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PUBLIC COMMENTS WILL BE ACCEPTED THRU OCTOBER 4th, 2021.

Address all comments concerning the ***Science Plan*** to Task Force Chair Dr. Caird Rexroad, National Program Leader for Aquaculture, Agricultural Research Service, Office of National Programs, 5601 Sunnyside Avenue, Room 4-2106, Beltsville, Maryland 20705. Submit electronic comments to AquaSciencePlan@usda.gov.

Address all comments concerning the ***Regulatory Efficiency Plan*** and the National Aquaculture Development Plan to Task Force Chair Kristine Cherry, Chief, Regulatory and Policy Branch at NOAA Fisheries Office of Aquaculture, NOAA National Marine Fisheries Service, 1315 East-West Highway, Room 14461, Silver Spring, MD 20910-3282. Submit electronic comments to Aqua.RegPlan@noaa.gov.

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A National Strategic Plan for Aquaculture Research 2021–2025

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A Report by the Science Planning Task Force

SUBCOMMITTEE ON AQUACULTURE

COMMITTEE ON ENVIRONMENT

of the

NATIONAL SCIENCE & TECHNOLOGY COUNCIL

2021

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About this Document

In October 2018, the SCA established the Science Planning Task Force charged with updating the National Strategic Plan for Federal Aquaculture Research 2014–2019 to communicate Federal priorities for research, science, and technology development that will facilitate expansion of domestic aquaculture. The SCA also established a parallel Regulatory Efficiency Task Force charged with developing a new work plan for interagency coordination to improve regulatory efficiency.

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Abbreviations and Acronyms

APHIS	Animal and Plant Health Inspection Service
ARPA-E	Advanced Research Projects Agency-Energy
ARS	Agricultural Research Service
BETO	Bioenergy Technologies Office
BOEM	Bureau of Ocean Energy Management
CDC	Centers for Disease Control and Prevention
DOC	Department of Commerce
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
EERE	Office of Energy and Renewable Energy
EPA	Environmental Protection Agency
ERS	Economic Research Service
FDA	Food and Drug Administration
FSIS	Food Safety Inspection Service
FWS	Fish and Wildlife Service
HHS	United States Department of Health and Human Services
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service
NIFA	National Institute of Food and Agriculture
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NSF	National Science Foundation
NSTC	National Science and Technology Council
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
R&D	Research and Development
RMA	Risk Management Agency
SCA	Subcommittee on Aquaculture
SG	NOAA Sea Grant
U.S.	United States
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USGS	United States Geological Survey

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Executive Summary

Aquaculture offers Americans safe, affordable, and healthy food choices produced with minimal impacts on the environment. Aquaculture is the most efficient form of animal protein production in the world and currently provides more than half of the seafood consumed globally. Conservation and fisheries organizations also depend on aquaculture for producing and restoring threatened fish species and supplementing natural reproduction of wild species of commercial and recreational importance. In addition, aquaculture producers and industries that support aquaculture such as animal feeds, health management companies, and equipment manufacturers are vital contributors to rural economies.

U.S. aquaculture is regulated by a suite of environmental, human health, animal health and consumer protection laws driving producers to utilize environmentally efficient farming systems, with modest space and freshwater requirements, having low carbon footprints, and often providing restorative ecosystem services. Expanding U.S. aquaculture will diversify and complement our well-managed fisheries and terrestrial food production systems by adding an important underdeveloped sector to enhance the resiliency of the overall US food supply. Americans can help to ensure global food security for future generations, increase our capacity to mitigate the effects and impacts of climate change, and respond to the economic challenges of the Covid-19 pandemic by providing jobs in rural, urban, coastal and tribal communities. by strategic expansion of US aquaculture.

This plan serves to communicate Federal priorities for research and technology development that will facilitate responsible expansion of domestic aquaculture. This plan will be foundational for supporting a science-based industry that increases seafood availability, creates jobs, and provides economic and recreational opportunities while providing for the restoration and promotion of healthy aquatic ecosystems. Federal aquaculture research programs are for the benefit of the American people, inclusive of current and future generations. This plan identifies critical objectives for the following strategic goals that will support U.S. aquaculture development through Federal agency and interagency research, science, and technology coordination over a 5-year term.

- **Goal 1. Develop Economic Growth through Aquaculture**
  - Objective 1.1: Identify market opportunities for U.S. aquaculture products
  - Objective 1.2: Enable science-based expansion of domestic aquaculture
  - Objective 1.3: Educate and train a skilled aquaculture workforce
- **Goal 2. Improve Aquaculture Production Technologies and Inform Decision-making**
  - Objective 2.1: Provide farmers with access to improved genetics
  - Objective 2.2: Develop production technologies that minimize environmental impacts
  - Objective 2.3: Advance fish nutrition and feed production technologies
  - Objective 2.4: Improve engineering systems for aquaculture
- **Goal 3. Uphold Animal Well-Being, Product Safety, and Nutritional Value**
  - Objective 3.1: Develop strategies to protect the health and well-being of aquaculture species
  - Objective 3.2: Promote the safety and nutritional value of U.S. aquaculture products

These strategic goals will guide Federal agencies, with public and private sector partners, in building an interagency collaborative and multidisciplinary research framework to address the Nation's aquaculture priorities. Agency activities related to this plan are subject to the availability of appropriations and must be consistent with domestic and international legal obligations.

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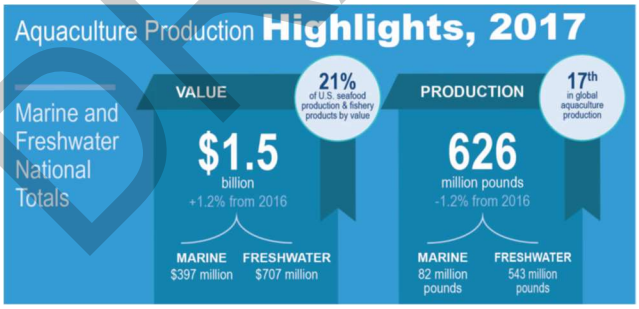
Introduction

Aquaculture industries provide jobs, revenue, and infrastructure development to coastal and inland States. Expanding domestic aquaculture by increasing scientific and technical knowledge needed for sustainable production of safe and nutritious seafood in the United States will create new jobs from coastal communities to the agricultural heartland, foster sustainable aquaculture practices, and enhance wild fisheries and habitats. In 2017, U.S. aquaculture production ranked 17th in the world and provided for human consumption, sport fish, baitfish, ornamentals, crustaceans, mollusks, algae, and other aquatic products on 2,932 farms across 48 States having combined sales of $1.5 billion (Figure 1).[1]

Done responsibly and in accordance with U.S. laws, aquaculture is good for people, good for the economy, and good for the planet. Like any human activity, seafood farming can have negative environmental and social effects. However, much has been learned during the past thirty years to farm seafood sustainably and safely within the context of science-based, informed regulatory regimes that maintain healthy oceans.[2,3,4,5,6]

Seafood, wild or farmed, is one of the best sources of nutrients essential for human health and well-being.[7] Given limits to terrestrial agriculture and commercial fishing, farming of seafood will be critical to providing protein to a growing global population.[8] Aquaculture is also one of the most environmentally efficient ways to produce food (efficient use of feed, takes up little space, low carbon footprint), [9,10] and some forms of aquaculture help to restore ecosystems. Thus, expanded use of aquaculture will be an essential element of food systems designed to reduce and mitigate the effects of climate change.[11,12] As half of the world's seafood supply, aquaculture is also an inseparable part of broader seafood policy. The market and supply chain disruptions caused by the coronavirus pandemic point to the need to expand options for local seafood supply and jobs especially in hard hit and underserved rural communities from working waterfronts to the agricultural heartland.



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[1] https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Aquaculture/index.php
[2] https://www.nature.com/articles/s43016-020-0127-5
[3] https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12351
[4] https://www.noaa.gov/stories2013/pdfs/2013_PriceandMorris_MarineCageCultureandTheEnvironment(5).pdf
[5] https://onlinelibrary.wiley.com/doi/book/10.1002/9780470960967
[6] https://www.worldfishcenter.org/content/blue-frontiers-managing-environmental-costs-aquaculture
[7] https://doi.org/10.1016/j.plefa.2019.10.002
[8] http://www.fao.org/3/ca9229en/ca9229en.pdf
[9] https://www.tandfonline.com/doi/full/10.1080/03632415.2014.966818
[10] https://www.pnas.org/content/115/20/5295
[11] www.oceanpanel.org/future-food-sea
[12] https://www.sciencedirect.com/science/article/pii/S0308597X20309751

Figure 1. 2017 U.S. aquaculture production reported in NOAA's annual Fisheries of the United States, 2018[13]

Aquaculture is recognized as one of the most efficient ways to produce protein for human consumption and is expected to contribute significantly to meeting the nutritional demands of a growing global population. Aquatic animals are highly resource-efficient, with better feed efficiency rates than terrestrial animals. Marine plants and filter feeders such as oysters require almost no freshwater and are used to improve coastal water quality while providing a high-value crop. The United States has bountiful freshwater and marine natural resources; plentiful feed grains; well-established aquaculture research infrastructures; and excellent scientists, pioneers, and entrepreneurs to drive innovation.

Broadly defined, ***aquaculture*** refers to the cultivation of any aquatic organism(s) throughout all or part of its lifecycle in marine or freshwater environments for any purpose. Examples of where aquaculture benefits the Nation include:

- Rebuilding stocks of threatened or endangered species;
- Serving as a sustainable source of food production of fish, shellfish, and seaweeds;
- Providing ecosystem services that enhance healthier habitats such as restoration of oyster reefs and kelp beds;
- Providing healthy sources of protein for the human diet;
- Enhancing recreational and commercial fisheries;
- Providing live organisms for aquaria enthusiasts; and
- Being a potential new source of biofuels.

Aquaculture science is a multidimensional field consisting of a combination of agriculture and aquatic ecosystem disciplines. Multidisciplinary expertise and approaches are necessary for identifying long-term solutions to aquaculture challenges. Methods for cultivating aquatic organisms are diverse and complex, often requiring species-specific protocols for breeding, rearing, and harvesting in various environments including ponds, rivers, lakes, and marine or land-based closed-containment systems that utilize tanks or raceways. Worldwide aquaculture includes more than 600 species[14] including at least 46 that are produced domestically[15]; for many there is a need to optimize culture methods to improve production efficiency, product quality, sustainability, animal well-being, and maximize nutrition for human consumption.

The seafood supply chain ranges from aquatic farmers and commercial fishing to industries such as feed and equipment manufacturing, fish health companies, harvesting, processing, distribution, and retail outlets. Although Americans consume a great deal of imported aquaculture products, domestic seafood is disproportionately sourced from fisheries (Figures 2 and 3).

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[13] https://www.fisheries.noaa.gov/feature-story/fisheries-united-states-2018

[14] The State of the World's Aquatic Genetic Resources for Food and Agriculture 2019

[15] The U.S. Country Report of the First State of the World's Aquatic Genetic Resources for Food and Agriculture 2017

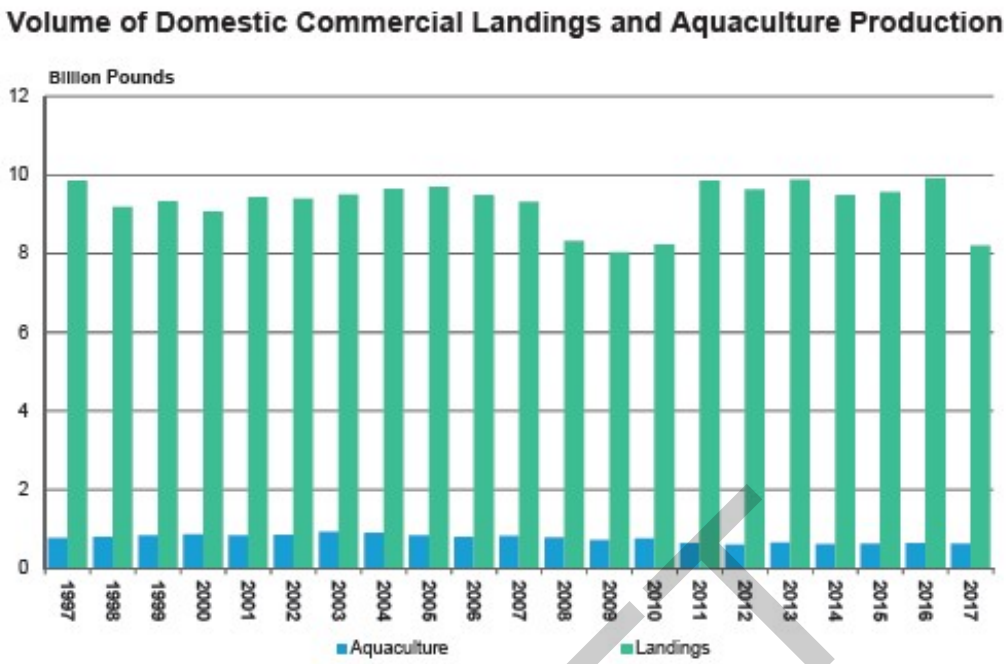

Figure 2. Volume of domestic commercial landings and aquaculture production in billion pounds reported in NOAA's annual Fisheries of the United States, 2018.[16]

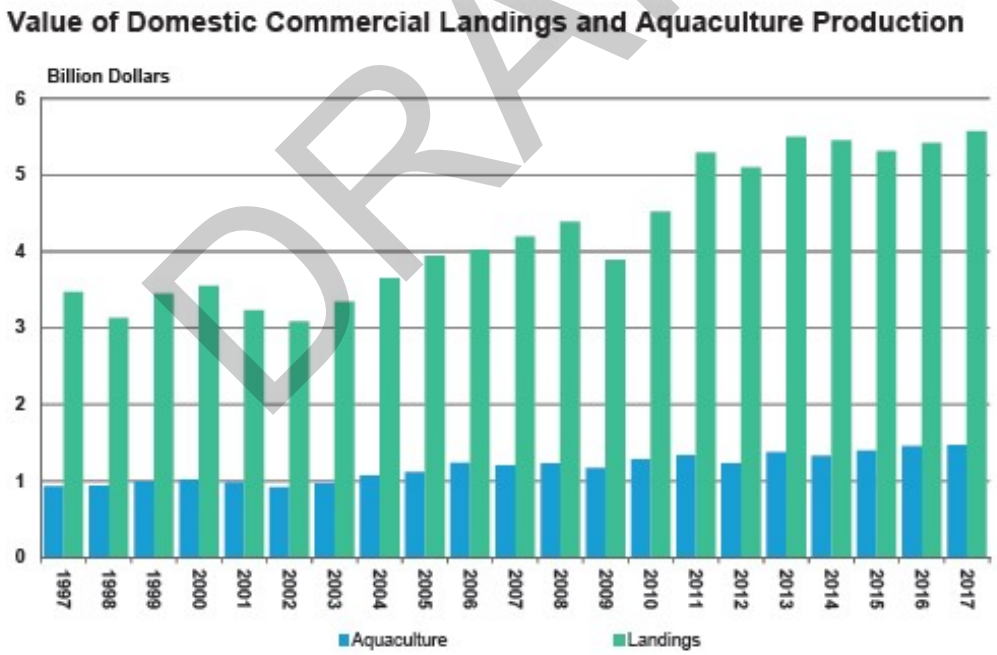

Figure 3. Value of domestic commercial landings and aquaculture production in billion dollars reported in NOAA's annual Fisheries of the United States, 2018.[17]

[16] https://www.fisheries.noaa.gov/feature-story/fisheries-united-states-2018

[17] https://www.fisheries.noaa.gov/feature-story/fisheries-united-states-2018

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By value, nearly 90 percent of the seafood we eat comes from abroad, more than half of it from aquaculture[18] (Figure 4). The 90 percent figure includes seafood caught in the United States, processed abroad, and imported in the processed form back into the United States.

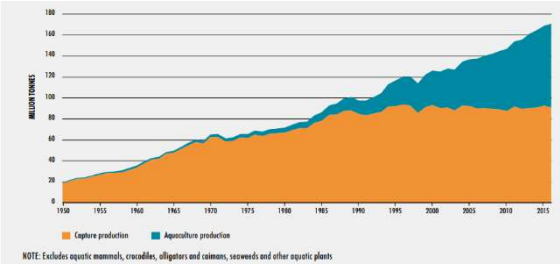

Figure 4. Increasing volume of seafood production from aquaculture compared with fisheries from the State of the World Fisheries and Aquaculture 2018. [19]

Driven by imports, the U.S. seafood trade deficit had grown to $14 billion in 2016.[20] A dramatic increase in domestic aquaculture is needed to complement well-managed wild-harvest fisheries, drive down the trade deficit in seafood, and meet the growing demand for seafood, which is high in healthy protein and omega-3 fatty acids with many essential vitamins and minerals.

Aquaculture provides new ways to generate prosperity while conserving and enhancing the Nation's natural resources. This plan proposes the following vision for U.S. aquaculture:

A globally competitive, science- and technology-driven sector that meets increasing demands for aquatic products that are affordable and meet high standards for safety, quality, nutrition, and environmental stewardship while providing new opportunities for profitability and economic growth.

Although excellent research and technological advances in support of domestic aquaculture development are under way, they are currently limited. This plan addresses the critical need to ensure the continued effectiveness of Federal aquaculture research and technology transfer programs. Coordination of multidisciplinary Federal research programs is needed to maximize the return on Federal investment to improve competitiveness, production efficiency, economic viability, and long-term environmental sustainability through advances in ecosystem management, genetics, nutrition, health, and technology. The plan also urges more public-private-nongovernmental organization sector collaborations and cooperation throughout the supply chain, from aquaculture service industries to farms to markets that stimulate innovation and entrepreneurism, thereby increasing market opportunities for U.S. products. The primary goals of this plan are as follows:

- **Goal 1. Develop Economic Growth through Aquaculture;**
- **Goal 2. Improve Aquaculture Production Technologies and Inform Decision-making; and**
- **Goal 3. Uphold Animal Well-Being, Product Safety, and Nutritional Value.**

Each goal has strategic objectives that outline how Federal agencies, with public and private sector partners, can build an interagency collaborative and multidisciplinary research framework to meet the Nation's aquaculture priorities. Concurrent with establishing a Science Planning Task Force, the SCA also established a Regulatory Efficiency Task Force charged with developing a new work plan for interagency coordination to improve regulatory efficiency. These two plans are companion documents.

[18] The State of World Fisheries and Aquaculture 2018 http://www.fao.org/3/I9540EN/i9540en.pdf

[19] https://sustainablefisheries-uw.org/state-of-world-fisheries-and-aquaculture-2018/

[20] Fisheries of the United States 2017 https://www.fisheries.noaa.gov/resource/document/fisheries-united-states-2017-report

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Status of Aquaculture in the United States

Despite having well-managed domestic wild fisheries, the United States imports most of the seafood Americans consume at a cost of $20 billion.[21] Over half of these imports come from foreign aquaculture production. In comparison, the United States currently ranks 17th in aquaculture production, producing just 444,369 (0.56 percent) of the world's 80,030,862 metric tons of animal-based seafood.[22] Given that a large portion (~50 percent) of domestic consumer demand for seafood is met through aquaculture, there is an undeniable opportunity for U.S. farmed seafood.

While the value of U.S. aquaculture is reported around $1.5 billion (Figure 5), the U.S. aquaculture industry's value is much larger when accounting for U.S-produced feed and feed ingredients, equipment, genetics, disease treatments, and other inputs used by foreign and domestic producers. Therefore, economic impacts from aquaculture benefit all states, not only those having significant farm production. For example, the U.S. Soy Exporting Council estimated that China alone used more than 7.5 million metric tons of soy for aquaculture feeds in 2010 produced in states not having fish or shellfish production.[23] Therefore, expanding aquaculture has the potential to provide new economic opportunities for every state, not just those with access to large bodies of water.

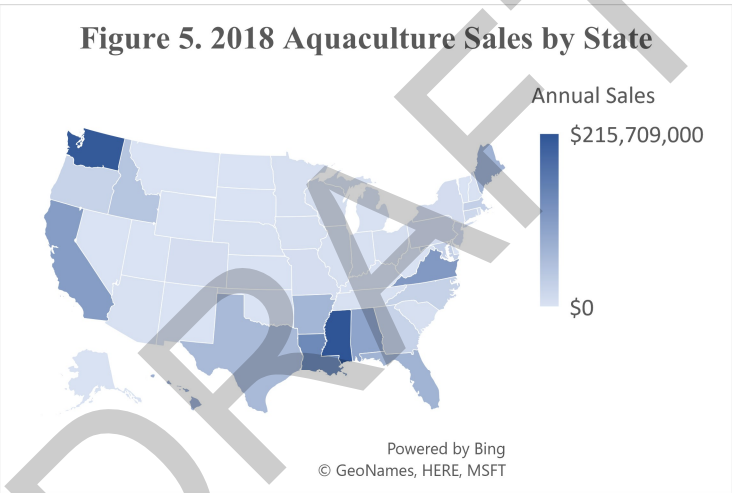

Figure 5. 2018 direct aquaculture sales by state in U.S. dollars.[24]

Aquaculture offers the United States a tremendous opportunity for economic growth through expansion into aquatic resources not currently used to farm fish, including the Great Lakes or offshore in the Gulf of Mexico or Exclusive Economic Zone. In particular, technological advances are allowing seafood to be produced farther from shore and on land in tanks using recirculating systems.

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[21] FAO, GLOBEFISH - Information and Analysis on World Fish Trade

[22] https://www.fisheries.noaa.gov/national/sustainable-fisheries/fisheries-united-states

[23] https://www.unitedsoybean.org/article/aquaculture-around-the-globe

[24] https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Aquaculture/index.php

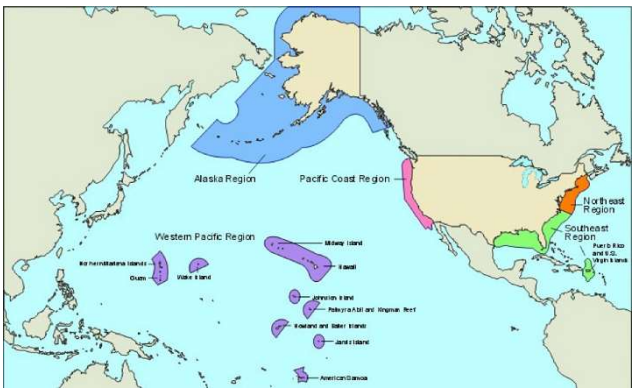

Figure 6. The Exclusive Economic Zone in the United States is the largest of any nation.[25] In this figure different colors are used to identify the five major regions (Alaska, Western Pacific, Pacific Coast, Northeast, and Southeast).

Existing technologies are adequate for demonstrating offshore aquaculture's technical feasibility; however, research is needed to refine production methods and ensure financial sustainability of this emerging aquaculture sector so that investors have a high likelihood of profitability. Similarly, land-based recirculating aquaculture systems offer the capacity to produce freshwater or marine species in containment and far from their native habitats. These relatively new approaches to raising fish are still a frontier in agriculture, remaining largely untested at commercial scale and requiring significant advancements in technological, biological, and economic methods and strategies. Finally, aquaponic and multitrophic aquaculture systems that seek to demonstrate the benefits of integrating production of multiple species, such as hydroponic plants and fish,[26] require research that enables large-scale production of both fish and vegetables in one sustainable and efficient system.

A second opportunity for economic growth stems from new culture methods for species that previously have not been domesticated but are sourced from wild harvests. This includes species valued for human consumption, that contribute ecosystem services or provide recreational activities, or have been identified as a priority for conservation efforts. One example is the culture of algae that are high in protein and long-chain omega-3 fatty acids. Algae can be produced directly for human consumption or incorporated into fish and other animal feeds as a complement to wild-caught forage fish. Worldwide macroalgae production has been growing at 8 percent a year for the last decade and is currently at 28.5 million wet tons per year.[27] The United States alone has the potential to cultivate more than 100 million metric tons of microalgae per year.[28] Algae production can leverage resources that do not compete with agricultural uses, such as brackish water in the Southwest and offshore along our expansive coastline.[29] Portions of algal biomass not used for food or feed purposes can be converted into renewable fuels and products.

Expanding aquaculture production and the availability of healthy seafood products will have positive health implications for the growing global population. Seafood is considered part of a healthy eating

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[25] https://oceanservice.noaa.gov/facts/eez.html

[26] U.S. Department of Commerce, "Fisheries of the United States, 2017"

[27] Food and Agriculture Organization of the United Nations, "The State of the World Fisheries and Aquaculture," http://www.fao.org/3/a-i5555e.pdf, 2016.

[28] Argonne National Laboratory, National Renewable Energy Laboratory, and Pacific Northwest National Laboratory. "2017 Algae Harmonization Study: Evaluating the Potential for Future Algal Biofuel Costs, Sustainability, and Resource Assessment from Harmonized Modeling"

[29] Ibid.

pattern, containing a wide variety of vitamins, minerals, and healthy fatty acids. Of the Protein Foods subgroups (i.e., meat, poultry, and eggs; seafood; and nuts and seeds) listed in the 2015–2020 Dietary Guidelines for Americans,[30] seafood was the only subgroup being under-consumed by all age groups and both sexes. On average, U.S. consumers 2 years and older eat less than half of what is recommended in the Dietary Guidelines.

Expansion of U.S. aquaculture through increased use of our aquatic resources must be accomplished through strategies that minimize environmental impacts. Additionally, recognizing the interconnectedness of human, animal, and plant health mediated in part through waterways and use of water recourses, aquaculture practices—and the science underpinning them—should take into consideration, where appropriate, opportunities to minimize secondary impacts. An expanded aquaculture industry must integrate with current and future uses of land, water, and other resources that are increasingly constrained, and in some instances, degraded. Efforts to integrate the aquaculture industry in this landscape should be directed toward the integration of farming systems with monitoring technology and computational modeling to site farms appropriately and ensure their environmentally sound operation and management. Scientifically informed management is especially important for mitigating existing environmental challenges such as eutrophication and climate change, multiple overlapping use conflicts, and emerging challenges such as microplastics that contaminate the environment and may transmit up the food chain.[31]

It is imperative that the United States takes advantage of this opportunity to enjoy the improved environmental quality and resiliency that domestic aquaculture, guided by strong science, can provide. Given its abundant natural resources, global leadership in science and technology, and heritage as an agricultural nation, the United States is positioned to continue to grow aquaculture through science-based expansion strategies that simultaneously address the economic, societal, and environmental challenges facing our country. This plan identifies goals that will support economic growth, increase our collective knowledge of aquaculture, and develop responsible production technologies that can be sustained through future generations. Agency activities related to this plan are subject to the availability of appropriations and must be consistent with domestic and international legal obligations.

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[30] https://health.gov/dietaryguidelines/

[31] Auta HS, Emenike CU, Fauziah SH. "Distribution and importance of microplastics in the marine environment: A review of the sources, fate, effects, and potential solutions." Environ Int. 2017;102:165–176.

Goal 1. Develop Economic Growth through Aquaculture

Aquaculture provides opportunities to harness technological innovation that will increase agricultural outputs needed to provide future generations of Americans with nutritional security. This will require a skilled workforce across the Nation, including rural[32] and coastal communities. The range of economic conditions in rural and coastal communities covers the spectrum from areas that are growing and economically vibrant to areas that are economically distressed and underutilized. The economies of many rural and coastal communities are founded on the availability of abundant natural resources, and are supported by traditional sectors such as agriculture, manufacturing, mining, fisheries, and forestry. While aquaculture provides economic opportunity in many different places, rural and coastal communities have unique potential to benefit from the expansion of aquaculture.

This goal focuses on delivery of tools that address societal understanding of aquaculture, provide science-based information for regulatory decision-making, improve understanding of the economic aspects of aquaculture businesses, create the specialized workforce needed to develop a robust aquaculture industry, and ensure that the growth of the aquaculture industry is consistent with social values and environmental law. Additionally, new tools are needed to assist with the quantification and valuation of the benefits to the environment that can be attributed to aquaculture. For example, algae and shellfish can mitigate local ecological damage associated with high anthropogenic nutrient loading and acidification of freshwater and near-shore marine systems. Using strong science-based tools and balanced approaches to develop aquaculture will lead to new economic opportunities for Americans across the Nation.

Objective 1.1: Identify market opportunities for U.S. aquaculture products

Developing new economic opportunities requires business plans that consider how products are valued by consumers and the relationship of production costs to the prices the public is willing to pay. For instance, Americans value where and how their food is produced; therefore, new aquaculture operations must consider consumer acceptance of production strategies and account for siting of operations at the national, state, local, or business levels. Tradeoff analyses for both societal goals and business goals across industry segments must be developed. There is a need for social, behavioral, and economic research on constraints and opportunities to produce and sell aquaculture products in foreign and domestic markets.

Federal research agencies must determine the best strategies for adding U.S. aquaculture production to the current seafood industry without negatively impacting fisheries, including evaluations of the

[32] Rural America includes the majority (72 percent) of the Nation's land and is home to 46 million people. Report to the President of the United States from the Rask Force on Agriculture and Rural Prosperity, 2017

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entire value chain from production to consumption. Research is needed to better understand market interactions among aquaculture production, fisheries, and other food-producing sectors.

Research in the following actions will facilitate market development for U.S. aquaculture products. The agencies listed below will support or conduct R&D activities or consult with science programs to identify research priorities and form science-based policy.

- **Action 1.1.1** DOC NOAA (NMFS, NOS), DOI (USFWS, USGS), EPA, and DOD (USACE) will identify policy, regulatory, social and political issues that limit opportunities for aquaculture and develop science-based information to support objective and consistent decision-making.
- **Action 1.1.2** DOC NOAA (SG, NMFS), and DOE (BETO) will develop economic models for enhanced profitability (e.g., farm budgets, information needed for loans and insurance, risk management, resilience).
- **Action 1.1.3** USDA (NASS), DOI (USGS), and DOC NOAA (NMFS) will collect and analyze economic information on how aquaculture complements wild harvests to supply domestic seafood (e.g., working waterfronts, seafood processing capacity, off-season support for commercial fishing).

Objective 1.2: Enable science-based expansion of domestic aquaculture

A key impediment to the growth of the aquaculture industry is the complex and often unpredictable regulatory framework. Aquaculture businesses are regulated under an array of Federal, state, and local laws that govern a range of issues, including but not limited to animal health, water quality, impacts to navigation, and property rights. Many of these issues and Federal actions to improve regulatory efficiency for aquaculture are outlined in a report from the Subcommittee on Aquacultures Regulatory Efficiency Task Force.[33]

Science has a key role to play in informing Federal and state regulatory and management decision-making processes. Regulatory processes require objective, efficient, and timely decisions that are based on the best available science and appropriate risk management. Developing science-based approaches to siting and managing aquaculture facilities includes minimizing negative impacts to protected species and habitats, reducing risk of invasive species introductions, minimizing use conflicts, evaluating risks associated with disease and genetic risks of breeding between escaped farmed and wild populations, improving our understanding of existing uses to minimize conflict with other user groups, minimizing risks to water quality, and other tools. Such advancements will continually employ state-of-the-art scientific tools and approaches to advance the quality, consistency, and efficacy of regulatory decision-making for the benefit of industry, society, and the environment. Science-based tools can include risk assessment models, GIS tools and maps, guidance and synthesis documents, disease countermeasures, and access to expertise for advice.[34] Such science-based management tools will be key to realizing the goals of economic performance, legal compliance, and environmental compatibility.

Beyond compliance, science can help industry more easily produce quality products valued by consumers by developing aquaculture systems that enhance ecosystem services beyond food production. R&D projects can produce methods and technologies that minimize environmental impacts and increase efficiency of growing aquatic proteins. Science-based regulatory tools will lead to

[33] A Strategic Plan to Enhance Regulatory Efficiency in Aquaculture.

[34] The tools and science information needs of regulatory agencies are outlined in greater detail in the Strategic Plan to Enhance Regulatory Efficiency in Aquaculture.

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continuous improvement in economic, environmental, and social performance in all types of aquaculture industries.

The following actions will balance regulatory decision-making and environmental compliance with economic goals. The agencies listed below will support or conduct R&D activities or consult with science programs to identify research priorities and form science-based policy.

- **Action 1.2.1** DOC NOAA (NOS, SG, NMFS), EPA, and DOE (ARPA-E, BETO) will develop tools for both regulators and producers who will assess potential production sites for their capacity to minimize negative impacts to protected species and habitats, reduce risk of invasive species introductions, minimizing use conflicts, evaluate risks associated with disease and genetic risks of breeding between escaped farmed and wild populations, improve our understanding of existing uses to minimize conflict with other user groups, and minimize risks to water quality.
- **Action 1.2.2** DOC NOAA (NOS, SG, NMFS) will support the development of models that account for the potential effects from environmental change on aquaculture production in the United States.
- **Action 1.2.3** DOC NOAA (NOS, NMFS), DOI (USGS), and EPA will provide tools that inform state and local regulators developing guidance on potential new locations aquaculture facilities can expand to improve environmental quality in the Great Lakes and marine waters.
- **Action 1.2.4** DOI (USFWS, USGS), and DOC NOAA (NMFS) will develop methods and best practices to use for recreational opportunities, and/or increase commercial fisheries harvests.

Objective 1.3: Educate and train a skilled aquaculture workforce

The Nation needs an aquaculture workforce that represents all levels of education. Currently, employers have difficulty recruiting candidates who have the skills and expertise required to raise aquatic animals. To plan for the aquaculture workforce of the future it is imperative to prepare current and future workers with skills derived from aquaculture-specific training and education that enhance their expertise and capacity for implementing state-of-the-art practices.

The following actions will support aquaculture workforce development. The agencies listed below will support or conduct R&D activities or consult with science programs to identify research priorities and form science-based policy.

- **Action 1.3.1** DOC NOAA (SG, NMFS) and USDA (NIFA) will support educational opportunities to improve production practices, facilitate regulatory compliance, improve decision-making, and enhance communications.
- **Action 1.3.2** DOC NOAA (SG) will assess the trends of various educational backgrounds (postsecondary, community college, trade schools, and graduate education) to inform strategies that address the shortage of a skilled aquaculture workforce.
- **Action 1.3.3** USDA (NIFA) and DOC NOAA (SG) will support the expansion of public and private training programs, externships, and apprenticeships to provide the relevant skills to support industry needs.

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Goal 2. Improve Aquaculture Production Technologies and Inform Decision-making

Current aquaculture technologies and management tools provide the foundation for further innovation in seafood production, marine resource management, and economic development. However, continual improvements are needed to expand aquaculture consistent with society's increasing need for seafood produced locally under our strict environmental and food safety laws, and to improve the competitiveness of the U.S. industry. The biological sciences and engineering fields converge at a critical juncture of the organism, the culture system, and the environment. Therefore, optimizing aquaculture production requires matching the biology of the species with a production system they can thrive in with minimal impacts on the external environment. For example, a species like rainbow trout must be raised in cool, clear water raceway systems while catfish are raised in warm water pond culture. Federal science programs serve industry development by 1) focusing on pre-commercial and transitional development of technology to improve production efficiency, product quality, and profitability; and 2) addressing potential environmental and social costs of production by developing tools for informed and objective decision-making at multiple levels of government.

Objective 2.1: Provide farmers with access to improved genetics

Currently, fewer than 10 percent of all animals produced in aquaculture have been improved for aquaculture production through selective breeding[35], and many juveniles or seed stocks are directly harvested from wild populations or are the offspring of wild parents. For microalgae and macroalgae, selective breeding programs to improve traits such as biomass yield, chemical composition, and disease resistance have only recently been implemented, including approaches that employ genome-enabled selection technologies. Unlike much of terrestrial agriculture, wild populations still exist for a wide variety of newly cultured aquatic organisms. In those few aquatic species that have been domesticated, genetic selection programs have yet to be implemented, do not use state-of-the-art technologies, or have advanced only a few generations. There is a significant opportunity to apply genetic and genomic advances to agronomic improvement. Desirable production traits include disease resistance and fast, efficient growth, which results in increased product yield with lower inputs and lower waste production.

Aquaculture faces the challenge of domesticating and enhancing the economically important traits of aquatic species for commercial production while applying best science-based practices to successfully integrate commercial interests with protective measures for natural populations. For example, many aquaculture production systems are connected to aquatic natural resources such that farmed escapees

[35] Gjedrem T, Rye M. Selection response in fish and shellfish: a review. Rev Aquaculture. 2018:10(1). https://doi.org/10.1111/raq.12154

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could interact and mate with wild counterparts. Selectively bred salmon in net pens could escape and interact with natural salmon populations, potentially reducing genetic diversity and capacity for adapting to environmental stressors. Existing technologies such as those that produce sterile offspring to eliminate or minimize interactions with their wild counterparts must be implemented so genetic improvements made in cultured populations do not impact their wild counterparts.

Federal efforts for stock restoration for imperiled species recovery and for recreation programs currently strive to minimize genetic impact on wild stocks by ensuring that only animals with closely related genetics are released into native waters.[36] Tools and technologies for managing populations' genetics are species-specific and must be developed for each population.

The following actions will support genetic improvement and minimize risks to natural populations. The agencies listed below will support or conduct R&D activities or consult with science programs to identify research priorities and form science-based policy.

- **Action 2.1.1** USDA (ARS), DOC NOAA (NMFS), and DOI (USGS and USFWS) will develop and operationalize a framework for genetic risk assessment and management that includes realistic science-based expectations for implementing genetic improvement programs, particularly selective breeding, while minimizing risk to wild populations from escapes.
- **Action 2.1.2** USDA (ARS, NIFA), DOE (BETO), DOI (USGS, USFWS), and DOC NOAA (NMFS, SG) will develop and implement state-of-the-art genetic and genomic tools for breeding program(s) for fish, shellfish, microalgae, and seaweeds to improve production efficiency, product quality, animal well-being, and overall health.
- **Action 2.1.3** DOC NOAA (NMFS, SG), USDA (ARS, NIFA), and DOI (USGS, USFWS) will develop technologies to prevent or reduce interactions and competition with native populations.
- **Action 2.1.4** USDA (ARS), DOI (USFWS), and NOAA (NMFS) will ensure preservation of population diversity including wild-type and selectively bred populations.

Objective 2.2: Develop production technologies that minimize environmental impacts

The need for practices to increase food production in a way that avoids or minimizes harm to the environment resonates globally in all agricultural production sectors, including aquaculture. Successful aquaculture depends on healthy ecosystems that provide clean water and nutrient cycling that processes or reuses wastes and co-products. In the United States, aquaculture's environmental performance has improved dramatically during the past 20 years, driven by the need for more efficient use of resources and inputs due to rising costs of fuel and feed, increased awareness of environmental issues associated with aquaculture, application of science-based best management practices, technological innovation, knowledge about proper siting of facilities, and evolving aquaculture-specific environmental regulations at the state and Federal levels. Commercial aquaculture production in the United States operates under some of the most stringent environmental requirements in the world. Similarly, Federal agencies adhere to sound science and best management practices when employing aquaculture to fulfill their recovery and restoration missions.

Efficient and effective aquaculture production systems reduce inputs, operating costs, and wastes and create optimal conditions for growth, adaptability, and reproduction. Production efficiency and animal or plant well-being start with properly matching species to appropriate production environments and

[36] Paquet PJ, Flagg T, Appleby A, et al. Hatcheries, Conservation, and Sustainable Fisheries—Achieving Multiple Goals: Results of the Hatchery Scientific Review Group's Columbia River Basin Review. Fisheries 2011;36:547–561.

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market demands. Defining optimal conditions requires a comprehensive understanding of the physiology of early development, growth, nutrition, stress response, and reproduction.

The following actions will improve production efficiency and develop new aquaculture production strategies that minimize environmental impacts. The agencies listed below will support or conduct R&D activities or consult with science programs to identify research priorities and form science-based policy.

- **Action 2.2.1** DOC NOAA (NMFS, NOS, SG), USDA (ARS, NIFA), DOI (USGS), and DOE (ARPA-E, BETO) will support or conduct research to document the ecosystem services provided by aquaculture and identify new opportunities to utilize them.
- **Action 2.2.2** DOC NOAA (SG), USDA (NIFA), and HHS (FDA) will conduct or support research to inform policies based on Federal science that supports innovation in aquaculture, traceability, and identification.
- **Action 2.2.3** DOC NOAA (NMFS, SG) and DOI (USFWS) in association with state agencies and others will develop aquaculture methods that cost-effectively enhance, preserve, and rebuild wild stocks and their ecosystems.

Objective 2.3: Advance fish nutrition and feed production technologies

The growth and sustainability of the fish farming industry depends on the availability of adequate sources of feed. Therefore, it is important to identify feed ingredients, feeding practices, and feed production technologies that meet fish nutrient requirements, are palatable, and that do not have deleterious effects on the growth and health of the fish, on wild fish stocks harvested for feed, or on the broader ecosystem. Some finfish and shrimp aquaculture production systems have traditionally relied on the use of fish meal and fish oil as feed ingredients to provide a source of essential amino acids, minerals and vitamins, and essential fatty acids. However, due in part to Federal research, that is changing, and these industries are pioneering the development of numerous alternative feed ingredients.

Many of the human health benefits of seafood consumption stem from the long-chain, highly unsaturated omega-3 fatty acids that enrich many aquaculture seafood products, which is achieved by the use of fish oil in aquaculture feeds. However, demands for fish meal and fish oil are high with concomitant high costs, and are somewhat limited by natural flux in wild harvests. To address these issues, new sources of fish feed ingredients must be identified that ensure quality and food safety of aquaculture products.

Achieving the desired partitioning of nutrients into the competing systems of muscle development, digestive metabolism, health maintenance, and reproduction is critical for improving productivity and reducing cost and waste. Stressors caused by nutritional and environmental factors and their interactions must be understood to limit poor animal health, disease, and product quality; suboptimal growth and production efficiency; and excess waste.

The following actions will improve the feeds used in aquaculture systems. The agencies listed below will support or conduct R&D activities or consult with science programs to identify research priorities and form science-based policy.

- **Action 2.3.1** DOC NOAA (SG), DOE (BETO, ARPA-E), USDA (ARS, NIFA), DOI (USGS), and HHS (FDA) will collaborate to support or conduct research that determines the nutrient requirements to feed new and existing cultured species of finfish, mollusks, and microalgae and seaweeds at all stages

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of life to increase nutritional efficiency and provide maximal nutritional value for human consumption while minimizing potential impacts on wild fish stocks and the broader ecosystem.

- **Action 2.3.2** USDA (ARS, NIFA), DOC NOAA (NMFS, SG), DOI (USGS), and HHS (FDA) will support or conduct research to provide feed manufacturers with cost-effective choices in feed ingredients suitable for marine and freshwater aquaculture production.
- **Action 2.3.3** USDA (ARS, NIFA) and DOC NOAA (SG, NMFS) will conduct or support research to develop feeds and feed production methods (including live feeds) for all life stages of target organisms that result in high performance.
- **Action 2.3.4** DOC NOAA (NMFS, SG), DOI (USGS), USDA (NIFA), and HHS (FDA) will collaborate to provide Extension Service and production assistance for new aquafeeds and aquaculture products to standardize growth conditions, identify factors affecting expansion to commercial scales, reduce risk for new farm and production systems, and inform feed regulatory approval.

Objective 2.4: Improve engineering systems for aquaculture

Production systems for aquaculture in the United States include pond-based systems (e.g., catfish and crawfish production); raceway systems (e.g., rainbow trout and microalgae); near-shore and offshore net-pens and cages (e.g., Atlantic salmon and marine fish); hatcheries (e.g., Pacific salmon and marine fish); intertidal, off-bottom, and long-line coastal shellfish production; freshwater and marine algae (including seaweed) production systems; and recirculation systems (e.g., aquaponics, salmon, yellow perch, tilapia, ornamental species, and oyster spat). The hatcheries and nurseries for all these types of aquaculture represent unique engineering challenges, but all production systems would benefit from advanced monitoring and control systems, labor-saving process engineering, and other specialized devices. For example, renewable energy for the operation of offshore systems could be supplied by integrated marine wind and water power technologies.[37]

Aquaponics, the cultivation of plants in water downstream of aquatic animal production, demonstrates the potential of integrating hydroponics with modern aquaculture systems.[38] Further R&D in combining complementary systems may enable large-scale production of both fish and vegetables in one system. This has the potential to help revitalize rural economies and provide for local production in food deserts where access to affordable, healthy food options is limited.[39]

Significant opportunities exist to improve the performance and productivity of aquaculture production systems through innovative engineering and new devices and technologies. There is significant potential to adapt current commercial technologies and engineering solutions from other sectors, such as municipal wastewater treatment, manufacturing, medicine, information technology, artificial intelligence, sensors, and energy, that can be integrated into aquaculture systems to improve productivity and efficiency.

The following actions will improve the efficiency and sustainability of aquaculture production systems. The agencies listed below will support or conduct R&D activities or consult with science programs to identify research priorities and form science-based policy.

- **Action 2.4.1** USDA (ARS, NIFA), DOC NOAA (SG, NMFS), and DOI (USFWS) will support research that ensures robust aquaculture system performance at reasonable costs that maximize production

[37] LiVecchi A, Copping A, Jenne D, et al, *Powering the Blue Economy; Exploring Opportunities for Marine Renewable Energy in Maritime Markets*. Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy; 2019.

[38] U.S. Department of Commerce, "Fisheries of the United States 2017"

[39] https://www.ers.usda.gov/data-products/food-access-research-atlas/

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potential, safety, and economic performance while minimizing labor needs and impacts on wild organisms.

- **Action 2.4.2** USDA (ARS), DOE (BETO), and DOC NOAA (NMFS, SG) will support or conduct research that develops highly effective hatcheries and harvest and processing equipment.
- **Action 2.4.3** USDA (NIFA), DOI (USGS), and DOC NOAA (SG) will support or conduct research to develop or improve various types of specialized aquaculture systems such as aquaponics, integrated multitrophic aquaculture, or other approaches that may be appropriate for U.S. aquaculture.
- **Action 2.4.4** DOC NOAA (SG, NMFS) and USDA (NIFA) will provide Extension Service support, test beds, and demonstration and production assistance through public-private partnerships to increase the rate of knowledge transfer from research to implementation.

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Goal 3. Uphold Animal Well-Being, Product Safety, and Nutritional Value

Given seafood's many health benefits, the 2015-2020 US Dietary Guidelines for Americans recommends increasing seafood consumption in the United States.[40] Demonstrating the safety and nutritious value of domestic aquaculture products will inform consumer decisions on seafood purchases. Similarly, promoting health benefits could improve food security as higher demand will stimulate more domestic aquaculture production. Access to healthy farmed seafood products starts with healthy aquatic organisms grown in healthy aquatic ecosystems.

"One Health"[41] concepts recognize that the health of people is connected to the health of farmed organisms and the environment. One Health approaches to developing healthy ecosystems are collaborative, multisectoral, and transdisciplinary—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes. These approaches recognize the interconnection between people, animals, plants, and their shared environments.[42] Optimal implementation of One Health principles requires the development and coordination of programs, policies, legislation, and research in which multiple sectors communicate and work together to achieve better public health outcomes. Specifically, the concept focuses on ways to improve food security, quality, and safety; control diseases; and manage environmental factors through harmonization and standardization. To apply the One Health concept to aquaculture, Federal research should be coordinated to:

- Improve aquatic animal and algal health management;
- Ensure the safety of all biologics and therapeutics being used in domestic aquaculture;
- Promote and ensure the safety and health benefits of consuming aquaculture products;
- Minimize the potential for impacts on the environment from aquaculture facilities;
- Restore endangered species and habitats;
- Increase the socioeconomic health of communities;
- Improve U.S. food and nutritional security; and
- Where appropriate, minimize negative secondary impacts to human, animal, and plant health.

Objective 3.1: Develop strategies to protect the health and well-being of aquaculture species

[40] 2015-2020 Dietary Guidelines for Americans, https://health.gov/dietaryguidelines/2015/guidelines/ accessed July 13, 2019

[41] One Health, World Health Organization, https://www.who.int/features/qa/one-health/en/, accessed July 13, 2019

[42] https://www.cdc.gov/onehealth/index.html

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Disease causes economic and ecological losses across the aquaculture sector. In addition to direct losses to production, disease can have broader indirect impacts on the surrounding ecosystem, public perception, demand for cultured products, and policy decisions. Accordingly, significant investments should be directed toward understanding priority disease issues and developing tools and capabilities to proactively address them. Wherever possible, prevention of disease through good farm management (i.e., maintaining good water quality, not overfeeding, not overstocking) and sound on-farm biosecurity programs and vaccination is preferred to treatment with pharmaceuticals. This also includes the need to integrate oceanographic and epidemiological models to help site and manage marine aquaculture. Disease prevention is also improved by national and regional biosecurity efforts, including inspection and approval protocols for aquaculture inputs such as feed, eggs and juveniles.

Where preventive measures have not been developed or are not adequate, safe and effective treatment options must be developed to avoid unnecessary losses and protect animal and plant welfare. Research is needed to characterize important and emerging disease issues, identify effective prevention measures, including vaccines, and develop safe and effective treatment options using approved drugs and biologics.

Domesticating aquaculture species for commercial production often requires treatments with specific drugs to better predict spawning times and enhance reproductive success or develop monosex or sterile populations. These treatments can reduce the impacts of sexual dimorphism, reduce risks associated with escapes, and protect investments in selected stocks. Anesthetics are also needed for tagging, weighing, and nonlethal sampling wild and domesticated stocks.

Key actions listed below will protect aquatic animal health and the agencies listed will support or conduct R&D activities or consult with science programs to identify research priorities and form science-based policy.

- **Action 3.1.1** USDA (APHIS, ARS), DOC NOAA (SG, NMFS), and DOI (USGS, USFWS) will conduct research and industry outreach to improve farm-level biosecurity and management practices to maintain adequate water quality, minimize animal stress, and prevent diseases.
- **Action 3.1.2** DOI (USFWS), USDA (APHIS), and DOC NOAA (SG) will conduct outreach to improve regional and national biosecurity procedures including transfers of juveniles and other aquaculture inputs and products.
- **Action 3.1.3** HHS (FDA), USDA (APHIS, ARS), DOI (FWS,USGS), and DOC NOAA (SG) will collaborate to support or conduct research that identifies and characterizes key unmet needs or provides information on the safety and effectiveness for drugs and biologics across the aquaculture sector, including vaccine and disease treatments, anesthetics, marking agents, and tools to aid in spawning and gender control.
- **Action 3.1.4** HHS (FDA) will validate new chemical detection methods for residues of approved and unapproved drugs to support regulatory compliance and surveillance activities.
- **Action 3.1.5** HHS (FDA), USDA (APHIS), and DOI (USFWS) will develop standardized criteria to interpret laboratory tests intended to provide surveillance for monitoring antimicrobial resistance and to inform judicious use of antimicrobials.
- **Action 3.1.6** HHS (FDA) and DOI (USFWS) will investigate alternative approaches to the standard drug development process to increase availability of approved therapies for U.S. aquaculture.
- **Action 3.1.7** USDA (APHIS, ARS) and DOI (USGS) will conduct research to detect and characterize important and emerging aquatic diseases to support early detection (biosurveillance) and develop effective responses.

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Objective 3.2: Promote the safety and nutritional value of U.S. aquaculture products

Domestic seafood produced in aquaculture systems is safe and nutritious. The consumption of seafood has been associated with a lower risk of heart disease-related death and, part of a healthy eating pattern, with a lower risk of obesity.[43] Seafood has also been associated with better health outcomes for children when mothers consume seafood while pregnant or breastfeeding. For these reasons, the *2015–2020 Dietary Guidelines for Americans* recommends that the general population should eat at least 8 ounces of seafood per week; the average American consumes less than half that amount. Research that further documents the safety and benefits of seafood consumption will help inform the public and support increased consumption.

The following actions will inform consumers that seafood is safe and demonstrate the health benefits of domestic farm-raised seafood products. The agencies listed below will support or conduct R&D activities or consult with science programs to identify research priorities and form science-based policy.

- **Action 3.2.1** HHS and USDA (ARS) will determine the overall seafood consumption benefits and risks and communicate dietary recommendations at various life stages to the public.
- **Action 3.2.2** USDA (ARS) and DOI (USGS) will determine the nutritional profile of aquaculture and wild-caught products.
- **Action 3.2.3** HHS (FDA) and USDA (APHIS) will develop an integrated food safety and disease prevention program for use by domestic aquaculture farms.

Implementing the Federal Aquaculture Research Strategy

Responsible expansion of domestic aquaculture production will require wise investment of Federal resources to develop and implement new technologies, train a highly skilled workforce, inform policy- and decision-making, create jobs, and identify opportunities for economic growth. This section identifies the roles for the Federal government, academia, research organizations, and the commercial sector and strategies for ensuring coordination.

Annual Federal expenditures for aquaculture R&D support core research capabilities in universities, Federal laboratories, and small businesses that solve critical problems and generate new or improved technologies and better practices for industry. There are also opportunities to develop new industries to meet the growing demand for seafood and respond to the challenges of a changing environment. This plan recognizes that multidisciplinary research and coordination of various types of Federal research programs are needed to improve competitiveness, production efficiency, economic viability, and long-term environmental sustainability through advances in all areas of aquaculture research. Federal aquaculture research is supported by multiple departments, with each program bringing unique perspectives and strengths to the overall portfolio of aquaculture science. The primary roles of Federal research agencies are to:

- Prioritize research needs and fund high-quality projects that develop new or improved technologies and drive growth in productivity;
- Support sound science for policy, regulatory, and permitting decisions that allow responsible industry development; and
- Support effective extension and education functions that help translate and deliver new knowledge for the public good and facilitate farm-level adoption of improved technologies.

[43] 2015-2020 Dietary Guidelines for Americans, https://health.gov/dietaryguidelines/2015/guidelines/ accessed July 13, 2019.

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Federal research, extension, and education activities are implemented through intramural programs at Federal laboratories and extramural programs where funding is provided to academic, industry, nongovernmental or other research organizations.

Federal Research Laboratories

Federal laboratories have a unique role in developing tools for aquaculture production and management through investments in long-term, stable funding in key infrastructure. This includes test sites and hatcheries; environmental modeling; geospatial data and siting tools; feed mills; pilot-scale grow-out facilities; genetics programs; and analytical reference, inspection, and fish health and disease laboratories that would be difficult to sustain without such long-term security. Federal laboratories also have access to restricted datasets that are not always available to the general academic community.[44] In addition, Federal scientists can quickly respond to emerging challenges such as new disease outbreaks and other unforeseen issues. Federal laboratories are extremely effective at meeting their missions, especially when coupled with extramural programs described in the next section.

Academia and Research Organizations

Federal extramural research programs partner with academic and other research organizations by supporting activities that address Federal research priorities. Compared with Federal laboratories, extramural research supported by competitive grants is best suited for short-term (1- to 4-year) research projects; addressing emerging industry needs; and encompassing a much broader range of topics (including high-risk/high-payoff ideas). Competitive grants bring in innovative ideas from other scientific fields, and can connect industry, state programs, research institutions, and extension programs. These shorter-term research efforts enhance, and are enhanced by, the scientific backbone created by longer-term intramural programs that support the Federal infrastructure described above.
The United States is rare among nations in that it has a solid history of active extension services focused on aquaculture. The USDA NIFA supports Cooperative Extension Services that primarily focus on freshwater aquaculture, whereas NOAA Sea Grant supports extension primarily in marine aquaculture. Both agencies coordinate aquaculture extension at the national level through the National Aquaculture Extension Steering Committee (NAESC). The importance of the Extension Service in facilitating the creation of useful science and transferring that science to the end user cannot be overstated. The Extension Service is a large part of why the United States leads in science and technology generally, serving as a professional connection between research institutes and the end-users of scientific information.

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[44] For example, data covered under the Foundations for Evidence-Based Policymaking Act of 2018 (https://www.congress.gov/bill/115th-congress/house-bill/4174)

Commercial Sector

Federal research and development investments that advance responsible expansion of domestic aquaculture production will be most effective through continual engagement with farmers, feed companies, animal health companies, nongovernmental organizations, and manufacturers of gear and production systems. This engagement is critical for identifying and prioritizing research needs, creating a highly skilled workforce, and participating in policy-making processes at the levels of Federal, state, tribal, and local governments. Although some of this communication can occur through the Extension Service, whenever possible representatives of the commercial sector should also represent themselves directly and through allied stakeholder organizations.

Coordination and Collaboration

Coordination and collaboration across sectors are essential for maximizing the impact of the Federal aquaculture R&D portfolio. The Subcommittee on Aquaculture serves to enhance interagency coordination and is the primary contact for stakeholders interested in Federal activities related to aquaculture science. Coordination and collaboration among Federal agencies, academia, and the commercial sector is critical to:

1) Avoiding duplication in research approaches while maximizing impact on key science needs;
2) Identifying and prioritizing research needs;
3) Evaluating the impacts of research outcomes;
4) Transferring technologies to the commercial sector and regulatory process;
5) Developing sound, science-based policies that ensure responsible production of safe and nutrition aquaculture products;
6) Identifying market opportunities for expanding production; and
7) Training and employing a highly skilled workforce.

Expanding domestic aquaculture would benefit from developing scalable commercial marine aquaculture production sites projects through public-private partnerships that serve to determine the economic viability of state-of-the-art production technologies, quantify the environmental impacts, and inform future policy-making decisions. These testbeds would serve as pre-permitted incubators to conduct industry-relevant scale and pre-commercial testing; however, they require a critical mass of long-term resources that are not typically available to intramural and extramural programs.

Federal Agencies Supporting Aquaculture Research and Development

The following Federal agencies administer research programs related to aquaculture funded by extramural and/or intramural resources.

Army Corps of Engineers

USACE Civil Works Regulatory Program regulates activities affecting navigable waterways and discharges of dredged or fill material into waters of the United States. Regulated activities can include both shellfish and non-shellfish aquaculture within inshore and offshore waters. The Corps' decision-making authority for these activities involves among other things, a determination that the regulated activity is not contrary to the public interest, including consideration of compliance with other applicable Federal laws such as the Magnuson-Stevens Fishery Conservation Management Act, Endangered Species Act, and National Environmental Policy Act.

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USACE Civil Works–Planning works with non-Federal partners to construct oyster reefs for the purposes of ecological restoration in degraded habitats, and to create/restore reefs that physically dampen wave energy and prevent negative impacts on the shoreline.

USACE Civil Works–Operations funds mitigation fish hatcheries under multiple authorities often in partnership with other state or Federal (e.g., USFWS, NOAA) agencies

Department of Agriculture

Agricultural Research Service conducts intramural research on marine and freshwater systems and delivers technologies that improve domestic aquaculture production efficiency, animal health, nutrition, genetics, and product quality while minimizing impacts on natural resources. Current research includes shellfish and freshwater and marine finfish farmed across a diverse array of production systems.

Animal and Plant Health Inspection Service serves to protect and promote U.S. agricultural health and to administer the Animal Welfare Act.

Economic Research Service anticipates trends and emerging issues in agriculture, food, the environment, and rural America and to conduct high-quality, objective economic research to inform and enhance public and private decision-making. ERS provides monthly data on the domestic aquaculture industry and U.S. trade in aquaculture products.

Food Safety and Inspection Service protects the public's health by ensuring the safety of meat, poultry, and processed egg products. Through the 2008 and 2014 Farm Bills, FSIS inspects siluriformes, including catfish, under the Federal Meat Inspection Act.

National Agricultural Statistics Service produces the Census of Aquaculture every 5 years, which expands on the data collected about aquaculture collected from the Census of Agriculture and provides a comprehensive picture of the aquaculture sector at the state and national levels. NASS also produces annual reports for catfish and trout.

National Institute of Food and Agriculture addresses national needs for aquaculture research, education, extension, and technology transfer to support U.S. aquaculture production through the Regional Aquaculture Center program; by funding aquaculture extension educators via Cooperative Extension at land-grant universities; and NIFA's competitive research programs, which address diverse freshwater and marine aquaculture research areas and species.

Risk Management Agency provides insurance policies to help aquaculture producers manage risk. Currently, cultivated clams and oysters have specific plans available in four states, while a whole-farm revenue protection plan is available to alligator, baitfish, clams, fish, oysters, trout, aquatic plants, and watercress producers across the country.

Department of Commerce

NOAA National Marine Fisheries Service provides key infrastructure, dedicated aquaculture scientists, and professional technical support staff through regional Fisheries Science Centers to focus long-term efforts on enduring industry and regulatory science needs. NMFS also provides extramural funding to support industry development. NMFS Seafood Inspection Program works to ensure confidence in U.S. seafood by protecting and strengthening the seafood market through global trade, establishing

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partnerships with industry and consumer groups, providing seafood inspection services, and analyzing seafood safety risks.

NOAA Sea Grant provides grants and an Extension Service that support the development of sustainable marine and Great Lakes aquaculture to help coastal communities maintain a safe and sustainable local seafood supply. Sea Grant's investment in aquaculture focuses on research and technology transfer, often through one-to-one interactions with extension agents, to support and expand America's aquaculture industry.

NOAA National Ocean Service National Centers for Coastal Ocean Service programs specialize in understanding the environmental interactions of aquaculture with marine and human ecosystems. Interdisciplinary scientists focus on coastal planning to address conflicts among ocean uses, to inform and support public outreach and education efforts, and to increase awareness of the environmental, economic, and social opportunities aquaculture can provide coastal communities.

Department of Energy

Advanced Research Projects Agency–Energy's Macroalgae Research Inspiring Novel Energy Resources program supports research effort to develop innovative technology solutions for the cost-effective production of macroalgal biomass as a bioenergy feedstock in the open ocean of the U.S. Exclusive Economic Zone at energy-relevant scale.

Energy Efficiency and Renewable Energy's Bioenergy Technologies Office offers competitive R&D funding opportunities relevant to aquaculture and energy. As part of their bioenergy mission BETO supports the R&D of algae crop, cultivation systems, and conversion to biofuels and bioproducts. DOE serves alongside USDA as a co-chair agency member of the Biomass Research and Development Board, which is charged through the enactment of the Biomass Research and Development Act of 2000 to coordinate Federal programs to promote the use of biobased industrial products. EERE also has the Wind Energy and Water Power Technologies Offices that offer competitive R&D funding opportunities that could support off-shore, marine energy systems.

Department of Health and Human Services

Food and Drug Administration protects public health by regulating aquaculture drugs and feeds, and helping to ensure the safety of our Nation's seafood supply. Through incentives afforded by the Minor Use and Minor Species Animal Health Act of 2004 and working with stakeholders, the Center for Veterinary Medicine works to help make more animal drugs legally available for minor species including fish. The Center for Veterinary Medicine also reviews the safety of new ingredients for use in aquaculture feeds. The FDA operates a mandatory food safety compliance program for all domestic and imported fish and fishery products under the provisions of the Federal Food, Drug, and Cosmetic Act, and pertinent regulations. FDA partners with other Federal, state, and local agencies in a cooperative effort to manage food safety risks and provide consistent standards and regulations for seafood products in various industry sectors.

Department of the Interior

U.S. Fish and Wildlife Service operates the National Fish Hatchery System (NFHS) aimed at the recovery, restoration, and mitigation of aquatic species, populations, and systems across the country. The NFHS consists of 70 production facilities that propagate more than 100 species each year and depend directly on the support of 14 research and development centers aimed at improving production

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and assessment. The R&D centers include Fish Health Centers and Fish Technology Centers, representing diverse expertise including genetics, physiology, nutrition, aquatic animal health, pathogen identification and management, and assessment modeling. In addition, the Aquatic Animal Drug Approval Partnership (AADAP) program works with other Federal agencies, states, tribes, universities, and private partners to obtain FDA approval of new medications or other production aids for use in fish culture and fisheries management. AADAP provides legal access to a broad variety of experimental medications currently in the approval process through the National Investigational New Animal Drug Program and conducts research studies that evaluate the safety and efficacy of these experimental medications.

U.S. Geological Survey provides high-quality science to inform management for harvested species, threatened and endangered species, at-risk species and species of management concern, and their habitats. USGS works with Federal, state, local, and tribal partners to sustain hunting, fishing, and wildlife-related recreational activities. USGS also conducts research into the cause and mitigation of environmental and anthropogenic stressors that may affect the health and sustainability of species of management concern (including invasive species and disease). USGS science supports stock assessments of Great Lakes forage fish used by states, tribes, and provinces to manage a $7 billion commercial and recreational fishing industry. USGS conducts risk assessments and advanced tool development for discovery, surveillance, and control of fish diseases of cultured and wild fish managed by other Federal, state, tribal, and international agencies. For investigating invasive species and disease, USGS maintains freshwater high-containment laboratories and a marine saltwater containment facility.

Environmental Protection Agency

Environmental Protection Agency implements programs to protect human health and the environment. The Office of Water restores and maintains oceans, watersheds, and their aquatic ecosystems to protect human health, support economic and recreational activities, and provide healthy habitat for fish, plants and wildlife. The Office of Research and Development conducts research that provides the foundation for credible decision-making to safeguard human health and ecosystem from environmental pollutants. EPA's Safe and Sustainable Water Resources research program provides the science and innovative technologies that the agency and the Nation need to maintain drinking water resources and systems, as well as to protect the chemical, physical and biological integrity of the Nation's waters.

National Science Foundation

National Science Foundation is an independent Federal agency created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense..." NSF supports basic research and people to create knowledge that transforms the future. This type of support is a primary driver of the U.S. economy. enhances the Nation's security and advances knowledge to sustain global leadership.

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THIS IS A DRAFT DOCUMENT OF THE NSTC SUBCOMMITTEE ON AQUACULTURE

PUBLIC COMMENTS WILL BE ACCEPTED THRU SEPTEMBER 10, 2021.

Address all comments concerning the ***Science Plan*** to Task Force Chair Dr. Caird Rexroad, National Program Leader for Aquaculture, Agricultural Research Service, Office of National Programs, 5601 Sunnyside Avenue, Room 4-2106, Beltsville, Maryland 20705. Submit electronic comments to AquaSciencePlan@usda.gov.

Address all comments concerning the ***Regulatory Efficiency Plan*** and the National Aquaculture Development Plan to Task Force Chair Kristine Cherry, Chief, Regulatory and Policy Branch at NOAA Fisheries Office of Aquaculture, NOAA National Marine Fisheries Service, 1315 East-West Highway, Room 14461, Silver Spring, MD 20910-3282. Submit electronic comments to Aqua.RegPlan@noaa.gov.

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