NOAA Science Advisory Board Report

A Review of NOAA's Aquaculture Science Portfolio

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The NOAA Science Advisory Board (SAB) was asked to review the Draft Strategic Aquaculture Science Plan (SASP) and the research priorities identified by the NOAA Marine Fisheries Advisory Committee (MAFAC) so that the SAB could propose tactics to optimize return on investment by ensuring the science is done with the appropriate tools. The SAB was directed to provide guidance on allocating the resources of NOAA's aquaculture research enterprise between the NOAA labs (Fishery Science Centers and National Centers for Coastal Ocean Science), competitive grant programs (e.g. Sea Grant's National Aquaculture Initiative, the Saltonstall-Kennedy program and the Small Business Innovative Research Program) and various public-private partnerships.

Aquaculture science is supported by both NOAA and U.S. Department of Agriculture (USDA) funding. While there is some overlap between these programs, marine aquaculture research is mostly supported by NOAA while freshwater aquaculture research is mostly funded by the USDA. There are certainly exceptions, such as genetics work on marine species being supported by USDA's Agricultural Research Service, and freshwater fish culture work in the Great Lakes being supported by Sea Grant. There are also areas of overlap, for instance land-based culture of marine species as well as work on marine and freshwater fish diets that has been supported by both agencies.

While aquaculture (like terrestrial agriculture) has been practiced for millennia, intensive aquaculture was not really possible until the techniques for hatcheries were developed in the 1940s and 1950s. Given the relatively young nature of aquaculture, there is a great need for basic research into the dietary and physiological requirements of many species. It also means that the development of culture techniques and the tools that make this work possible is evolving at a rapid pace. The relatively recent development of genomics tools, advanced computational power and other exciting scientific developments will surely accelerate production gains.

The NOAA marine aquaculture science portfolio is diverse and operates on many different scales reflecting the broad diversity of the industry. Marine aquaculture in the U.S. encompasses dozens of species of shellfish, finfish and macrophytes. While the SASP report primarily focuses on marine aquaculture (mariculture) it is acknowledged that much of the scientific understanding and technologies can be applied to both land-based and marine-based systems.

There is a cultural imperative to produce more sustainable seafood to feed the next two billion mouths that are anticipated to join the global population in a few decades. This will require NOAA to foster both basic science and science that will speed the development of production by developing new tools and solutions for the myriad of challenges that still exist. This mandate is even more critical as climate change is negatively impacting many marine ecosystems and wild fisheries.

Secretary of Commerce Wilbur Ross has acknowledged that "Growth in the domestic aquaculture industry holds great promise to create jobs and reduce our dependence on seafood imports" (10/27/18). Expanding aquaculture production has been recognized as a top priority of NOAA's Blue Economy strategy.

Virtually every review of America's science portfolio has recognized the need for a balanced investment in both basic and applied science (NRC 2014). Efforts to evaluate the payoff for investments in these two types of science are confounded by the uncertainty of how and when discoveries produced by investments in basic science produce information or approaches that lead to future improvements in yield or survival.

From a fundamental standpoint, it is clear that when one examines the various approaches to science (federal labs, competitive grants, public- private partnerships, and prizes) each approach offers advantages and disadvantages. For example, genetics research is typically based on long-term, multi-generational efforts to improve cultured stock through years of selective breeding. Recent advances in genomics promise to accelerate these advances by allowing scientists to develop marker-assisted selection, but successful breeding programs are not achieved on a 2-5 year timeline typical of a competitive grant.

Conversely, research that is geared towards solving specific challenges may best be addressed through an external grants program or a public-private partnership, research that is focused on bringing an idea to commercial implementation may be best funded through technology transfer (or R2X) programs such as Small Business Innovative Research Programs.

Rather than move all of our scientific investments from one approach to another, it would be prudent to maintain a balanced portfolio of resources and approaches and seek to improve the effectiveness of all modes of science support mechanisms by identifying the strengths and addressing the weaknesses inherent in each.

We would also be remiss if we did not identify the hazards of underfunding research in general and aquaculture, in particular. For example, over the past decade, NOAA has reduced the number of federal aquaculture scientists at the Northeast Fisheries Science Center (NEFSC) by almost half. Retirements and reassignments have stripped the lab of capacity to study fundamental issues while cuts to operating budgets have left the lab unable to buy basic supplies and repair critical equipment. Underfunding of the research enterprise is one way to ensure failure.

NOAA continues to state that aquaculture is a priority for development of its Blue Economy, but the dollar value of the investment in aquaculture research pales in comparison to the funds allocated to managing groundfish stocks or protected resources. In the U.S., 90% of the seafood we consume is imported, and half of that is farmed overseas, contributing some $15B to the trade deficit. If we want to decrease our reliance on imports and improve domestic seafood production, we must increase our investments in research and development.

Increases in aquaculture production are often constrained less by scientific innovation than by societal perceptions. We know how to grow many species sustainably; however, firms often are unable to obtain permits to do so because of competing uses and other constraints, including sociological constraints. The absence of a federal agency with authority to grant leases for aquaculture in the EEZ is another significant constraint.

NOAA should invest in projects that address the other constraints that prevent expansion of aquaculture in state waters.

Proposed aquaculture projects are also constrained by concerns about protected resources and potential conflicts with commercial fishing. The precautionary principle has made it nearly impossible to obtain permits for certain types of new projects. These issues can often be addressed by a proper risk analysis. The requirement that aquaculture have zero impacts is inconsistent with other uses of the marine environment. The fact that NOAA is tasked with both increasing seafood production and protecting natural resources often puts various divisions of NOAA at odds with each other.

Findings

The SASP is clearly a work in progress and will benefit from extensive editing. The SAB review team provided extensive comments on the SASP document; however, the team decided that the Google form provided to make suggested recommendations was not the best vehicle to provide substantive comments. Instead, we developed a Strengths / Weaknesses analysis to provide recommendations on tactics. What follows is an analysis of each of the elements of NOAA's aquaculture research portfolio with recommendations on how each might be improved.

Strengths and weaknesses of each sector of the NOAA science portfolio

NOAA Labs

Specific NOAA facilities engaged in aquaculture research include the Northeast and Northwest Fishery Science Centers and the National Centers for Coastal Ocean Science (NCCOS).

Strengths

Federal labs have the benefit of a steady investment in the infrastructure (both the intellectual talent and the analytical equipment) to allow them to both quickly evaluate emerging technologies and to work on long term projects that may take decades to resolve. For example, the NCCOS Lab in Beaufort has done great work on developing siting tools that identify existing uses and ecological features of prospective sites and literature reviews on key topics that help regulators understand thorny issues such as interactions with protected resources.

Perhaps the best role for the Federal labs lies in analyzing the output of basic scientific discovery and looking for ways to bring those advances into practical application by working with industry partners to bring develop new approaches to the many production challenges that aquaculture is facing. National and international collaborations can increase the opportunities for discovery and development of new products and technologies.

If properly funded and resourced, federal labs have the potential to respond rapidly to industry emergencies without the 6 to 12 month delay (and the inherent uncertainties) involved in the competitive grant process.

Weaknesses

Federal labs are usually led by scientists who have had an excellent science career and have often led research programs. While it is important for a lab director to have an understanding of scientific research, it is also critical that the individual has demonstrated exceptional management abilities including: superior communication skills, the ability to develop focused strategic plans and the organization skills to ensure the successful implementation of those plans.

Because investments in NOAA's aquaculture research labs have been sharply cut, it is often difficult for federal researchers to attend conferences to learn about emerging technologies and seek collaborations with outside scientists and industry partners. Such interaction is critical to take full advantage of the infrastructure and equipment investments in these labs and to capitalize on advances from the broader science community. The reluctance of funding agencies to support international travel further hampers the sharing of information and slows the pace of innovation. Federal researchers should be encouraged and funded to participate in conferences and engage in partnerships with scientists from the university and private sectors in order to find synergies for tackling major research questions and solicit collaborative projects.

Federal labs compete for top tier talent with the university and private sectors both domestically and internationally. To ensure our federal labs continue to attract the best and brightest researchers it is critical that the labs have adequate resources for equipment and staff.

Competitive Research Awards

Sea Grant manages a variety of marine aquaculture research initiatives and collaborative grant opportunities. The Saltonstall-Kennedy grant program funds innovations in fisheries and aquaculture. NOAA's Small Business Innovative Research Program (SBIR) funds innovative projects that are near commercialization. An additional mechanism that is used throughout NOAA is the Cooperative Institute (CI) Model which is a partnership between NOAA and a research institution or consortium of member institutions. These generally are 5 year commitments with the potential for a renewal period of up to five additional years.

Strengths

NOAA has a variety of research opportunities that support externally competitive research awards utilizing creative partnerships with academic institutions, local communities, NOAA research laboratories, and the private sector. Awards typically span a year or two, but some longer-term agreements last up to five years and are renewable. Academic institutions can take advantage of competitive grants and cooperative agreements and nimbly focus on emerging research priorities. These awards can range from fundamental research to transitioning research results into applications, operations, and commercialization.

The organizational structure of these awards allows NOAA projects to leverage inexpensive, talented pools of graduate student labor to perform experiments and conduct research.

Many academic institutions have developed world-class programs and procured advanced instrumentation in areas of specific focus. Their reputation and the concentration of expertise tend to attract talented students and researchers with an interest in that field, further cementing their pre-eminence in the field.

Many academic institutions and Sea Grant Programs have the ability to attract talented researchers with a broad array of skill sets and interests, fostering the ability to perform interdisciplinary research. Interdisciplinary research is the hallmark of marine and oceanographic centers in the U.S. and vital to advancing complex and diverse research topics such as aquaculture. For example, genetics research needs to go hand in hand with physiology research and predicting the impacts of climate change demands a sophisticated understanding of the physiology of the organisms as well as the physical and chemical processes of the ocean.

Cooperative Institutes are excellent for longer-term and medium term projects that benefit from interdisciplinary collaboration and collaboration between academic/research institutions and NOAA. We are not currently aware of an aquaculture-focused research theme in a Cooperative Institute, although some aquaculture work may occur in NOAA Cooperative Institutes, especially those CIs that have strong fisheries programs. Given the interdisciplinary needs of aquaculture research and application it might be reasonable to more thoroughly examine this potential structure as a means for accomplishing some of the science goals. In addition, cooperative institutes may also have the flexibility of embracing industry partnerships that might be helpful in transitioning research into application.

SBIR programs have a strong record of bringing new technologies to commercialization. Some of this success is driven by a rigorous selection process, demands for full business plan development and evidence of promising preliminary research.

Weaknesses

Requests for Proposals (RFPs) don’t always solicit the exact research topics that are being sought and only minimal investments are made in our grant review and selection process. Review panels are invariably staffed by volunteers and sometimes there is adequate expertise on the panel to make appropriate recommendations on improving proposals or deciding who gets funded. It is particularly difficult to get industry participants on panels given their need to focus on business. Even a token stipend for review panel members could help ensure these panels are able to put more time into this work.

The competitive nature of grants sometimes has the unfortunate reputation of requiring major work to be completed before a successful proposal is granted. Hence, researchers often solicit funds for work that has already been completed. The grant review process exacerbates this problem by favoring projects with strong evidence of preliminary studies.

Public-Private Partnerships

Cooperative Research and Development Agreements (CRADA) are arrangements that allow NOAA to work with the private sector for development or transition of technologies in an arrangement where intellectual property needs to be protected. Various types of consortia have been successful in bringing industry and researchers together to solve vexing problems. Private venture capital is another avenue to provide funds to support research efforts to develop promising technologies though partnerships with federal or university labs.

Strengths

Private investors may be in a position to make substantial investments in research. The financial strength of the private partner confers a significant advantage on a project and can decrease the time required to move a project from planning to implementation. Further, private groups can have influence in the regulatory realm. Private commercial enterprises rarely have the facilities, equipment or expertise to perform and execute scientific experiments to test new ideas or evaluate promising technologies. Partnering with federal labs or universities can ensure that ideas are properly evaluated with rigorous scientific approaches, also ensuring that the results of much of this work is broadly shared in published literature.

CRADAs provide a way for private industry to utilize federal infrastructure assets (including both laboratory and human assets) to develop technologies and preserve intellectual property rights. NOAA has had several success stories using this mechanism.

Weaknesses

Unfortunately, private investors are typically seeking investments that guarantee a substantial, short-term return on investment. Indeed, rarely do private investors, investment firms and banks even consider supporting aquaculture because the ROI is uncertain and regulatory hurdles may delay project implementation for years.

Some of these projects may insist on retaining intellectual property rights for discoveries or inventions made with public investments, which limits the benefits of public investments to the broader community.

X-Prize competitions

The X-prize has awarded millions in prizes to scientific and technical teams that have made significant scientific advances (i.e. in situ pH sensor, high resolution mapping of the ocean bottom, etc.).

Strengths

The X-prize can attract many entrepreneurs to develop numerous approaches to vexing challenges for a relatively modest investment.

X-prize competitions are perhaps best suited for the development of new tools or devices that allow significant leaps forward instrumentation or technology that could otherwise take years to develop using more conventional approaches.

Weaknesses

While the Xprize offers substantial rewards for teams that win they do not provide any support for teams to acquire/assemble critical components, test prototypes or travel to/from the competition.

Fostering Innovation in Aquaculture Research

There are ample opportunities to develop novel approaches and equipment for aquaculture because the industry is relatively young, and because aquaculture is developing during a period of rapid scientific advancement in fields such as materials science, engineering and genomics. NOAA should consider employing proven approaches to foster innovation such as:

- Encouraging multi-disciplinary participation in projects
- Encouraging racial and gender diversity in projects
- Sponsoring maker-spaces, business accelerators or pre-permitted aquaculture development zones
- Providing small grants to companies to allow them to try new approaches.
- Encouraging researchers with no prior experience to collaborate on aquaculture projects

Missing elements in the Draft Strategic Aquaculture Science Plan (SASP)

Two elements of the research enterprise were not well developed in the SASP; test beds and demonstration projects. These are both useful both for the extension and evaluation of ideas gleaned from international information exchange and as platforms for research to refine and examine the utility of projects nearing the implementation phase. Federally funded demonstration projects can also be intensively studied and monitored on a scale that might be unaffordable for commercial projects.

Demonstration projects are particularly valuable for the examination of potential protected resources interactions, since they can be dismantled in the event of negative outcomes without destroying the investment of private capital.

General Comments on the SASP:

- The SAB Review Team felt that the organization of the SASP was inverted. Putting the tactical review (table 2) in front of the topical foci (Section 2) should be reconsidered.
- The topical foci do not necessarily align with the stated objectives in a logical way. This will probably be resolved when the topical foci geared toward “Tools for Rules” or R2A are included.
- It was not clear how NOAA would go about prioritizing the many topical foci and what sorts of decision making tools might be employed. Since the budgetary resources for aquaculture science are severely constrained, this process is foundational.
- In some respects the SASP reflects the dichotomous nature of NOAA with regard to both fisheries and aquaculture; NOAA is responsible for both advancing and promoting aquaculture as well as regulating and minimizing the negative externalities of aquaculture.
- The SAB noted that several sections of the SASP had not been written, making it difficult to assess the overall plan.

Recommendations

1. Maintain a balanced portfolio of resources and approaches to aquaculture science, and seek to improve the effectiveness of all modes of science support mechanisms by identifying the strengths and addressing the weaknesses inherent in each approach.
2. If increasing aquaculture production is a priority of the Blue Economy, it should be appropriately resourced with adequate funding. Federal labs engaged in aquaculture research need more staff and adequate funds for maintenance and the purchase of cutting edge equipment.
3. NOAA should invest in projects that address the sociological constraints that prevent expansion of aquaculture in state waters.
4. NOAA should evaluate potential interactions between aquaculture projects and protected resources using rigorous risk analysis tools and acknowledge that all activities have some impacts. Striving for zero impacts is not practical or consistent with how we manage other marine-based activities.
5. Researchers at our federal labs should be encouraged to participate in national and international collaborations and conferences to increase the opportunities for discovery and development of new products and technologies. Funds for such travel should be allocated separately so lab managers don’t have to choose between attending conferences and facilities maintenance.
6. To ensure our federal labs continue to attract the best and brightest researchers it is critical that the labs have adequate resources for equipment and staff.
7. Interdisciplinary research and extension components should be strongly encouraged in competitive grants.
8. To ensure industry participation in proposal review panels, NOAA should consider offering stipends or other incentives.
9. NOAA should consider establishing an aquaculture-focused Industry-University Cooperative Research Institute or develop an aquaculture focused research theme within an existing Cooperative institute for longer-term projects that would benefit from interdisciplinary collaboration.
10. NOAA should collaborate with USDA to examine Requests for Proposals before they are published to minimize areas of overlap.
11. RFPs should request projects using specific language to attract projects that are of high priority as opposed to broad topic areas that tend to attract proposals that may only peripherally address priority issues.
12. NOAA should consider the potential for developing demonstration projects and test-bed facilities, especially for novel projects that are challenged to get permits because regulators have questions about potential impacts or negative interactions.

National Research Council 2014. Furthering America's Research Enterprise. Washington, DC: The National Academies Press. https://doi.org/10.17226/18804.

Adams, James D & Chiang, Eric P & Starkey, Katara, 2001. " Industry-University Cooperative Research Centers," The Journal of Technology Transfer, Springer, vol. 26(1-2), pages 73-86