National Strategic Plan for Federal Aquaculture Research (2014-2019)

National Science and Technology Council
Committee on Science
Interagency Working Group on Aquaculture

June 2014

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL
WASHINGTON, D.C. 20502

Dear Colleagues:

Aquaculture research and development is a growing sector of agriculture that offers alternative farming in a variety of aquatic environments. In 2012, U.S. consumers spent an estimated $82.6 billion on seafood, making the nation one of the top three seafood markets worldwide. Yet the domestic farm gate value of aquaculture products only approaches $1.3 billion annually. Thus, much of the U.S. demand is supplied by international imports. Current aquaculture productivity in the Nation is driven by annual Federal investments in research and development of approximately $100 million. Advancing and expanding this sector will provide the domestic production of greater seafood products and economic opportunities for the United States. The following National Strategic Plan for Federal Aquaculture Research seeks to advance aquaculture research and development to provide more domestic production of seafood products and increase economic opportunities through aquaculture in the United States.

The Interagency Working Group on Aquaculture (IWGA) — a working group under the Life Sciences Subcommittee of the National Science and Technology Council's Committee on Science — was established to increase the overall effectiveness and productivity of Federal aquaculture research, technology transfer, and technology assistance programs; further encourage the development of public-private sector collaborations; as well as coordinate efforts among Federal agencies engaged in the science, engineering, and technology of aquaculture. To that end, the IWGA members have developed the *National Strategic Plan for Federal Aquaculture Research* to provide a framework for coordination and collaboration across agencies and to serve as a guide for member agencies in prioritizing their aquaculture-related activities.

Aquaculture is an increasingly integral source of safe, nutritious, and sustainable seafood for consumers worldwide. Increases in demand for aquaculture products, food security considerations, and job creation highlight the need for increased domestic development. This plan is intended to serve as a roadmap for implementing the targeted strategic goals outlined in it. The Committee on Science looks forward to the development of more robust implementation plans to advance aquaculture for the nation's interests.

Sincerely,

Philip Rubin, OSTP (Co-Chair, COS)

6/16/2014
Date

France Cordova, NSF (Co-Chair, COS)

6/16/2014
Date

Francis Collins, NIH (Co-Chair, COS)

6/16/2014
Date

About the National Science and Technology Council

The National Science and Technology Council (NSTC) is the principal means by which the Executive Branch coordinates science and technology policy across the diverse entities that make up the Federal research and development (R&D) enterprise. One of the NSTC's primary objectives is establishing clear national goals for Federal science and technology investments. NSTC prepares R&D packages aimed at accomplishing multiple national goals. The NSTC's work is organized under five committees: Environment, Natural Resources, and Sustainability; Homeland and National Security; Science, Technology, Engineering, and Mathematics (STEM) Education; Science; and Technology. Each of these committees oversees subcommittees and working groups that are focused on different aspects of science and technology. More information is available at www.whitehouse.gov/ostp/nstc.

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About the Interagency Working Group on Aquaculture

The Interagency Working Group on Aquaculture (IWG-A) operates under the Life Sciences Subcommittee of the Committee on Science of the National Science and Technology Council. Pursuant to Sec. 6(b) of the National Aquaculture Act of 1980, the IWG-A (formerly known as the Joint Subcommittee on Aquaculture) was created to increase the overall effectiveness and productivity of Federal aquaculture research, technology transfer, and technology assistance programs. The IWG-A supports Sec. 2(c) of the National Aquaculture Act of 1980, which contains the national policy that encourages the development of aquaculture in the United States.

About this Document

This document is the strategic plan to guide Federal research in aquaculture. Developed by the IWG-A and published by OSTP, the plan describes ways that government can help advance and expand domestic interests in aquaculture, providing for greater economic and recreational opportunities in the United States. The plan identifies the current Federal resources in research and extension, the need for the best research to inform public policy and regulatory decisions, and the need for improved public understanding of aquaculture, its diversity, and potential benefits and risks.

Acknowledgements

We thank the many people who contributed their expertise, knowledge, and time. The Strategic Plan for Federal Aquaculture Research is informed by many different viewpoints and agency mission areas that range from commercial production to restoration of fishery stocks and conservation of critical habitats. A principal goal is to develop a plan that is realistic in priorities,

achievable over time, and that will inspire and coalesce stronger collaboration required among public, private, and non-governmental communities to advance aquaculture in the Nation as a public good. We also thank the many individuals and organizations that provided public comments in response to a Federal Register solicitation, which contributed many improvements and added focus on critical present and emerging needs. In addition, numerous members of the Interagency Working Group on Aquaculture provided valuable input. Lastly, we want to recognize the efforts of several OSTP liaisons to the IWG-Aquaculture during the development of this plan, including: Chavonda Jacobs-Young, Peter Schmeissner, Carlos Peña, and Sean Jones.

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EXECUTIVE SUMMARY

In 2012, consumers in the United States spent an estimated $82.6 billion on seafood, making the U.S. one of the top three seafood markets worldwide. Yet the domestic farm gate value of aquaculture products only approaches $1.3 billion annually. Thus, much of the U.S. demand is supplied by international imports. Current aquaculture productivity in the Nation is driven by annual Federal investments in research and development of approximately $100 million. Advancing and expanding this sector will provide the domestic production of greater seafood products and economic opportunities for the United States.

Aquaculture yields public benefits that extend beyond producers to directly impact consumers, and provides diverse ecosystem services. A sector of agriculture, aquaculture offers alternative farming in a variety of aquatic environments, from inland freshwater ponds to marine coastal and offshore waters. Aquaculture also provides an important tool used to enhance commercial and recreational fisheries, and to restore threatened and endangered species and habitats.

Congress and the Executive Branch recognized the importance of aquaculture with passage of the National Aquaculture Act in 1980 that stated, "It is, therefore, in the national interest, and it is the national policy, to encourage the development of aquaculture in the United States".

The Interagency Working Group on Aquaculture (IWG-A), under the National Science and Technology Council and the Office of Science and Technology Policy, developed the Strategic Plan for Federal Aquaculture Research to increase the overall effectiveness of Federal aquaculture research, technology transfer, and assistance programs.

This plan aligns with the Administration's outcome-oriented goals for multi-disciplinary research to accelerate technology commercialization and innovation, and addresses key aims in the National Bioeconomy Blueprint, the National Ocean Policy Implementation Plan, and Administration guidance on regulatory efficiency. It is also consistent with the White House Rural Council's objectives of strengthening rural communities and promoting economic growth. In addition, the plan reinforces departmental and agency strategic guidance, such as the Department of Agriculture's Strategic Plan 2010-2015, the National Oceanic and Atmospheric Administration (NOAA) 5-Year Research and Development Plan 2013-2017, and policies on aquaculture from the Department of Commerce.

The plan proposes this vision statement for the future of aquaculture in the U.S.:

A globally competitive, technologically appropriate, and diverse aquaculture sector in the United States that meets increasing demand for seafood and products that are affordable and meet high standards for safety, quality, and environmental stewardship, with maximum opportunity for profitability and economic growth.

The purpose of this plan is to:

- Communicate Federal priorities for research, science, and technology development that encourage aquaculture in the Nation with the goal of building an industry that increases

seafood availability, jobs, economic opportunities, and recreational opportunities, while providing for the restoration and promotion of healthy aquatic ecosystems.

- Promote adoption and implementation of ideas, concepts, approaches, technologies, and capabilities to advance U.S. aquaculture production, and further establishment of technological and environmental leadership in aquaculture.

This plan includes 9 critical strategic goals, with outcomes and milestones that identify Federal agency and interagency research, science, and technology priorities over the midterm (5 years) that will support aquaculture development in the United States.

Strategic Goals

1. Advance Understanding of the Interactions of Aquaculture and the Environment
2. Employ Genetics to Increase Productivity and Protect Natural Populations
3. Counter Disease in Aquatic Organisms and Improving Biosecurity
4. Improve Production Efficiency and Well-being
5. Improve Nutrition and Develop Novel Feeds
6. Increase Supply of Nutritious, Safe, High-quality Seafood and Aquatic Products
7. Improve Performance of Production Systems
8. Create a Skilled Workforce and Enhance Technology Transfer
9. Develop and Use Socioeconomic and Business Research to Advance Domestic Aquaculture

The plan includes introductory material to provide background and perspective on the role and scale of aquaculture domestically and worldwide. It also highlights the potential for job creation and economic development through expanded domestic aquaculture.

While there is excellent research and technology development currently underway, the plan recognizes that multi-disciplinary research and coordination of Federal research programs are needed to improve competitiveness, production efficiency, economic viability, and long-term environmental sustainability through advances in genetics, nutrition, health, and technology.

The plan also discusses opportunities to develop industries to meet the growing demand for seafood and to respond to the challenges of climate change, including the effects on ocean chemistry. Finally, the plan urges more public-private sector collaboration and cooperation throughout the supply chain from aquaculture service industries to farms to markets that stimulate innovation and entrepreneurism and increased market opportunities for U.S. products.

INTRODUCTION

The IWG-A prepared the National Strategic Plan for Federal Aquaculture Research to identify Federal interagency research, science, and technology priorities, goals, and objectives over the midterm that will support aquaculture development in the Nation, as cited under law. This plan is not intended to serve as a development plan that addresses policies, regulations, financing, zoning, disaster assistance, crop insurance, or other issues that may impact incentives for development investment. However, aquaculture-related actions by Federal agencies and partners on research priorities will contribute to solving such regulatory and socioeconomic challenges. In addition,

this document is not an implementation plan with budget proposals and agency action details. Rather, the plan is intended to inform future Federal budget processes and agency level implementation plans for achieving these strategic goals.

Vision

A globally competitive, technologically appropriate, and diverse aquaculture sector in the United States that meets increasing demand for seafood and products that are affordable and meet high standards for safety, quality, and environmental stewardship, with maximum opportunity for profitability and economic growth.

Plan Framework

This plan addresses the critical need to increase the overall effectiveness of Federal aquaculture research, technology transfer, and assistance programs. While excellent research and technological development is currently underway, the plan recognizes that multi-disciplinary research and coordination of Federal research programs are needed to improve competitiveness, production efficiency, economic viability, and long-term environmental sustainability through advances in genetics, nutrition, health, and technology. The plan also urges more public-private 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. In particular, this plan is intended to:

- Communicate Federal priorities for research, science, and technology development that encourage aquaculture in the Nation, with the goal of building an industry that increases seafood availability, jobs, economic opportunities, and recreational opportunities, while providing for the restoration and promotion of healthy aquatic ecosystems.
- Promote adoption and implementation of ideas, concepts, approaches, technologies, and capabilities to advance U.S. aquaculture production, and further establishment of technological and environmental leadership in aquaculture.

The plan identifies nine strategic goals, each with outcomes and milestones:

1. Advance Understanding of the Interactions of Aquaculture and the Environment
2. Employ Genetics to Increase Productivity and Protect Natural Populations
3. Counter Disease in Aquatic Organisms and Improving Biosecurity
4. Improve Production Efficiency and Well-being
5. Improve Nutrition and Develop Novel Feeds
6. Increase Supply of Nutritious, Safe, High-quality Seafood and Aquatic Products
7. Improve Performance of Production Systems
8. Create a Skilled Workforce and Enhance Technology Transfer
9. Develop and Use Socioeconomic and Business Research to Advance Domestic Aquaculture

These strategic goals will help Federal agencies, with public and private sector partners, to build an interagency collaborative and multi-disciplinary research framework to meet the Nation's aquaculture priorities through coordination with the Office of Science and Technology Policy and the National Science and Technology Council.

This plan aligns with the Administration's outcome-oriented goals for multi-disciplinary research to accelerate technology innovation and commercialization and key aims found in the National Bioeconomy Blueprint,[1] the National Ocean Policy's Implementation Plan,[2] and Administration guidance on regulatory efficiency,[3] and it is consistent with the White House Rural Council objectives of strengthening rural communities and promoting economic growth.[4] The plan also adheres to departmental and agency strategic guidance, including: The Department of Agriculture's Strategic Plan 2010-2015,[5] The National Oceanic and Atmospheric Administration (NOAA) 5-Year Strategic Plan 2013-2017,[6] and The National Science Foundation's Empowering the Nation through Discovery and Innovation, NSF Strategic Plan for 2011-2016.[7]

In addition, the *2010 Dietary Guidelines for Americans* recommended that consumers increase seafood consumption.[8] A seafood diet offers a healthy protein choice for children to help reduce childhood obesity, which is an Administration priority.[9]

Solutions are required for aquaculture to overcome numerous critical challenges and to realize the opportunities for expansion of commercial enterprises, stock-enhancement programs, and species and habitat restoration. These solutions depend on the understanding and application of scientific knowledge, as well as strong public-private collaborative partnerships to optimize societal and scientific benefits from the Nation's collective capacity for research and technology development in aquaculture.

This plan was developed by an interagency team of Federal scientists and agency staff. The writing team for each strategic goal had representatives from the Departments of Agriculture, Commerce, and Interior. The teams consulted published literature and summaries of recent research priorities including, but not limited to, the following:

- A 2008 workshop on technical barriers to marine aquaculture in the United States co-sponsored by the National Institute of Standards and Technology and NOAA;[10]
- The NOAA/USDA Alternative Feeds Initiative;[11]
- The National Aquatic Animal Health Plan;[12]

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[1] Building a 21st Century Bioeconomy, Mary Maxon and Mike Stebbins, http://www.whitehouse.gov/blog/2011/10/12/building-bioeconomy (accessed 2 January 2012);
[2] National Ocean Policy Implementation Plan http://www.whitehouse.gov//sites/default/files/national_ocean_policy_implementation_plan.pdf
[3] Executive Order 13563 of January 18, 2011 Improving Regulation and Regulatory Review http://www.whitehouse.gov/sites/default/files/omb/inforeg/eo12866/eo13563_01182011.pdf
[4] White House Rural Council objectives of strengthening rural communities and promoting economic growth (http://www.whitehouse.gov/administration/eop/rural-council).
[5] Department of Agriculture, Strategic Plan, http://www.ocfo.usda.gov/usdasp/usdasp.htm
[6] http://nrc.oarhq.noaa.gov/CouncilProducts/ResearchPlans/5YearRDPlan.aspx
[7] National Science Foundation, Strategic Plan, http://www.nsf.gov/news/strategicplan/nsfstrategicplan_2011_2016.pdf
[8] U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Dietary Guidelines for Americans, 2010.* 7th Edition, Washington, DC: U.S. Government Printing Office, December 2010.
[9] http://www.letsmove.gov/white-house-task-force-childhood-obesity-report-president
[10] Browdy, C.L. and J.A. Hargreaves (editors). 2009. Overcoming Technical Barriers to the Sustainable Development of Competitive Marine Aquaculture in the United States. U.S. Department of Commerce, Silver Spring, MD USA. NOAA Technical Memo NMFS F/SPO-100. 114pp.
[11] The Future of Aquafeeds, http://www.nmfs.noaa.gov/aquaculture/docs/feeds/the_future_of_aquafeeds_final.pdf
[12] National Aquatic Animal Health Plan, http://www.aphis.usda.gov/animal_health/animal_dis_spec/aquaculture/

- USDA's 5-year aquaculture stakeholder workshop (hosted in 2008 and 2013 by USDA's Agricultural Research Service Projects and National Institute of Food and Agriculture, Regional Aquaculture Centers);
- The 2008 NOAA National Symposium on Shellfish and the Environment; [13]
- The Department of Commerce (DOC)[14] and NOAA[15] aquaculture policies (2011); and
- Priorities identified by the DOC Marine Fisheries Advisory Council and the NOAA National Sea Grant College Program, State governments and tribes, and industry, non-profit, scientific, and other associations and groups.

Public comments were solicited on the draft plan in a Federal Register notice published in July 2012. The plan incorporates many of the suggestions made via public comment.

Many public comments noted that the draft plan lacked detailed implementation actions and specific numeric goals. For the purposes of this plan, the strategic goals outlined are intended to provide targets and directions. Specific implementation planning for Federal action is needed, and alignment with this strategic plan will be identified in implementation documents.

One set of comments not addressed specifically in this plan focused on marine algal research. The commercial potential in this sector seems promising; however, the current scope of Federal research in this area is limited. We anticipate development in algal production for food and fuel could result in increased Federal investment. New factors and trends over the next 5 years will influence research investments based on commercial opportunities, markets and technological developments.

BACKGROUND

Role of Aquaculture

For purposes of this plan, aquaculture is defined as the propagation and rearing of aquatic organisms (for commercial, recreational, or public purpose) in controlled or selected environments. Commercial aquaculture contributed half of the world's seafood in 2012.[16] Aquaculture, both private and public, helps restore endangered, threatened, and depleted commercially and recreationally fished species and addresses essential fish habitat, shoreline protection, and water quality concerns (such as oyster restoration and aquatic plant and seaweed recovery activities). Regional planning approaches can support future marine aquaculture development, in harmony with other resource use issues, as described in the National Ocean Policy Implementation Plan for the National Ocean Council.[17]

A compelling case can be made for increasing scientific and technical knowledge for aquaculture to produce safe and nutritious seafood in the United States, create new jobs from the coastal

[13] NOAA National Symposium on Shellfish and the Environment, http://aquaculture.noaa.gov/pdf/shellfishsymp08.pdf
[14] Department of Commerce Aquaculture Policy, http://www.nmfs.noaa.gov/trade/DOCAQpolicy.htm
[15] NOAA Marine Aquaculture Policy, http://www.nmfs.noaa.gov/aquaculture/docs/policy/noaa_aquaculture_policy_2011.pdf
[16] FAO Fisheries and Aquaculture Department. 2011. World Aquaculture 2010. FAO Fisheries and Aquaculture Department. Technical Paper. No. 500/1. Rome, FAO. 105 pp.
[17] National Ocean Policy Implementation Plan. Op. cit. [4]

communities to the agricultural heartland, foster sustainable aquaculture practices, and enhance or restore wild fisheries and habitats. An increase in aquaculture and wild-harvest fisheries will help meet the growing demand for seafood, a food source high in healthful 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.

Aquaculture is now recognized as one of the most efficient ways to produce protein.[18] Aquatic species are highly resource-efficient, with feed conversion rates (amount of feed needed to produce a product) for fish and shrimp that compare very favorably with terrestrial animal production.[19] For example, mollusks and seaweeds take up nutrients from the surrounding water and require no supplemental feed. The United Nations Food and Agriculture Organization (FAO) projects that aquaculture will be critical to feeding a growing world population.[20]

Aquaculture Sector Status

Globally, aquaculture has evolved dramatically since Federal legislation was first enacted in 1980 and 1985[21]. While wild fish harvests have stabilized, aquaculture has driven growth of the seafood sector, influenced product diversity, and addressed both economic development and environmental conservation goals in aquatic ecosystems. The sector is driven by knowledge and technology and continues to innovate and adapt to societal needs for nutritious food, jobs, species enhancement, and species and habitat restoration.

Several factors and new trends may drive an increase in U.S. commercial aquaculture production. The U.S. has bountiful freshwater and marine natural resources, plentiful feed grains, world class aquaculture research infrastructures, and scientists, pioneers, and entrepreneurs to drive innovation. The seafood supply chain ranges from farmers and fishermen to upstream and downstream industries (feed and equipment manufacturing, harvesting processing, distribution, and retail outlets) to consumers.

The United States is now among the three largest seafood markets in the world. Aquaculture is becoming an increasingly integral source of safe, sustainable seafood for consumers worldwide as supplies from wild-capture fisheries remain flat. In 2011, U.S. consumer seafood expenditures were $57 billion in food service and $27.6 billion in retail sales for home consumption.[22] The top 10 species presently consumed domestically represent about 90 percent of the total U.S. seafood consumption; six of these species come from farmed or a mix of farmed and wild sources, including shrimp, salmon, and tilapia.

The United States and other countries are currently working to rebuild wild stocks of seafood. But, even if habitats are restored and well-managed wild stocks contribute more to the world supply of

[18] Hall, S.J., A. Delaporte, M.J. Phillips, M. Beveridge, and M. O'Keefe. 2001. Blue Frontiers: Managing the Environmental Costs of Aquaculture. The WorldFish Center, Penang, Malaysia.
[19] Torrisson, O., R.E. Olsen, R. Toresen, G.I. Hemre, A.G.J. Tacon, F. Asche, R.W. Hardy, and S. Lall. 2011. Atlantic Salmon (Salmo salar): The "Super-Chicken" of the Sea? Reviews in Fisheries Science, 19(3): 257-278.
[20] FAO Fisheries and Aquaculture Department. Op. cit.[17]
[21] National Aquaculture Act, Op. cit.[1]
[22] Fisheries of the United States 2011, Current Fishery Statistics No. 2011, National Marine Fisheries Service, Office of Science and Technology, August 2012.

seafood, experts note that most of the future increase in seafood production will come from aquaculture.[23]

Increases in demand for aquaculture products, food security considerations, and job creation highlight the need for increased domestic development. Demand for seafood in the United States may grow as a result of a growing population and increased consumer awareness of seafood's health benefits (as long as demand is not dampened by higher seafood prices). The *2010 Dietary Guidelines for Americans*,[24] published by the Departments of Agriculture and Health and Human Services, recommends that Americans double their current consumption of seafood from a wide range of species as a healthy food choice.

Future supplies of seafood for U.S. consumers will largely come from a combination of increased domestic aquaculture production and imported aquaculture products. As the growing middle class in many emerging economies consumes more seafood, competition for quality seafood products will increase and these products may cost more, impacting seafood-dependent businesses and consumers. The growing global demand for seafood also presents an export opportunity for U.S. producers.[25]

Although current U.S. aquaculture production largely comprises fish and shellfish, the cultivation of marine algae is showing promise as a source of food, animal feed, cosmetics, health, biofuels, and other industrial products. Commercial aquaculture also produces baitfish and hatchery stock for recreational and commercial fishing, ornamental fish and other products for the aquarium trade, alligator and other species for leather goods, and various products and co-products for pharmaceutical, cosmetic, and industrial uses.

Despite these global and national trends that may drive an increase in U.S. aquaculture production, the United States today is a minor producer, supplying only about 5 percent of the seafood consumed domestically.[26] The Nation is increasingly dependent on imports to meet seafood demand. In fact, 80 to 90 percent (by value) of the seafood that Americans eat is imported, creating a seafood trade deficit nearing $11 billion in 2012. Approximately 50 percent of this seafood is from aquaculture and 50 percent from capture fisheries. [26] Compared with U.S. manufacturing, agriculture, and fisheries, commercial aquaculture is relatively small and at an early stage of development. The annual farm gate sales of private domestic aquaculture production approached $1.3 billion in 2010.[27]

Aquaculture also supports commercial and recreational fisheries and fisheries restoration. Private and public salmon hatcheries release juvenile fish that are later caught in capture fisheries and supply about 40 percent of the commercial catch of salmon around Alaska and more than 80 percent of catches off the Washington, Oregon, and California coasts. These hatcheries use fish

[23] FAO Op. cit.[17]
[24] U.S. Department of Agriculture and U.S. Department of Health and Human Services. Op.cit.
[25] See for example, USDA Foreign Agricultural Service GAIN Report No CH11853, "Demand for high-end U.S. Seafood in South China remains strong" December, 7, 2012.
[26] Department of Commerce, NOAA Fisheries, Office of Science and Technology, US Foreign Trade, Current Fisheries Statistics No. 2010-2, Imports and Exports of Fishery Products Annual Summary, 2010. http://www.st.nmfs.noaa.gov/st1/trade/documents/TRADE2010.pdf (accessed 3 January 2012).
[27] Fisheries of the United States 2011. Op cit.[23]

culture during the critical early life rearing stage before releasing juvenile fish into the natural environment for stock enhancement and restoration programs.

In 2006, more than 40 million licensed anglers generated over $46 billion in retail sales with a $115 billion impact on the Nation's economy, creating employment for more than 828,000 people and stimulating local businesses.[28] Many of these anglers, and the resultant economic benefits, depend on aquaculture for these hatchery reared and released fish. A recent economic study[29] estimated that the economic contribution of the private, recreation-based aquaculture industry in the western region of the United States is $1.9 billion annually, and supports 26,229 full-time jobs. The top trout hatcheries of the U.S. Fish and Wildlife Service produced fish that generated more than 3.9 million angler days, directly supporting more than 3,500 jobs with $325 million in total economic benefits to local economies.[30] The 123 million fish (all species) stocked by the National Fish Hatchery System generated more than 13 million angler days in 2006.[31] States in the Gulf of Mexico region have proposed new hatcheries to supplement recreational and commercial species and to restore species affected by the Deep Water Horizon oil spill. Hatchery stocks are also used to help restore Atlantic salmon in Maine, Pacific salmon and abalone on the West Coast, and native oysters and aquatic plants (marsh grasses) around the country.

Rationale for Science and Technology Capacity

Annual Federal expenditures for aquaculture research have averaged approximately $94 million in recent years, with a split of $40 million to extramural (Federal funds awarded to non-Federal entities) and $54 million to intramural programs (Federal funds allocated to Federal agency-supported research programs). These funds support core research capabilities in universities and Federal facilities and small businesses that solve critical problems and generate new technologies and better practices. While there is currently excellent research and technology development ongoing in Federal, university, and private research facilities, the plan recognizes that multi-disciplinary research and coordination of Federal research programs are needed to improve competitiveness, production efficiency, economic viability, and long-term environmental sustainability through advances in genetics, nutrition, health, and technology. There are also opportunities to develop new industries to meet the growing demand for seafood and to respond to the challenges of climate change, including the effects on ocean chemistry.
The primary rationale for Federal investment in aquaculture research, science, and technology development is to:

[28] U.S. Fish and Wildlife Service News Release, June 18, 2007. "*Preliminary Data Shows Americans Spent $120 Billion on Wildlife Related Recreation in 2006*. http://www.fws.gov/news/NewsReleases/showNews.cfm?newsId=3FCF5C3E-9D8A-682C-8154BFD40A3656AF (accessed 3 January 2012).
[29] Deisenroth, D., and C.A. Bond. 2010. *The Economic Contribution of the Private, Recreation-Based Aquaculture Industry in the Western United States*. Ft Collins, CO: Colorado State University. Available at: http://dare.colostate.edu/tools/aquaculture.aspx .
[30] "The Economic Effects of Rainbow Trout Stocking by Fish and Wildlife Service Hatcheries in FY 2004" by Dr. Jim Caudill, U.S. Fish and Wildlife Service, Division of Economics, Arlington, Virginia, December, 2005.
[31] Conserving America's Fisheries: An assessment of Economic Contributions from Fisheries and Aquatic Resource Conservation by Joseph John Charbonneau and James Caudill, U.S. Fish and Wildlife Service, Division of Economics, Arlington, Virginia, September 2010.

- Provide building blocks for jobs and economic growth:[32] The Federal government has a national interest in fostering technological innovation and transfer in partnership with industry entrepreneurs. [32] In fact, commercial aquaculture can create an estimated 75,000 to 100,000 direct and indirect jobs in the U.S. with every 1 million metric tons of production because of its significant economic multiplier factor;[33]
- Maintain research capabilities for basic and applied research so that today's investment in research drives future growth in productivity: New technologies will improve the effectiveness of inputs and integrate evolving technologies in new and better ways for high payoffs from Federal investments. Such growth is critical for future aquaculture sector expansion and competitiveness;
- Support effective extension education functions that help translate and deliver new knowledge for the public good and facilitates farm-level adoption of new technology;
- Fill research gaps in a sector dominated by small companies with limited ability to conduct research and advance the industry and address societal interests; and
- Support sound science for policy, regulatory, and permitting decisions that allow sustainable industry development: Scientific knowledge is required to understand the environmental effects of private and public sector aquaculture and mitigation options for sustainable development that is acceptable to the public.

STRATEGIC RESEARCH GOALS

Strategic Goal 1: Advance Understanding of the Interactions of Aquaculture and the Environment

The need for practices to increase seafood production in a way that avoids or minimizes harm to the environment, native species, and habitats resonates globally in all agricultural production sectors, including aquaculture. Successful aquaculture depends on healthy ecosystems that provide clean water and nutrient cycling to process or reuse 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, public awareness of environmental issues, 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 fulfilling their recovery and restoration missions.

Aquaculture production, like any human activity, can have a variety of potential impacts beyond minimally adverse effects on the environment, depending on species, production system, and location. In some cases, pathogens and parasites may be transferred from wild to farmed fish and vice versa, and protected marine mammals or migratory waterfowl may interact with aquaculture

[32]"Promoting Research and Development: The Government's Role" Chairman Ben S. Bernanke, At the Conference on "New Building Blocks for Jobs and Economic Growth," Washington, D.C., May 16, 2011 http://www.Federalreserve.gov/newsevents/speech/bernanke20110516a.htm

[33]Knapp, Gunnar (2008). "Potential Economic Impacts of U.S. Offshore Aquaculture," in Rubino, Michael (editor). Offshore Aquaculture in the United States: Economic Considerations, Implications & Opportunities. U.S. Department of Commerce; Silver Spring, MD; USA. NOAA Technical Memorandum NMFS F/SPO-103. 263 pages.

activities. New technology and management approaches are now in use and are required to minimize or eliminate negative environmental interactions including impacts to water quality, benthic geochemistry, biodiversity, and interactions with protected species.

Outcomes

- Aquaculture that operates in harmony with healthy, productive, and resilient freshwater and marine ecosystems
- Science-based Federal agency policies, regulations, and permitting decisions concerning aquaculture that incorporate practical conservation measures
- New knowledge and tools to monitor, predict, and adapt to the effects of climate change and ocean acidification

Milestones

- Expanded science knowledge that provides the necessary ecological and technological data, tools, and analyses to: (1) effectively and efficiently improve and manage aquaculture development in harmony with species and habitat restoration; and (2) monitor, assess, and address any adverse and positive environmental effects of aquaculture
- Verified models and spatial planning tools for inland, coastal, and marine ecosystems that predict the carrying capacity for various cultured aquatic species, consider the cost and feasibility of ecosystem-level management to appropriately site aquaculture activities, and reduce or eliminate potential adverse environmental effects
- Innovative, efficient, improved designs and operating methods for aquaculture production systems that reduce energy and feed consumption per unit of output, avoid potential unacceptable adverse environmental effects, and generate net environmental benefits (e.g. incorporate use of irrigation water)
- Identification and expansion of ecosystem service benefits of commercial and public aquaculture (e.g., water quality and habitat restoration due to shellfish planting and harvest operations, shellfish restoration, and seaweed farming).
- Innovative approaches to sustain financing of aquaculture activities that create and maintain ecosystems services (e.g., nutrient trading)
- Ongoing monitoring and mitigation of the effects of climate change and ocean acidification on aquaculture and development of adaptation strategies

Strategic Goal 2: Employ Genetics to Increase Productivity and Protect Natural Populations

To support the growth of seafood consumption in the United States and worldwide, critical research and development needs include the domestication and genetic improvement of the aquaculture production traits of cultivated species. Also, as genetic changes are made in cultured populations, the nature of interactions and mating between escaped farmed species and wild populations in close proximity to them must be understood in order to minimize adverse genetic impacts. Aquaculture faces the challenge of domesticating and enhancing the agronomic traits of aquatic animals for commercial production, while learning best science-based practices to successfully integrate commercial interests with protective measures for natural populations.

Currently, fewer than 15 percent of all animals produced in aquaculture have been improved for aquaculture production through selective breeding; many juveniles or seed stocks are directly harvested from wild populations or are the offspring of wild parents. Unlike much of terrestrial agriculture, wild progenitor populations still exist for a wide variety of cultured aquatic organisms. In those few aquatic species that have been domesticated, genetic selection is only a few generations advanced. Furthermore, there is tremendous opportunity to apply genomic advances to agronomic improvement. Desirable production traits include disease resistance and fast, efficient growth, which means increased product yield with lower inputs and lower waste production.

Federal efforts for stock restoration, the recovery of imperiled species, and stocking for recreation programs currently strive to minimize genetic impact on wild stocks by ensuring that only genetically appropriate animals are released into native waters.[34] There are opportunities for public and private entities to raise aquatic species for public restoration and recreation purposes, in addition to products for commercial markets. Yet the genetic management of each type of population is different.

Outcomes

- The establishment of breeding programs and other genetic tools that can rapidly improve the agronomic, product quality and production traits of aquaculture species
- Conservation of genetic variation and diversity in wild populations
- Measure, monitor, model, and control the risks of the genetic impacts of cultured populations on wild stocks

Milestones

- Development and implementation of genetic improvement programs with multi-trait selective breeding for growth efficiency, disease resistance, and product quality that maximize production efficiency and environmental compatibility of aquaculture
- Defined distribution of genetic variation within and between populations of interest for commercialization, augmentation, restoration, or recreation. This will inform decision-making on which populations have the most potential for economic development or which natural populations are most sensitive to environmental perturbation and responsive to habitat restoration
- Development and refinement of genetic risk models to aid in science-based regulation and management of commercial and public aquaculture activities
- Development of techniques to reduce the risks of undesired genetic impacts on natural populations that can adversely impact sensitive native or endangered species or biodiversity in natural systems

[34] P. J. Paquet, T. Flagg, A. Appleby, J. Barr, L. Blankenship, D. Campton, M. Delarm, T. Evelyn, D. Fast, J. Gislason, P. Kline, D. Maynard, L. Mobrand, G. Nandor, P. Seidel, S. Smith. 2011. Hatcheries, Conservation, and Sustainable Fisheries—Achieving Multiple Goals: Results of the Hatchery Scientific Review Group's Columbia River Basin Review. Fisheries Vol. 36 (11): 547-561.

Strategic Goal 3: Counter Disease in Aquatic Organisms and Improving Biosecurity

Disease has the potential to induce economic and ecological losses across the aquaculture sector. It is essential to control endemic, emerging, and catastrophic infectious diseases that can cause commercial and environmental loss of aquatic animal and plant production. It is equally important to control potential transfer of disease between wild and farmed populations of aquatic organisms. The National Aquatic Animal Health Plan (NAAHP),[35] developed through the IWG-A, provides guiding principles and recommendations to industry, states, tribes, and Federal agencies on actions to protect the health of wild and farmed aquatic animals (finfish, mollusks, and crustaceans, etc.) and minimize the impact of disease when they occur.

While progress has been made in combating certain pathogens that can cause disease through vaccines and a limited number of approved animal drugs and chemicals, significant losses still occur in commercial and restoration aquaculture. Little is known about diseases of aquatic plants or seaweeds. The diversity of cultured aquatic species and associated pathogens and parasites is a significant challenge. Great demand exists for improving the survival, growth, vigor, and health of cultivated stocks through improved technologies and practices. For example, a critical need exists to develop validated techniques for early and rapid detection of many diseases in order to prevent and quickly respond to outbreaks and to facilitate safe and timely commerce.

Research is needed to improve the characterization of causative agents of disease, their diversity, and basic epidemiological traits such as host, vector, and geographical range. Further understanding of host immunity is needed to develop effective immuno-biologics, diet/feeds, drugs, pesticides, and genetic selection that offer broad protection and improve mass delivery systems for these agents. Molecular tools allow new and comprehensive ways to examine host immunity and disease resistance, while aiding in the production of vaccines and development of specific pathogen-resistant stocks. Advances in understanding and characterizing the microbial environments both within and surrounding the cultured organisms (metagenomics) will be useful in aquaculture settings.

Important targets for aquaculture animal health-related science and technology are to: (1) increase the understanding of disease transmission dynamics, including carrier states, pathogen, vector and parasite movements, and environmentally permissive factors, including internal and external microbial environments; (2) advance the understanding of the interactions between cultivated aquatic species and natural populations from an aquatic animal health perspective; (3) expand and standardize biosecurity practices within culture systems to reduce the spread of disease and optimize efficient disinfection; (4) identify therapeutics that effectively treat disease and biologics to prevent disease; and (5) develop surveillance and certification systems that provide reliable information on disease status that enable low-risk animal movement.

Outcomes

[35] National Aquatic Animal Health Plan, Op. cit.[13]

- Biosecurity practices and measures for commercial farms and hatchery operations to prevent pathogen introduction and reduce losses due to disease outbreaks
- Reduction in the risks of potential disease transmission between aquaculture operations and wild stocks and the environment
- Improved surveillance and diagnostic technologies
- Characterization of disease-causing agents, including genetic diversity, host and geographic range, and variation in pathogenesis and pathogenicity
- Improved understanding of immunity using molecular tools and development of effective vaccines, drugs, and probiotics
- Enhanced public-private partnerships to identify, evaluate, and approve new vaccines and aquatic animal drugs

Milestones

- Increased availability of rapid, efficient, inexpensive, sensitive, and specific diagnostic and surveillance assays for detection and control of diseases to improve aquaculture production, ensure biosecurity, maintain and expand market access for aquatic animals in domestic and international trade, and serve restoration efforts
- New tools to characterize pathogenic agents in terms of host specificity and geographic range
- New tools to identify and characterize host defense mechanisms important in immunity and to compare animals with resistant/susceptible phenotypes
- Increased availability of well-designed, safe, and effective vaccines; new approved animal drugs; registered pesticides; and new probiotics

Strategic Goal 4: Improve Production Efficiency and Well-Being

Efficient, 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 market demands. Defining optimal conditions requires a comprehensive understanding of the physiology of early development, growth, stress response, and reproduction. Achieving the desired partitioning of nutrients into the competing systems of muscle development, digestive metabolism, health maintenance, and reproductive development 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 adverse impact on animal or plant well-being that leads to poor health, sub-optimal growth and production efficiency, poor product quality, and excess waste.

Outcomes

- Improved reproductive efficiency and early life-stage development methods to enhance survival and juvenile availability
- Enhanced feed efficiency, reduced feed costs, improved growth and nutrient retention, and reduced production of waste
- Novel tools to define and reduce stressors on fish well-being
- Models to facilitate both production of target sized organisms and the ability of producers to respond to changing market opportunities and trends

Milestones

- Expanded choices of commercially viable species to meet production environment and market demands
- Efficient growth and feed use to lower input costs and reduce loss of nutrients to the environment, thus improving environmental sustainability and profitability
- Improved animal well-being and product quality
- Practices to enable efficient production of target sizes in changing markets

Strategic Goal 5: Improve Nutrition and Develop Novel Feeds

Although supplies of the key aquaculture feed ingredients—fish meal and fish oil—have been relatively constant for more than 30 years, these resources are limited. Aquaculture worldwide currently uses the majority of available marine fish oils and fish meals. Therefore, if finfish and shrimp aquaculture is to increase worldwide, alternatives to marine fish meal and fish oil must be found. Also, feed ingredients need to be used more efficiently.

There are about 40 essential nutrients needed by all animals including vitamins, dietary minerals, essential fatty acids, and essential amino acids. These nutrients can be provided by a number of alternative ingredients. Alternative sources of protein and oil, for example, include feed ingredients used in livestock and companion animal feeds, novel byproducts from other industries, underutilized resources, or completely novel products. Existing commodities that have the potential for greater use in aquafeeds include protein concentrates from grains or oilseeds and byproducts from animal and fish processing. Novel byproducts from other industries include proteins recovered from biofuel production or single-cell proteins produced from inexpensive carbon sources. New products with potential for feeds include meals produced from worms, insects, and marine invertebrates, and meals and oils from micro-algae and seaweeds. Obtaining U.S. Food and Drug Administration approval of new aquatic animal feed ingredients will be critical for the development and use of novel ingredients.

Economics drive feed ingredient choices. Feed costs account for about 40 to 70 percent of the variable cost of finfish and shrimp culture. A global challenge is to identify novel feed ingredients and develop nutritionally complete diets that support optimal performance and health. Prepared feeds are the main source of essential nutrients necessary for optimal growth, reproduction, and health in commercially produced aquatic animals. Care must be taken to ensure that feeds support the health and performance of the cultured aquatic animals as well as confer the human health benefits of eating seafood. The potential for environmental impacts of the feeds or feed metabolites must also be considered.

Many of the human health benefits of seafood consumption stem from the long-chain, highly unsaturated omega-3 fatty acids found in many seafood products. These fatty acids, found in marine fish processed for fish meal and fish oil are not produced by these forage fish themselves, but rather by marine algae. The long chain omega-3 fatty acids then accumulate through the food web and become stored in aquatic animals after their consumption of prey and food items containing these fatty acids. The feeds produced and provided to cultured animals can be prepared to contain target levels of these fatty acids and other nutrients. Fish meal and fish oil can be

screened and, if necessary, further processed to remove contaminants such as polychlorinated biphenyls and heavy metals.

Outcomes

- New protein and oil alternatives for cultured aquatic animals to complement and reduce reliance on wild caught marine fish
- Feed and ingredient manufacturing systems to accommodate use of non-traditional ingredients
- Formulated diets that support optimal performance throughout the complete life cycle and across traditional and new species of commercial and restoration interests
- Determination of the consequences of changes to aquatic animal diet composition on consumer acceptance, human health and nutritional benefits, and environmental impacts

Milestones

- Increased availability of complete diets for traditional and new aquaculture species, with reduced reliance on marine fish meal and fish oil, and exploitation of new and improved feedstuff products and co-products made in the U.S.
- Development of feeds that define and support the nutritional value of fish and shellfish to human health and well-being
- Increased number and types of ingredients available to feed manufacturers
- Increased number of species with defined nutritional requirements to optimize the development of new species-specific commercial diets

Strategic Goal 6: Increase the Supply of Nutritious, Safe, High-Quality Domestic Seafood

Aquaculture food products contribute proven nutritional and health benefits to American consumers. Increasing evidence from human nutrition and medical research support the health benefits of seafood consumption. For example, positive health outcomes of seafood consumption include improved cognitive and cardiovascular function. Thus, the increased consumption of farmed and wild seafood supports national priorities to reduce obesity, early childhood diabetes, and the risk of chronic diet related disease. Yet the price and availability of seafood for U.S. consumers could be disrupted due to the low level of domestic seafood production, dependence on imported products, and increasing international demand for seafood. Increasing domestic production is needed to ensure U.S. food security generally and seafood security specifically, and to reduce the $11 billion seafood trade deficit. Given the health benefits of eating seafood, a dependable supply is also a national public health issue.

Outcomes

- Increased domestic supply of affordable and nutritious farmed seafood that meets U.S. food standards for safety and nutritional value
- Improved consumer understanding of the nutritional and sensory value, quality, and safety of farmed seafood to encourage acceptance and consumption
- Improved understanding of the factors and attributes that drive consumer preferences for aquaculture foods to align new products to consumer preferences

- Innovative methods, technologies, and approaches to improve product processing and tracking, shelf-life, and packaging that promote product quality, food safety, and human health
- Analytical methods for affordable, rapid detection of microbial and biological toxins, chemical residues, and human pathogens of highest concern for farm-raised products

Milestones

- Increased consumption of domestic aquaculture products
- Increased availability and diffusion of research-based information on the nutritional and quality attributes of aquaculture food products

Strategic Goal 7: Improve Performance of Production Systems

Production systems for aquaculture in the United States include pond-based systems (e.g., catfish and crawfish production); raceway systems (e.g., rainbow trout); near-shore and offshore net-pens and cages (e.g., Atlantic salmon); hatcheries (e.g. Pacific salmon); intertidal, off-bottom, and long-line coastal shellfish production; freshwater and marine algae (including seaweed) production systems; and recirculation systems (e.g., salmon, yellow perch, tilapia, ornamental species, and oyster spat). Significant opportunities exist to improve the performance and productivity of aquaculture production systems through advanced innovative engineering, as well as new devices and technologies. There is significant potential to adapt current commercial technologies and engineering solutions from other sectors of the economy, such as municipal wastewater treatment, manufacturing, medicine, information technology, and energy that can be integrated into aquaculture systems to improve productivity and efficiency.

Outcomes

- Cost-effective production systems and culture technologies to increase yield with *reduced inputs (feed, freshwater, and energy)*
- *Performance of aquaculture production systems that is compatible and integrated with desired animal well-being conditions and ecological factors*
- *Innovative systems and commercial scale demonstrations with field trials that measure economic and environmental outcomes to facilitate adoption by farmers and companies*

Milestones

- Increased production efficiency and reduced production and operating costs from technological innovations in engineering design, rearing, feeding, transporting, and harvesting fish and shellfish
- Development of systems that require less water, feed, and energy resources to contribute to sustainable intensification of aquaculture production
- Improved effluent treatment technologies to significantly reduce or eliminate wastes and the escape of established and potential aquatic nuisance species of concern
- Advances in aquaculture production systems that contribute to ecosystem services, species restoration, and stock enhancement for commercial and recreational fishing

Strategic Goal 8: Create a Skilled Workforce and Enhance Technology Transfer

U.S. Aquaculture depends on progressive science and technological innovation to create jobs, compete in world seafood markets, meet environmental requirements, and meet evolving social expectations. Continued U.S. leadership in aquaculture science and technology development will require building human capacity in diverse scientific fields to find solutions to scientific, economic, social, and management challenges. Public education and understanding of aquaculture science and the performance of diverse aquaculture systems create a scientifically literate population leading to sound policy-making. Science-based information, integrated with information delivery systems, offers new outreach opportunities to the public and the aquaculture community.

The purpose of Federal and university extension education and technology transfer is to efficiently integrate ideas, inventions, and technologies developed with both public and private funds into the commercial and restoration aquaculture sectors. Unlike in some sectors, most support for aquaculture research and technology development originates from public funding sources. Encouraging private sector involvement through cooperative and collaborative research ensures the relevance of research investments. Federally-funded technology transfer is facilitated through cooperative research and technology development agreements with the commercial and non-commercial aquaculture community.

Research and extension scientists, private for-profit and non-profit businesses, professional societies, and industry associations all share a need for timely information exchange on research outcomes and emerging issues. International scientific and industry exchanges can all accelerate technology development and diffusion at a global scale. New public policy choices and consumer preferences also raise new technology questions and drive the direction of future curriculum development and educational needs. The long-term development and sustainability of aquaculture will be determined, in part, by training scientists and technicians; effectively connecting science, industry, and society; and using innovations in education and technology transfer.

Outcomes

- New teaching tools and technologies that enhance and stimulate aquaculture education and training
- Technology transfer through integrated research, demonstration projects, and extension and education programs
- Effective communication strategies to disseminate best-available, science-based knowledge, tools, and technologies to reach target stakeholders including farmers
- Assessment of the trends and needs in domestic post-secondary education and training specific to aquaculture

Milestones

- Development of a prepared and trained workforce with specialized skills to support future technology driven industry growth

- Full use of effective technology transfer mechanisms such as patents, cooperative research and technology development agreements, licensing agreements, public-private partnerships, business incubators, demonstration farms, and extension education partnerships to encourage the co-development of future generations of technologies
- Enhanced dissemination and use of new information and communication technologies to provide timely, objective, science-based knowledge regarding aquaculture
- Completed national assessment of aquaculture education at post-secondary institutions in the United States

Strategic Goal 9: Develop and Use Socioeconomic and Business Research to Advance Domestic Aquaculture

As interest in aquaculture for commercial use, wild species enhancement, and restoration increases, so too has debate about the potential economic and social effects of aquaculture. In addition, the economic viability of domestic aquaculture continues to be constrained by regulatory, environmental, economic, social, market, industry, and technological factors that have been cited since the 1980s.[36,37] Economic and social challenges can include complicated and uncertain regulatory processes, market competition affecting domestic seafood product prices that affect both aquaculture farmers and fishermen, competition with other users of aquatic resources, and diverse cultural traditions and values.

Global market forces create economic and social pressures on aquaculture. Globalization has affected U.S. seafood markets beyond the increasing trade deficit. A significant, but difficult to quantify, percentage of imported aquaculture products can be attributed to the diffusion of U.S. science and technology as well as specialized equipment, exported feeds and grains, and capital investment. American consumers have benefited from lower-priced, abundant seafood, imported from more than 125 countries, and in many cases now available year-round due to aquaculture. U.S. equipment suppliers, feed manufacturers, and foodservice and retail companies have also benefitted from foreign business and investments and imported products; but reliance on imported seafood has costs and risks.

The United States has not captured the economic opportunity of the production and processing segment of the seafood value chain or the opportunity for added employment in these sectors. Concerns have also been raised with regard to food safety, environmental impacts, and the social effects of farming practices in some countries. In addition, some U.S. aquaculture producers (e.g. catfish) have been affected by low-cost imports of substitute products.

Some aquaculture activities operate in public waters rather than on privately owned property. Securing approval for a new commercial or restoration aquaculture project in public waters can be difficult, costly, and lengthy. Many competing uses for public waters, including tourism and

[36] National Research Council. 1978. Aquaculture in the United States: Constraints and Opportunities. A report of Committee on Aquaculture, Board on Agriculture and Renewable Resources, Commission on Natural Resources, National Academy of Sciences. 123 pp.
[37] Jensen, G.L. 2007. The evolutionary role of Federal policies and actions to support the sustainable development of aquaculture in the United States. Pages 179-207 *in* P.S. Leung, C.S. Lee and P. O'Bryen, editors. Species and System Selection for Sustainable Aquaculture, Blackwell Publishing, Ames, Iowa.

recreation, fishing, shipping, oil and gas facilities, and marine protected areas may further impede opportunities for aquaculture.

The economic and social value of aquaculture for enhancement and restoration purposes and collaboration among commercial, enhancement, and restoration aquaculture interests need to be better integrated. For example, State, Federal, tribal, non-profit, and commercial hatcheries (i.e. aquaculture facilities) produce fish and shellfish for release to enhance commercial fisheries (e.g., pink and chum salmon in Alaska); supply recreational species (e.g., salmon, trout, bass, and redfish); restore endangered, threatened, or imperiled species (e.g., salmon, trout, paddlefish, abalone, and corals); rehabilitate habitat (e.g., oysters, aquatic vegetation, and seaweeds); and mitigate for public fisheries lost as a result of water projects. These hatcheries create substantial economic value or generate monetary and nonmonetary benefits via species and habitat restoration. Although some programs have been quantified, the total economic value of captive propagation and stock enhancement in the United States has not been estimated.

Outcomes

- Identification of key regulatory, policy, socioeconomic, and environmental constraints to the improvement of the economics of commercial aquaculture and public stock enhancement and restoration in the United States
- Economic models to evaluate the relative cost and value of major components of aquaculture production, such as feed, survival, transport, harvest, processing, value-added processing, distribution, and marketing
- Collaborative opportunities among the aquaculture industry, the commercial fishing industry, and the conservation community (e.g. product marketing and employment crossover)
- Socioeconomic models to assess and report economic and social impacts of U.S. aquaculture in job creation and economic, environmental, and social development terms

Milestones

- Socio-economic research that informs Federal policy and management actions; land use or coastal zoning and marine spatial planning; economic incentive programs such as revolving loan, loan guarantee, or insurance programs; public-private partnerships; and outreach and education efforts
- Development of agricultural economic sensitivity analyses for major aquaculture species that inform existing models and indicate research priorities
- Market research that enables aquaculture producers to better respond to major trends affecting the profitability or competitiveness of U.S. aquaculture businesses
- Expanded seafood market demand that is met by complementary increases in domestic aquaculture and capture fisheries
- Assessment of the monetary and non-monetary benefits of Federal stock enhancement programs aimed at species and habitat restoration

PLAN IMPLEMENTATION GUIDELINES

The IWG-A, under the National Science and Technology Council, will serve as the coordinating agent for implementation actions that will emerge from this plan, as defined in its mission to

"increase the overall effectiveness and productivity of Federal aquaculture research, technology transfer, and assistance programs," as established by the National Aquaculture Act of 1980.[38]

Specific implementation actions include the following:

- The IWG-A, with support from the National Science and Technology Council, will develop and implement measures to improve coordination and cooperation and lower organizational barriers among departments and agencies to maximize available Federal government resources for public value.
- The IWG-A will promote and facilitate the exchange of technologies and breakthroughs between departments and agencies to maximize the effectiveness of Federal aquaculture research and technology development investments and effective outreach to maximize public value.
- Federal agencies will develop specific implementation plans to align critical Federal assets and programs with priorities identified in this plan.
- Federal agencies will identify the most critical assets needed to maintain a core capacity and competency for the Federal role in research and technology development based on needs of the broader user community.
- Federal agencies will engage industry, academia, and other non-Federal stakeholders in Federal aquaculture research and technology development.
- Federal agencies will improve the dissemination of Federal research and technology development outcomes. Federal agencies will identify and promote innovative policies, regulations, and approaches that complement and enhance Federal research and technology development investments to realize applications in aquaculture activities and field operations.

APPENDIX A

The National Aquaculture Act of 1980, as amended[39], outlines government support and policy for aquaculture[40] development in the Nation by:

1. Declaring that aquaculture development is in the national interest;
2. Calling for the establishment and implementation of a national aquaculture development plan; and
3. Encouraging aquaculture activities and programs in both the public and private sectors of the economy that will result in increased aquaculture production, coordination of domestic aquaculture efforts, conservation and enhancement of aquatic resources, and creation of new industries and job opportunities.

The legislation emphasizes the need for government-wide coordination of national activities regarding aquaculture, and to this end, it established a Federal interagency aquaculture coordinating group through the Office of Science and Technology Policy that operates as the

[38] National Aquaculture Act, Op. cit.[1]
[39] The National Aquaculture Act (Public Law 96-362, 94 Stat. 1198, 16 U.S.C. 2801, et seq.) and the National Aquaculture Improvement Act (Public Law 99-198, 99 Stat. 1641)
[40] The Act defines aquaculture as the propagation and rearing of aquatic species in controlled or selected environments. For purposes of this plan, aquaculture is defined as the propagation and rearing of aquatic organisms for commercial, recreational, or public purpose.

Interagency Working Group on Aquaculture (IWG-A). Currently, the IWG-A exists within the National Science and Technology Council's Committee on Science's Life Sciences Subcommittee. One of the primary functions of the IWG-A is to increase the overall effectiveness of Federal aquaculture research, technology transfer, and assistance programs.