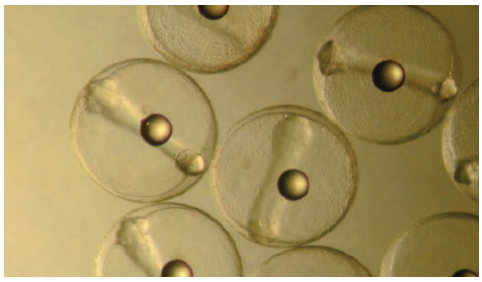



10-YEAR NOAA SEA GRANT AQUACULTURE VISION

March 2016

Prepared by the
Sea Grant Association

Sea Grant Association

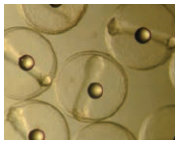
NOAA

Sea Grant

On the Cover

These juvenile Pacific geoducks, Panacea generosa, are large saltwater clams.

Photo Credit: Washington Sea Grant



Fertilized Summer Flounder eggs are a part of ongoing marine aquaculture research at Virginia Tech – Virginia Seafood Agricultural Research and Extension Center.

Photo credit: Michael Schwarz, Virginia Seafood Agricultural Research and Extension Center/Virginia Sea Grant

Virginia Sea Grant has funded marine ornamental industrial development at the Virginia Tech – Virginia Seafood Agricultural Research and Extension Center.

Photo credit: Stephen Urick, Virginia Seafood Agricultural Research and Extension Center/Virginia Sea Grant

A worker unloads harvested oysters from a vessel owned by Bloom Oyster Company in Norwalk, Connecticut.

Photo credit: Connecticut Sea Grant

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10-YEAR NOAA SEA GRANT AQUACULTURE VISION

March 2016

NOAA Sea Grant's 10-Year Aquaculture Vision: Sea Grant's integration of research, outreach and education will be instrumental in creating and applying aquaculture products, tools and services to foster the expansion of a sustainable U.S. marine and Great Lakes aquaculture industry.

INTRODUCTION

For nearly 50 years, the National Oceanic and Atmospheric Administration's (NOAA) National Sea Grant College Program (NSGCP) has invested in the development of sustainable marine and Great Lakes aquaculture businesses. For example, a $26-million investment in aquaculture research and technology transfer from 2012-2015 led to an economic impact of $200 million and included the creation or retention of 8,000 jobs (personal communication, Chris Hayes, National Sea Grant Office).

Sea Grant will likely be investing $50 to $100 million in aquaculture research and technology transfer over the next 10 years. A clear vision will help guide strategic investments to support and expand the aquaculture industry. In March 2015, the Sea Grant Association established a committee to develop a 10-year vision for aquaculture investments by NOAA's NSGCP. The purpose of this 10-year vision is to (1) determine Sea Grant's most appropriate roles over the next 10 years, and (2) identify priority research and outreach strategies leading to sustainable economic development, environmental conservation and social well-being.

The remainder of this document describes Sea Grant's 10-year aquaculture vision.

BACKGROUND

The U.S. government has invested in developing the country's aquaculture industry for decades. Recently, the White House and Congress placed additional emphasis on aquaculture development. They outlined plans and implemented strategies to accelerate technology development and increase U.S. aquaculture production (NSTC, 2014; NOC, 2013; DOC, 2011; NOAA, 2011; NOAA, 2007).

Over the 50 years of its existence, NOAA's NSGCP has made substantial investments in aquaculture research and outreach. These investments have led to the creation of new industry sectors including abalone, clams, oysters, shrimp, striped bass, sturgeon, yellow perch and assorted marine finfish. Continued Sea Grant investments in research and sustained technology transfer will help existing businesses to become more sustainable and significantly advance current production level species and new types of shellfish, finfish and crustacean aquaculture. Sea Grant's past investments have had positive and significant impacts on small businesses that have taken advantage of Sea Grant information, tools and services. Wise future investments in various areas, such as animal health, business management, economics, genetics, husbandry, law and policy, nutrition, production systems and reproduction, will allow Sea Grant to support the aquaculture industry.

Striped bass and their hybrids are popular food fish grown in multiple regions in of the United States. They are found on menus of fine-dining restaurants.

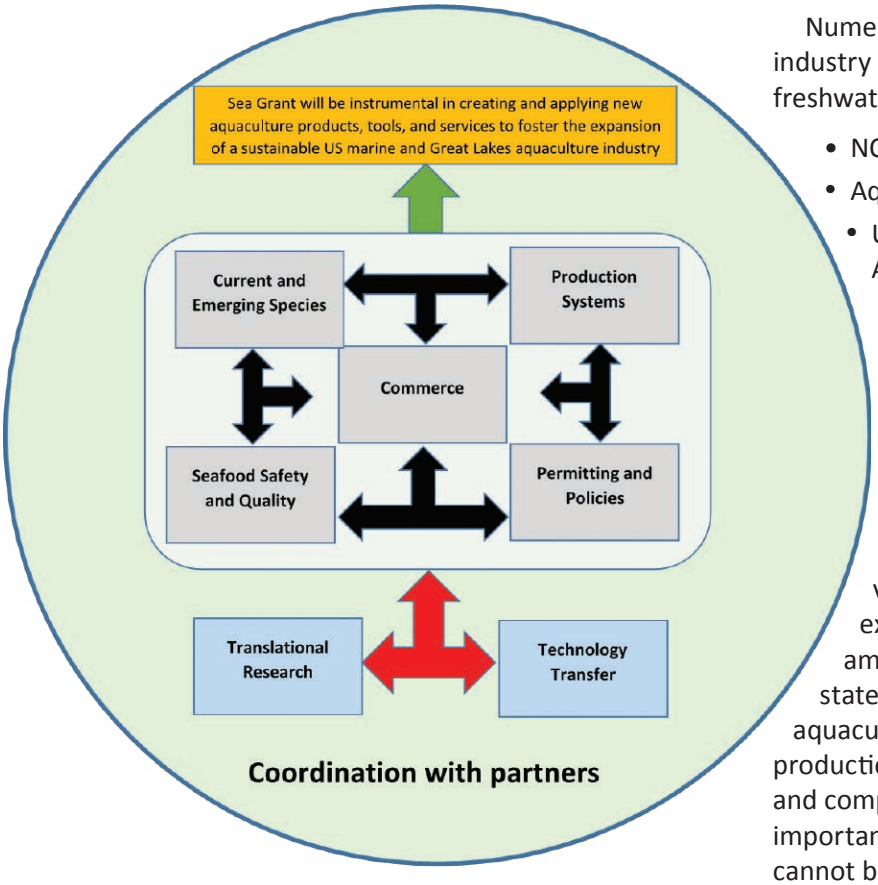


Figure 1. Conceptual model of Sea Grant's aquaculture vision

Other federal and state programs involved in aquaculture

Numerous federal and state-supported entities and industry associations invest significant resources in freshwater and marine aquaculture. Examples include:

- NOAA's Office of Aquaculture
- Aquaculture Interagency Working Group
- U.S. Department of Agriculture Regional Aquaculture Centers
- National Association of State Aquaculture Coordinators
- U.S. Food and Drug Administration
- U.S. Fish and Wildlife Service
- National, regional and local industry associations

Achieving Sea Grant's aquaculture vision will be impossible without nurturing existing partnerships and building new ones among the industry, academia, and federal and state programs. These partnerships will expand aquaculture production in a way that increases production and profitability, enhances the environment and complements our traditional fisheries. The importance of collaborating to the fullest extent possible cannot be understated and underpins Sea Grant's long-term vision (Figure 1).

PRIORITY FOCUS AREAS

The National Sea Grant Office and state Sea Grant programs contributed to the development of the five Sea Grant Aquaculture Focus Areas in this document.

The focus areas are:

- COMMERCE
- PERMITTING AND POLICIES
- CURRENT AND EMERGING SPECIES
- PRODUCTION SYSTEMS
- SEAFOOD SAFETY AND QUALITY

Twenty-two of the 33 state Sea Grant programs provided input for this vision document via an online survey during the summer of 2015. Sea Grant programs identified up to three national-level and three state-level marine and Great Lakes aquaculture issues. Follow-up questions guided the most appropriate response to the issue, the resources needed to respond and a description of a successful response.

Focus Area: *COMMERCE*

Priority

Provide economic and marketing research and associated outreach programming to increase the profitability and environmental sustainability of aquaculture businesses.

Background

The United States imports a majority of its edible seafood supplies, creating an annual seafood trade deficit exceeding $12 billion. The development of the U.S. aquaculture industry will require that it is competitive in the global marketplace.

On the domestic front, interstate commerce is challenging because many state and federal agencies are involved. Efficient trade across state lines will require increased coordination and a better understanding of regional and interstate commerce policies and legal issues.

Cost competitiveness and the use of proven business models, especially for indoor recirculating aquaculture systems (RAS), are two of the main bottlenecks to aquaculture development in the United States. While turnkey business models exist for outdoor systems, such as salmon in net pens, channel catfish in ponds, rainbow trout in raceways and shellfish in coastal environments, there are mixed results for indoor RAS for cobia, tilapia, hybrid striped bass, shrimp and other species. Appropriate business planning would result in job creation, reduced reliance on imported seafood, reinvigorated coastal and Great Lakes working waterfronts and diversified local seafood production. Sea Grant's past investments have had a positive and significant impact on small businesses that took advantage of Sea Grant information, tools and services.

What Sea Grant should do

- *Research*
  - Investigate international trade issues (e.g., effects of tariffs); identify major drivers of seafood trade into the United States; and analyze the economic impact of trade on the domestic seafood industry.

Recirculating aquaculture system tanks are used to rear Russian sturgeon at Atlantic Caviar and Sturgeon located near Lenoir, North Carolina.

Photo credit: Jeff Hinshaw, North Carolina State University

- Conduct economic analyses of using public waters for aquaculture, including an assessment of ecological and socio-economic impacts.
- Support comprehensive research and outreach targeting behavioral and consumer sciences; consumer perception and preferences; food safety; labeling and certifications; seafood demand studies; and promotion of local seafood.

- *Outreach*
  - Develop niche markets.
  - Coordinate and liaise among states and synchronize efforts among industry, government, and research and extension communities.
  - Develop optimal business models for diverse species, which would include hatcheries and grow-out for freshwater, low-salinity and marine species and systems.
  - Provide training on business planning and aquaculture business assessments related to capital investments, financing, insurance and risk.

Commercial oyster farmers work in Willapa Bay, Washington.

Focus Area: *Permitting and Policies*

Background

The aquaculture permitting process varies by state, culture system employed and purpose (research versus production). In addition, one aquaculture venture may need permits and approvals from multiple agencies at various levels of government. This situation forms a complex permitting landscape for agencies, research institutions and businesses to navigate. In addition, some agencies have a goal of ensuring that seafood in the marketplace is safe, wholesome and properly labeled. Other agencies aim to limit the risk of spreading aquatic animal diseases across state lines through commerce. As a result, agency activities regarding oversight of seafood commerce can be confusing due to overlapping and, at times, complex regulations. Aquaculture is already at the interface of industry and government regulations with some strong legal components. Interstate legal issues, in particular for shellfish and selected finfish, may adversely affect aquaculture operations if they prevent the implementation of desirable projects. It is important that there is a clear understanding of policies because of the diverse nature of aquaculture species and culture systems.

Photo credit: Washington Sea Grant

What Sea Grant should do

- *Research*
  - Identify common policies that will ensure uniform regional governance. Sea Grant should guide implementation of consistent interstate aquaculture rules that industry and government support.
- *Outreach*
  - Provide technical assistance to researchers working with the aquaculture industry to scale up technologies. Sea Grant Legal Programs should facilitate dialogue between government agencies, researchers and the aquaculture industry to increase understanding of current laws and policies, the needs of the aquaculture industry, and options for legal and regulatory reform.
  - Facilitate the development of model state laws and guidance to address typical legal and regulatory barriers to the aquaculture industry.
  - Conduct extensive outreach programs for aquaculture stakeholders to increase awareness of the legal responsibilities of state agencies as managers of public trust lands and waters, the challenges of balancing multiple uses of coastal lands and waters, and the legal authority of local governments to regulate land uses in certain zones.

Focus Area: *Current and Emerging Species*

Priorities

1. Increase domestic production of currently farmed and promising new species through research and extension efforts that support improvements in nutrition, reproduction, larval rearing and genomics to enhance growth, improve health and adapt to changing conditions, such as ocean acidification and climate change.
2. Improve hatchery production to produce reliable shellfish seed, macroalge seedlings and finfish juveniles to accelerate industry growth.

Background

Doubling U.S. aquaculture would create 50,000 jobs and increase farm gate value by more than $1 billion (Knapp 2008). Nash (2004) proposed a reasonable goal of increasing domestic U.S. aquaculture production by 1 million tonnes per year to reach a yearly farm gate value of more than $2 billion by 2025. The lion's share of this production, 760,000 tonnes, would have to be from finfish aquaculture of which 590,000 tonnes would be marine finfish. Additional production would be 47,000 metric tonnes from aquaculture of red swamp crawfish, *Procambarus clarkii*, and penaeid shrimp. Finally, shellfish production would increase 245,000 tonnes through aquaculture targeting American oysters, *Crassostrea virginica*; hard shell clams, *Mercenaria mercenaria*; Pacific oysters, C. gigas; Mediterranean mussels, *Mytilus galloprovincialis*; and blue mussels, *M. edulis.*

Photo credit: Michael Schwarz, Virginia Seafood Agricultural Research and Extension Center/Virginia Sea Grant

Sexing anesthetized wild cobia broodstock at Virginia Seafood Agricultural Research and Extension Center prior to transit to commercial land-based fish hatchery in a collaborative effort supported by Virginia Tech's Virginia Seafood Agricultural Research and Extension Center and Virginia Sea Grant.

Finfish

There have been significant advances in the husbandry and domestication of several promising new marine

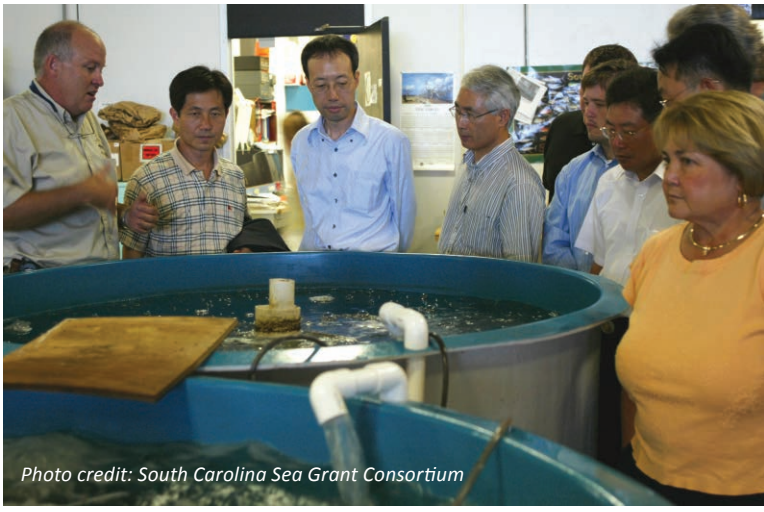


Photo credit: South Carolina Sea Grant Consortium

Wally Jenkins, left, of the South Carolina Department of Natural Resources, describes the red drum (Sciaenops ocellatus) stocking program funded by the South Carolina Sea Grant Consortium.

finfish species. Sea Grant should continue to support development of this industry sector. Promising species, such as red drum (*Sciaenops ocellatus),* Florida pompano (*Trachinotus carolinus),* Atlantic and Pacific amberjack species, (*Seriola dumerili, S. lalandi* and S. *rivoliana*), red porgy *(Pagrus pagrus*), cobia (*Rachycentron canadum*) and sablefish, (*Anoplopoma fimbria*) are all commercially grown with potential for significant increases in production. In addition, other species used for bait and marine ornamentals offer significant potential for business and conservation interests.

Crustaceans

There is potential to produce marine penaeid shrimp in high-density recirculating production systems close to high-value domestic urban markets. Increases in production of red swamp crawfish in ponds could also expand crustacean farming.

Molluscan shellfish

There is a common need for genetics research to improve yield, survival, growth, quality and safety of commonly cultured species, such as oysters, hard shell clams and mussels. Work in this area should consider the changing marine and estuarine environments caused by climate change.

While there are a number of potential emerging species, the following molluscan shellfish have shown promise as viable commercial candidates that warrant further research to improve production: Olympia oysters (*Ostrea conchaphila*), geoduck clams (*Panopea generosa*), sunray Venus clams (*Macrocallista nimbosa*), butter clams (*Saxidomus gigantean*), soft shell clams (*Mya arenaria*), purple-hinge rock scallops (*Crassadoma gigantean*), and razor clams (*Siliqua patula*).

For emerging molluscan species, there are critical research needs to optimize production in all stages, from hatchery through nursery and grow-out. In addition, adoption and commercialization of new species will benefit from extension support.

A sign at Southern Cross Sea Farms in Cedar Key, Florida, advertises aquacultured clams.
Photo credit: Florida Sea Grant

Photo credit: Connecticut Sea Grant

Sea Grant researcher Charles Yarish, center, and colleagues harvest kelp from a pilot underwater farm off Bridgeport in Long Island Sound in May, 2012.

Marine algae

The most valuable macroalgae are the kelps and a few species of red algae. The kelps are the largest of the macroalgae, and all have food, feed, extract, bioremediation, habitat and biomass market potential. There are many kelp species on the Atlantic and Pacific coasts. All have the same life cycles, and farming programs can use the same basic cultivation techniques. The other seaweeds with high cultivation potential, especially for food, feed and extract production, include the red dulse species (*Palmaria* spp.), nori or laver species (*Porphyra* spp.) and *Gracilaria* species. Research and development efforts are needed in the nursery phase for seed production (to include development of reliable seed stock, breeding, efficiency and density optimization), farm technology (to include sufficient and affordable moorings, harvest technology and biofouling mitigation), harvesting technology, processing technology and product development. Another area that will need research is food safety and analysis for seaweeds grown in different types of classified waters. All aspects of farming will require development of efficient culture methods to reduce the costs of production.

What Sea Grant should do

- *Research*
  - Develop sustainable alternative and emerging species including reproductive biology, nutrition and feeding, health, husbandry practices and other species-specific research.
  - Improve the efficiencies of existing marine and Great Lakes species.

- *Outreach*
  - Support the creation of collaborative, multidisciplinary research partnerships involving academia, private industry and NOAA and U.S. Department of Agriculture scientists to bring promising new species into commercial production.
  - Guide the use of sustainable alternative and emerging species.

Focus Area: *Production Systems*

Priority

Link industry needs to basic and applied research efforts, including establishing demonstration centers to develop and refine aquaculture systems and disseminate applied information to end users.

Background

The U.S. marine and Great Lakes aquaculture sector uses several production systems. In most cases, these systems are developed outside the United States or are non-standardized systems developed domestically. In addition, there is limited domestic research on system optimization and fewer demonstration efforts to transfer the existing research findings to the private sector. For example, the United States has largely developed recirculating aquaculture system technologies. However, producers typically do not have an available source of information to select the most appropriate system or assess the system's economics. Sea Grant should take the lead to develop production systems research and translate validated research to potential and established producers to enhance the sustainability and profitability of these systems.

Table 1 includes a list of current and emerging production systems used by the U.S. aquaculture sector and brief descriptions of information needed to enhance those systems.

Finally, as the U.S. marine aquaculture industry grows, there will be a need to adapt existing or develop new types of production systems for emerging species, such as seaweeds (marine macrophytes) and marine invertebrates (including ornamentals). There is also a need to develop energy efficient production systems, such as integrated multi-trophic aquaculture systems. The economic feasibility of commercial size operations must be demonstrated to encourage the growth of these sectors.

Species	Type of Production	Information Needs
Finfish	**Recirculating aquaculture systems (RAS)**	Comparisons among different systems. There is no template in place to guide potential and established producers in the selection of the best system for their particular needs.
	Offshore pen systems	Technology development for offshore aquaculture systems. Demonstration scale projects of offshore production systems using most appropriate species.
Finfish and Crustaceans (shrimp)	**Ponds**	Better information on the system dynamics of marine ponds. Better management strategies for brackish and saltwater shrimp ponds.
Crustaceans (shrimp)	**RAS-based raceway culture systems**	Improved production systems and management practices for producers.
Molluscan shellfish	**Surface and submerged gear**	Optimization of a variety of nursery and grow-out technologies including longlines, raft and floating container systems for large-scale production systems. Development of best management practices and examination of the use of alternative designs and materials.
Seaweeds	**Surface and submerged gear**	Improved production systems and management practices for producers. Development of new species.
All Species	**Reproduction and hatchery systems**	Improved hatchery production, larvae feeds and health for all species produced. Sustained technology transfer to commercial operations to ensure consistent supply of and economically viable production of high-health seed stock.

Table 1. List of current and emerging production systems used by the U.S. aquaculture sector and a brief description of information needed to enhance those systems.

What Sea Grant should do

- *Research*
  - Develop new and optimize existing culture systems and practices.
  - Develop new and optimize existing integrated multi-trophic systems for marine aquaculture development. Ensure that outreach is a significant and well-funded aspect of each project.
  - Improve the efficiency of technology and input use in production.
  - Improve the economics of commercial scale production in the United States
  - Develop cost-saving technologies for production, harvest and processing.
- *Outreach*
  - Establish a network of regional aquaculture demonstration centers where systems and culture practices can be refined, validated and demonstrated to the private sector. These centers should be encouraged to foster commercially based collaborative research and development where the private sector can test production technologies on a small scale to evaluate investment risks for commercial scale production.
  - Ensure that outreach and technology transfer is a significant and well-funded aspect of each project.

People learn about oyster aquaculture at a business training area in Alabama.

Focus Area: *Seafood Safety and Quality*

Priority

Conduct research and provide technical assistance and outreach to aquaculture producers, resource managers, scientists and consumers to ensure the safety and quality of sustainably cultured seafood products to meet public demand.

Background

There are multiple human health and seafood safety issues facing U.S. aquaculture, and they include:

- Maintaining existing or developing new regulatory requirements to ensure a safe and sustainable seafood supply for export and import.
- Developing rapid, affordable and FDA-approved tests to detect human pathogens and toxins.
- Identifying and reducing impacts from existing and emerging contaminants and biotoxins.
- Enhancing product quality and consumer confidence.
- Managing a sustainable resource.

What Sea Grant should do

- *Research*
  - Develop or improve environmental monitoring tools, forecasting models and faster biotoxin analyses.
  - Assess rising concerns about bacteria and viruses, such as Vibrio species and norovirus, in a changing environment.
  - Develop value-added aquaculture products.
  - Improve the understanding of aquaculture interactions with wild stocks and the natural environment relative to diseases and other factors affecting product quality and sustainability.
- *Outreach*
  - Provide extensive consumer education programs on seafood quality and food security.
  - Continue Hazard Analysis Critical Control Point (HACCP) research, technical transfer and outreach to ensure a safe and wholesome seafood supply.
  - Conduct outreach and technical assistance regarding seafood contaminates.
  - Strengthen consumer confidence and build markets by working with seafood handlers, such as meat

cutters and fishmongers, to improve seafood quality and safety and provide information to consumers.

- Guide development of product diversity.
- Provide technical assistance and outreach to develop value-added aquaculture products.
- Provide technical assistance and outreach to improve the understanding of aquaculture interactions with wild stocks and the natural environment relative to diseases and other factors affecting product quality and sustainability.

California Yellowtail (Seriola dorsalis) is a popular species proposed for farming in federal waters off San Diego, California.

AREAS FOR INVESTMENT TO ACHIEVE THE VISION

Investments in an integrated program of research, outreach and partnership building and a balanced focus area portfolio will enable Sea Grant to achieve its vision. Table 2 provides a matrix summarizing recommended investments.

Focus Area	Areas to Invest Resources		
	Research	Outreach	Partnership
Commerce	Detailed economic analysis of cost of production for various species and systems.	Business and marketing worKshops.	Nurture partnerships with ongoing marketing programs with industry organizations and other marketing efforts.
Permitting and Policy	Extensive background analysis of state laws and policies.	Law and policy workshops and facilitate dialogue among permitting agencies.	State and federal permitting agencies and the private sector.
Current and Emerging Species	Hatchery and seed stock production technologies and production protocols for emerging species.	Applied demonstration workshops, support outreach personnel to work directly with existing and new aquaculture producers.	Research institutions, agencies and the commercial sector.
Production Systems	Production system and emerging species hatchery and seed stock production technologies and production protocols.	Applied demonstration workshops and support outreach personnel to work directly with existing and new aquaculture producers.	Integrate and leverage existing infrastructure capacity at partner institutions to enhance outreach and demonstration capacity.
Seafood Safety and Quality	Develop new and enhance existing seafood safety tools and new products.	Develop new and enhance existing seafood safety services and technology transfer programs.	Develop new partnerships and leverage existing partnerships with seafood safety agencies (e.g. FDA and USDA).

Table 2. Areas to invest Sea Grant resources by focus area and broad research, outreach and partnership categories.

WHAT WILL HAPPEN BY ACHIEVING THE VISION

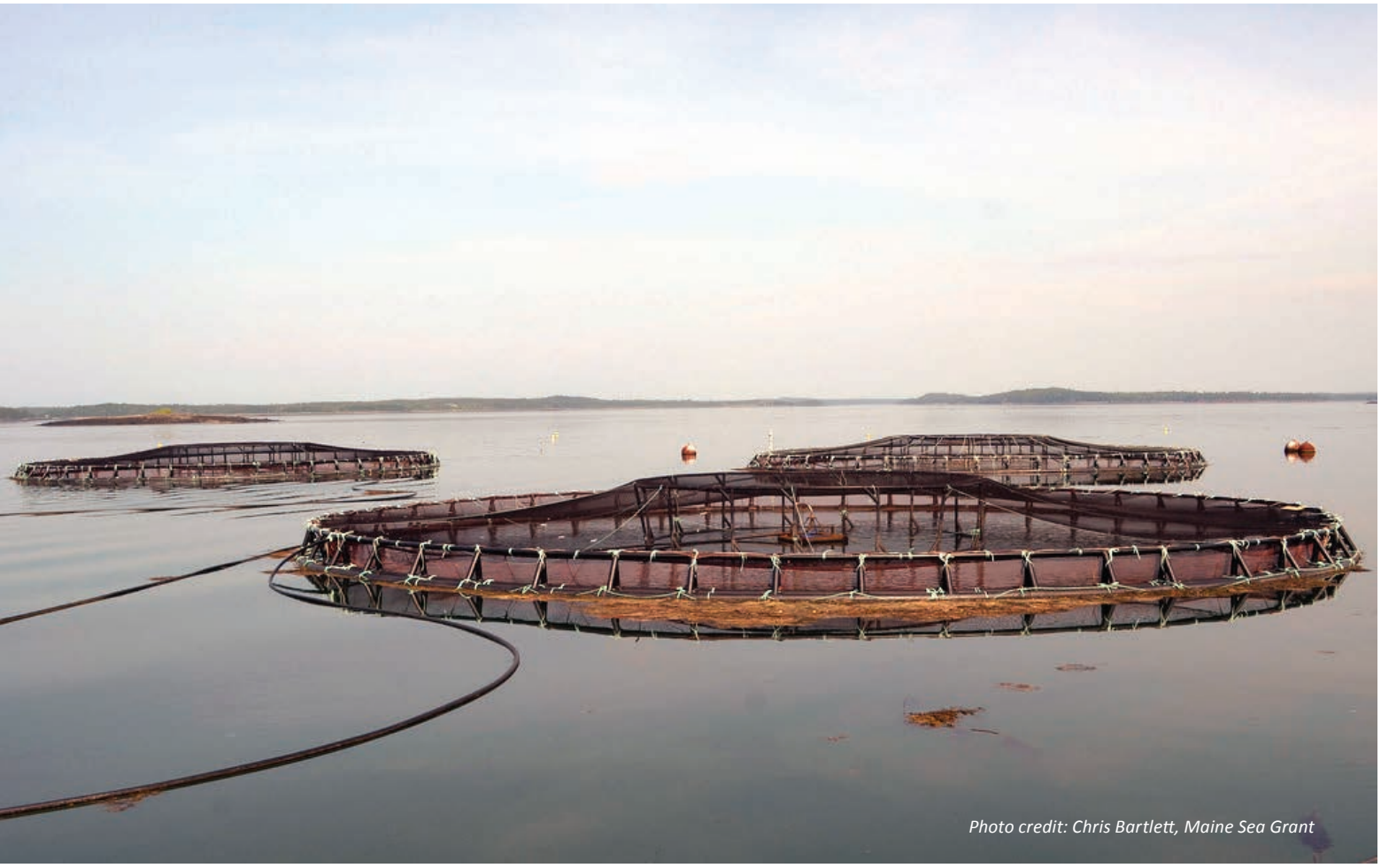
Realizing Sea Grant's aquaculture vision will lead to a vibrant U.S. coastal aquaculture industry able to augment traditional harvest and support fishing communities through increased employment and revenues. This, in concert with traditional capture fisheries, will increase domestic seafood production and maximize the economic, employment and health benefits of increased supplies of sustainable seafood.

Successful implementation of this vision document will INCREASE:

- U.S. jobs
- Aquaculture production
- Value and quality of products
- Exports of high-quality seafood
- New markets because of stronger and uniform product standards and better monitoring
- Seafood safety and security
- Seafood consumption and consumer confidence in farmed seafood
- Consistent and fair application of aquaculture laws and policies

Successful implementation of this vision document will DECREASE:

- Unemployment
- The national seafood trade deficit
- The number of illnesses from consumption of aquaculture products
- Legal barriers to implement new techniques



These Atlantic salmon aquaculture net pens are located in Lubec, Maine.

CONCLUSION

Achieving the aquaculture vision requires Sea Grant to continue to invest resources in high-priority areas identified by all stakeholder groups. The greatest return on Sea Grant investments will occur by following these principles:

- Cause no harm to the environment or the seafood industry.
- Focus on the small business community.
- Invest in priorities that target critical issues and needs as identified throughout the coastal United States, but allow maximum flexibility to address regional, state and local issues and needs relevant to the aquaculture industry.
- Support projects and activities that are multi-dimensional in scope and focus, address issues and opportunities holistically, apply an integrated mix of research, education, extension and/or communications approaches, and when applicable, directly involve stakeholders and the industry.
- Invest in geographically and topically diverse integrated aquaculture research and outreach efforts.

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Dr. Han-Ping Wang presents a fish in his genetically improved yellow perch line at The Ohio State University South Centers in Piketon, Ohio. In addition to faster growth, the fish have also shown higher survival rates than local unimproved fish in the current experiments.

Credit: Ken Chamberlain/Marketing & Communications Ohio State University

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MASGP-16-015. This publication was supported by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration under NOAA Award NA14OAR4170098, the Mississippi-Alabama Sea Grant Consortium and the Sea Grant Association. The views expressed herein do not necessarily reflect the views of any of these organizations.

Suggested citation: Sea Grant Association. 2016. NOAA Sea Grant 10-Year Aquaculture Vision. MASGP-16-015.