outcomes within eco-regions.

- Evaluate the population structure and genetic diversity in natural abalone populations and perform physiological and genetic studies of eggs, larvae, and juveniles in a laboratory setting to provide guidance on impacts of environmental stressors such as temperature, hypoxia and acidification, inform restoration strategies, and aid commercial farms.

- Discuss roles and responsibilities to address the new demands for aquaculture permitting with NWFSC and WCRO leadership.

- Continue to build on existing programs with current funding: improve our understanding of juvenile quality and out-planting techniques as a means of recovering endangered abalone and prioritize trait selection and the role of exercise in improving grow-out for yellowtail.

- Prioritize filling a vacancy in Genetics, Physiology and Aquaculture program with a candidate with a Bioinformatics background.

- Work with the Office of Aquaculture and other Centers to establish a nationally-focused aquaculture economics research capacity.

- Discuss coordination, information sharing, collaborative research, CRADAs, and intellectual property with other Science Centers, especially the NWFSC, and begin a dialog with the WCRO. Continue collaborations with the NWFSC for growing red algae and begin collaboration to evaluate the genetic risks associated with different culture schemes and the risks of escapement. Reach out to the Southeast Center or another institution to discuss ways of incorporating Gulf of Mexico amberjack species into our genetics research.

- Integrate aquaculture into the agency's Ecosystem-Based Fisheries Management efforts on the West Coast. Complete and finalize the draft white abalone research plan and circulate to California state and academic partners and Navy collaborators.

- Develop an overall yellowtail research plan and consider which topics are best done by SWFSC and which are best done by other NOAA, academic and industry partners.

Continue to improve access and awareness of long-term ocean observing programs such as CalCOFI and their importance to site selection and environmental monitoring.

## Alaska Fisheries Science Center (AFSC)

The AFSC is involved with research on king crab and salmon stock enhancement research. Since the science review, the AFSC has begun work on macroalgae culture at the Kodiak Lab.

### *Recommendations from the Panel:*

The narrow focus on king crab and salmon research was surprising considering the potential of expanding shellfish and seaweed aquaculture in Alaska. The Panel suggests the AFSC prioritize research towards aquaculture of commercially important shellfish species, such as oysters and geoduck; increase funding for shellfish species with potential for industry development, sea cucumbers, and macro-algae; determine if king crab stock enhancement is cost-effective; and continue research supporting salmon enhancement aquaculture.

The long-term viability of the king crab stock-enhancement work is questionable. In terms of king crab, research should continue to gain quantitative information. Questions need to be answered on the habitat and reasons for reduced king crab populations. The low survival rate of released king crab also needs to be investigated further, for example, by focusing on determining optimal habitat for release sites.

To enhance resources, development of CRADAs with private companies should be a priority.

### *Response from the Alaska Fisheries Science Center:*

The general response from Reviewers was that AFSC should continue to support existing research and has substantial potential to develop additional mariculture[11] research. The AFSC is supportive of expanding its research efforts related to mariculture, and we agree that we are currently only partially fulfilling mandates and addressing partner and industry needs. Since the review, progress has been made at implementing some recommendations, and a strategic plan has been drafted that highlights funding and staffing prioritization nationally and within the AFSC. At this point, the AFSC is considering reprogramming funding for fish stock assessment surveys to provide support to expand an aquaculture program (e.g., $200K). Such a move would require support from the Alaska Regional Office. To properly implement an enhanced aquaculture program in Alaska, the AFSC plans to hire a senior scientist to serve as a point of contact for the AFSC and responsible for coordinating all aquaculture research at the AFSC. The AFSC intends to seek matching funding from the NMFS Aquaculture Program Office.

[11] The term "mariculture" has a unique meaning in Alaska. It refers to shellfish and seaweed marine aquaculture but excludes finfish net-pen aquaculture.

We appreciate the recommendations to continue the salmon enhancement research at AFSC, including the long-term data sets and Chinook salmon research projects, recent research into alternative protein sources, and stock assessments. However, staffing and funding reductions at the AFSC will negatively affect the future of the salmon program without a concerted effort at the national level to consider funding basic program sustainability. We also agree that the king crab research has potential – and should be continued to address out-stocking efficiencies and habitat requirements.

Reviewers commented that the potential for expanding shellfish mariculture research (e.g., oysters, geoducks, sea cucumbers, mussels, clams, rock scallops, and pinto abalone) in Alaska is not being met. There were some calls for macroalgae research and development; those efforts are underway at a minimal level to assist an increasing demand from coastal communities to develop capacity. Lastly, it was recommended that the AFSC consider research in disease assessment, environmental monitoring, climate change, and ocean acidification research. The AFSC is involved with such research to support stock assessments and can adapt these data collection programs as needed to support mariculture.

In terms of financial concerns, we agree with the Reviewers that the AFSC is lacking in base funding and staffing associated with mariculture research. Facility infrastructure exists to support additional research. CRADAs are a good tool for identifying industry goals and co-funding research priorities. The AFSC currently has one CRADA to develop commercial seaweed mariculture in Alaska. Future efforts in Alaska will require support to facilitate communication (e.g., workshops) between NOAA research scientists and industry leaders to determine appropriate research directions. We acknowledge that we should reach out to Sea Grant to accomplish some of this outreach. As noted above, the AFSC intends to propose reprogramming fish stock assessment resources, pending Alaska Regional Office support, to support a base funded aquaculture research program in Alaska and to seek matching funding from the NMFS Aquaculture Program Office.

Finally, we agree with the general recommendation that representatives from each region should meet regularly to “interact and exchange ideas and information”. This would be invaluable for putting different programs in perspective, considering collaborations, and assessing national priorities for funding. We would recommend that a representative be identified within each region that can adequately represent the priorities for the entire region.

***Action Items:***

- Continue salmon stock enhancement and king crab research to address out-stocking efficiencies and habitat requirements as funding allows.

- Pursue development of shellfish and macro-algae research projects by reprograming fish stock assessment funding, hiring a senior scientist to direct the program, and seeking matching funding from the NMFS Aquaculture Program Office.

## Pacific Islands Fisheries Science Center (PIFSC)

The PIFSC is not involved with aquaculture research at this time. The presentation provided to the Review Panel indicated that they have unused aquaculture facilities to devote to research, if the NOAA Aquaculture Program was able to fund them.

### *Recommendations by the Panel:*

The Review Panel recommends that an aquaculture research program should be considered for this facility, since it already possesses most of the system infrastructure. The PIFSC should focus on developing programs for potential species for the industry and communicating the availability of unused facilities. The general consensus was that funding this Center should not decrease funding of other NOAA Fisheries Science Center aquaculture programs. Otherwise, the Marine Mapper tool seems to be an excellent resource for stakeholders and regulatory agencies, and researchers should complete technical improvements to the Marine Mapper tool. The PIFSC should also seek to collaborate with NCCOS and other entities with expertise in modelling and mapping for cage culture.

### *Response from the Pacific Islands Fisheries Science Center:*

The Pacific Islands Fisheries Science Center has not received specific funding for aquaculture science and hence, have not developed a science and research aquaculture program *per se.* PIFSC staff that work on aquaculture take it on as a collateral duty. So, PIFSC's absence of a formal program is directly a reflection of directed funding; little else. The seawater systems were designed for live animal care and research in general for numerous taxonomic groups and may or may not be appropriate for aquaculture. Aquaculture applications were not a primary driver in the design of the facilities and may need adaptation depending on need to take on aquaculture projects. While we would welcome the opportunity to launch into aquaculture science, PIFSC's seawater systems, and laboratories were not installed with the intent to conduct aquaculture research. However, PIFSC will remain open to seeding an aquaculture component by exploring potential aquaculture partnerships, affirming active participation in national aquaculture activities, and committing PIFSC Science Council time to discuss aquaculture focus areas for FY19 and beyond.

### *Action Items:*

- Identify new or reaffirm current PIFSC Aquaculture Science Committee member and clarify PIFSC goals and membership expectations
- Add aquaculture as discussion focal area for current PIFSC 5-Year Science Plan activities
- Explore possible aquaculture partnerships with local industry and academic partners

## Southeast Fisheries Science Center (SEFSC)

The SEFSC is not involved with aquaculture research at this time.

### *Recommendations by the Panel:*

The Review Panel felt that there was a lack of interest in aquaculture at the SEFSC. Aquaculture could become a higher priority for this SEFSC. A lead 'coordinator' for marine aquaculture within the SEFSC's organizational structure could help make it an important contributor to NOAA Aquaculture by working with the numerous non-NOAA aquaculture labs in the region. A NOAA coordinated aquaculture program for the Gulf of Mexico and southern Atlantic States could begin to develop academic and industry collaborations. Nevertheless, funding the SEFSC – or establishment of a cooperative NOAA/non-NOAA Center closer to its stakeholders in the Gulf of Mexico and the southeast Atlantic states – could play a significant role in future marine aquaculture research and development. Furthermore, the general consensus was that funding the SEFSC, or establishment of a Cooperative Institute at an academic institution closer to its southeast stakeholders, should not decrease funding of aquaculture programs in other NOAA Fisheries Science Centers.

***Response from the Southeast Fisheries Science Center:***

As the SEFSC considers our science priorities for the future, we welcome exploring aquaculture research opportunities. In the southeast region, we have the first comprehensive regulatory program for aquaculture in federal waters. This program creates a coordinated permitting system for the Gulf of Mexico, opening the door for the region to expand seafood production and create new jobs in an environmentally sustainable manner. As this program develops, there may be increased needs and opportunities for aquaculture science in coordination with managers and the aquaculture community.

***Action Items:***

- SEFSC and Southeast Regional Office leadership to discuss future aquaculture science needs and priorities in the region.

Table 1. Summary of action items arising from the review.

| Program Review Action Item | Response Actions | Timeline |
|---|---|---|
| Strategic Planning Issues | • Develop a one NOAA Strategic Aquaculture Science Plan to include Centers, Grant programs and Extension<br>• Set up mechanism to collect stakeholder input on a regular basis<br>• Establish internal Aquaculture Steering Committee to meet regularly | • FY19 1st draft for review<br>• FY20 Publish final plan<br>• FY19<br>• FY19 |
| Resource Issues | • Review assumed flat budgets so we will explore enhanced leveraging options such as CRADAs, and other Public-Private partnerships<br>• Explore working with grants programs (SK, Sea Grant and SBIR) to leverage work at Centers on key topic areas.<br>• Explore international science agreements to leverage work at Centers on key topic areas<br>• Explore leveraging work with other agencies and organizations | • FY18 and a part of the SASP |
| Communications Issues | • Reestablish webinar series. Consider expanding topics<br>• Evaluate options for an | • FY18 and a part of the SASP |

| | | |
|---|---|---|
| | annual NOAA Aquaculture Science meeting<br>• Expand visibility of story map and maintain ICAF process<br>• Explore using ICAF to fund cross center projects | • FY19<br>• FY19<br>• FY19 |
| Topical/Species Coverage Issues | • Explore adding research initiatives on 1) Aquatic organism health and 2) Social and Economic dimensions<br>• Survey Regional Coordinators and MAFAC for additional priority topics<br>• Prioritize species development<br>• Encourage topical and species experts to work across regions | • Begin in FY18, fully develop a plan as a part of the SASP<br>• FY18 and 19<br>• FY19<br>• FY18 |
| Geographic Coverage Issues | • Explore adding an aquaculture scientist to coordinate regional research at the SEFSC, PIFSC and AKFSC<br>• Encourage scientists to work nationally<br>• Explore partnership opportunities with other labs in regions without specific aquaculture expertise | • FY18 and 19, fully develop a plan as a part of the SASP<br>• FY18 - continuing<br>• FY18 - continuing |
| Infrastructure | • Evaluate current and needed infrastructure as a part of the SASP<br>• Provide for equipment grants as a part of ICAF | • FY19, fully develop a plan as a part of the SASP<br>• FY18 continuing |

## APPENDIX I: Membership of the Aquaculture Science Committee

| Name | Role | Organization |
|---|---|---|
| **Mark Rath** | Review Coordinator | Office of Aquaculture |
| **Michael Rust** | Representative | Office of Aquaculture |
| **Gary Wikfors** | Representative | Northeast Fisheries Science Center |
| **James Morris** | Representative | National Oceans Service |
| **Michael Parke** | Representative | Pacific Islands Fisheries Science Center |
| **Refik Orhun (replaced Tom Jamir)** | Representative | Southeast Fisheries Science Center |
| **Robert Foy** | Representative | Alaska Fisheries Science Center |
| **Russ Vetter** | Representative | Southwest Fisheries Science Center |
| **Stephen Brown** | Representative | Office of Science and Technology |
| **Walt Dickhoff** | Representative | Northwest Fisheries Science Center |

## APPENDIX II: Terms of Reference

TOR hyperlink

## APPENDIX III: Full East and West Coast Reviewers Reports

Review hyperlink

## APPENDIX IV: Full Science Center Responses

Center Responses hyperlink