1) Title

Third Annual Report on Aquaculture and Policy in the United States of America for the 2015 U.S.-Japan Natural Resources (UJNR) Panel

2) Short Title

2015 U.S. Annual Report on Aquaculture for UJNR

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4) Keywords

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5) Abstract

The third United States (U.S.) National Report on Aquaculture for the 43rd U.S.-Japan Natural Resources (UJNR) Panel on Aquaculture overviews major policy items, current trends in aquaculture production, and other important developments currently affecting U.S. aquaculture.

Policy- NOAA is in the process of finalizing implementation of a Fishery Management Plan to permit aquaculture in federal waters in the Gulf of Mexico. The U.S. currently does not have a framework to permit aquaculture in the Exclusive Economic Zone, and this would be a first for the U.S., if it goes into effect.

Latest Topics- NOAA National Marine Fisheries Service (NMFS) is in the process of developing a strategic plan to guide all agency marine aquaculture activities. In 2016, NMFS will initiate a strategic review process for agency aquaculture science activities. NOAA continues to advance research on production methods and technologies for key species and tools to ensure sound management of the marine aquaculture sector.

Production Trends- The U.S. remains a relatively minor producer of aquaculture, ranking 14th globally in aquaculture production. In 2013, total U.S. marine and freshwater aquaculture production was 300,242 mt, valued at $1.4 billion, which was an increase in both value and volume over 2012. Aquaculture production in the U.S. is largely composed of catfish, crawfish, trout, salmon, oysters,

mussels, clams, tilapia, and shrimp. While U.S. aquaculture is remains largely composed of freshwater species (84% by volume), the U.S. marine aquaculture sector has continued to grow steadily at an annual rate of 5% per year by volume for the last five years (2008-2013).

6) Main Body of the Article

Introduction

The 2015 United States (U.S.) National Report on Aquaculture, which will be presented at the 43rd U.S.-Japan Natural Resources Panel on Aquaculture, overviews major policy items, current trends in aquaculture production of major aquaculture species, and other important developments affecting U.S. aquaculture.

Background

The U.S. imports over 90% of its seafood, over half of which is a product of foreign aquaculture. While aquaculture produces 50% of all seafood eaten worldwide, U.S. domestic aquaculture production remained low in 2013. The U.S. ranks 14th in global aquaculture production, behind countries with substantially less freshwater and marine aquaculture resources. Further development of U.S. aquaculture would increase domestic supplies of safe and sustainable seafood, as well as provide jobs and business opportunities in rural and coastal communities.

1. Policy

1.1 The Department of Commerce, NMFS, and Aquaculture

Marine aquaculture is an important part of the missions of the Department of Commerce (DOC) and the National Oceanic and Atmospheric Administration (NOAA). The DOC sees aquaculture as a way to create jobs and economic activity. A federal agency under the DOC, NOAA sees aquaculture as a critical component to meeting increasing global demand for seafood and maintaining healthy ecosystems.

The Office of Aquaculture is within the National Marine Fisheries Service (NMFS), a branch of NOAA. NMFS is involved in aquaculture from both science and policy perspectives: science to foster efficiency and sustainability and policy to enable marine aquaculture while ensuring environmental responsibility. Marine aquaculture is an increasingly important part of the NMFS missionby providing a growing amount of seafood to U.S. consumers supporting commercial and recreational fisheries, and helping restore species and habitat.

Aquaculture is garnering increasing attention from DOC, members of Congress, and the private business sector for its ability to provide economic opportunities (especially in fishing communities) and potential to grow more seafood domestically in a safe, sustainable way. In 2011, NOAA and the DOC released complimentary Aquaculture Policies supporting domestic production of seafood, maintaining and restoring healthy marine ecosystems, and creating employment and business opportunities.

The 2011 DOC and NOAA Aquaculture Policies can be found at:
http://www.nmfs.noaa.gov/aquaculture/policy/2011_policies_homepage.html.

1.2 The Inter-Agency Working Group on Aquaculture (IWGA)

The Inter-agency Working Group on Aquaculture (IWGA; formerly called the Joint Sub-committee on Aquaculture) is an inter-agency group under the auspices of the Life Sciences Sub-committee of the National Science and Technology Council housed in the White House. The purpose of the IWGA is to increase the overall effectiveness and productivity of federal aquaculture research, technology transfer, and technology assistance programs. Efficient, coordinated permitting processes will allow ocean industries, including commercial shellfish and finfish aquaculture, to save time and money and encourage economic growth without compromising federal agency responsibilities to protect health, safety, and the environment. Improved interagency coordination and less redundancy will reduce administrative waste and burden on federal agencies and reduce regulatory burden for industry.

Under the IWGA, an Aquaculture Regulatory Task Force (hereafter 'task force') was created in 2013 under the auspices of the National Aquaculture Act of 1980. The task force aims to implement permitting efficiencies for marine aquaculture in consultation and partnership with the National Ocean Council and the IWGA. The task force consists of the following federal agencies: USDA: ARS, NIFA, and APHIS; DOC: NOAA; HHS: FDA; DOI: USFWS; EPA; and the ACOE. The task force also includes the following organizations in the Executive Office of the President: National Ocean Council; Office of Management and Budget; and Office of Science and Technology Policy.

Agency Abbreviations:

ACOE: U.S. Army Corps of Engineers
APHIS: Animal and Plant Health Inspection Service
ARS: Agricultural Research Service
DOC: Department of Commerce
DOI: Department of the Interior
EPA: Environmental Protection Agency
FDA: Food and Drug Administration
HHS: Department of Health and Human Services
NIFA: National Institute of Food and Agriculture
NOAA: National Oceanic and Atmospheric Administration
USDA: U.S. Department of Agriculture
USFWS: U.S. Fish and Wildlife Service

1.3 Relevant Federal Laws Pertaining to Marine Aquaculture

The task force aims to implement regulatory efficiencies for marine aquaculture. Currently, the U.S. has a complex regulatory structure for marine aquaculture, leading to an often convoluted and time-consuming permitting process. For example, the initial start-up of a commercial shellfish aquaculture farm in the U.S. is subject to multiple regulatory requirements. In addition to an ACOE permit under the Rivers and Harbors Act (Section 10) and the Clean Water Act (Section 404), a commercial shellfish aquaculture farm must obtain all other required permits from the appropriate federal, state, local, and/or tribal authorities. Examples include leases and permits from state agencies and permits from other federal agencies under the Magnuson-Stevens Fishery Conservation and Management Act (for harvesting of some shellfish species in federal waters of the Exclusive Economic Zone); the National Marine Sanctuaries Act (for shellfish operations within a national marine sanctuary); Marine Mammal Protection Act (for shellfish aquaculture operations that may harm marine mammals); Migratory Bird Treaty Act (for shellfish aquaculture operations that may harm migratory birds); and other statutes.

Federal Requirements Addressed by the ACOE Regulatory Program for Commercial Shellfish Aquaculture**:**

The ACOE permit for commercial shellfish aquaculture directly addresses requirements under two federal laws:

- Rivers and Harbors Act – Section 10 of this law regulates activities and/or structures in, on, over, or under navigable waters of the U.S. The ACOE permit authorizes activities, such as the installation of buoys, floats, racks, trays, nets, lines, tubes, containers, and other structures, in navigable waters of the U.S. The primary focus is on the potential for these activities to interfere with other activities in navigable waters.

- Clean Water Act (CWA) – Section 404 of this law regulates discharges of dredged and/or fill material into waters of the U.S. As it relates to aquaculture operations, the ACOE permit authorizes activities such as seeding, rearing, cultivating, transplanting, and harvesting. The primary focus is on the potential effects of these activities on the chemical, physical, and biological integrity of waters of the U.S.

As part of the process for issuing a permit for commercial aquaculture under these two laws, the ACOE consults and coordinates with other federal agencies, coastal states, tribes, the public, and other parties as appropriate to meet additional legal requirements, including but not limited to the following:

- National Environmental Policy Act (NEPA) – This law may require the ACOE to prepare an environmental assessment or an environmental impact statement on the effects of aquaculture activities.

- Treaties – The ACOE is required to coordinate as necessary with federally recognized tribes to ensure aquaculture activities authorized under the permit do not impair reserved tribal rights. These rights include but are not limited to reserved water rights and treaty fishing and hunting rights.

- Endangered Species Act (ESA) – Section 7 of this law requires the ACOE to consult with NMFS and/or the USFWS, if a proposed federal action has the potential to adversely affect an ESA-listed species and/or the designated critical habitat for an ESA-listed species. The focus of these consultations is on the likelihood that the aquaculture activities authorized under the

ACOE permit would jeopardize ESA-listed species or result in the destruction or adverse modification of their critical habitat.

- Magnuson-Stevens Fishery Conservation and Management Act – The Essential Fish Habitat (EFH) provisions of this law require the ACOE to consult with NMFS, if a proposed federal action has the potential to adversely affect the habitat of wild fish stocks managed by NMFS. The focus of these consultations is on the potential for activities authorized under the ACOE permit to adversely affect EFH. One example of EFH is submerged aquatic vegetation in nearshore areas where most U.S. shellfish aquaculture production currently takes place.

- Coastal Zone Management Act – The federal consistency provisions of this law require state certification that the activities authorized by the ACOE permit comply with the enforceable policies of approved state coastal zone management programs and that these activities will be conducted in a manner consistent with the program.

- Clean Water Act – Section 401 of this law requires state or tribal certification that the activities authorized by the ACOE permit comply with water quality standards.

- National Historic Preservation Act – Section 106 of this law requires the ACOE to consult with the State Historic Preservation Officer or Tribal Historic Preservation Officer, if the aquaculture activities authorized by the permit may affect historic properties or areas of historic or cultural significance.

- Fish and Wildlife Coordination Act – This law requires the ACOE to consult with USFWS, NMFS, and appropriate state agencies, if the aquaculture activities authorized by the permit would modify a body of water in ways that could potentially harm fish and wildlife resources.

- National Marine Sanctuaries Act – Section 304(d) of this law requires the ACOE to consult with the National Marine Sanctuary Program, if the aquaculture activities authorized by the permit are likely to destroy or injure any sanctuary resource (for Stellwagen Bank National Marine Sanctuary, such consultations are required for action that “may affect” that sanctuary, which is a lower threshold).

1.4 The Gulf of Mexico Fishery Management Plan

The U.S. currently does not have a framework to permit long-term aquaculture projects in the Exclusive Economic Zone (EEZ), federal waters that are three to 200 miles (five to 322 kilometers) offshore. This is despite the huge potential for offshore aquaculture in the U.S. A recent publication from the Food and Agricultural Organization (FAO) of the United Nations (Kapetsky et al. 2013) listed the U.S. as number one in the world for offshore marine production potential. Japan also ranked highly in this category. The rankings were obtained by accounting for the area in each country’s EEZ when considering environmental and economic conditions.

An ongoing development for U.S. offshore aquaculture is the implementation of the Fishery Management Plan for Regulating Offshore Marine Aquaculture in the Gulf of Mexico (Aquaculture FMP). The Gulf of Mexico Fishery Management Council proposed regulations for an Aquaculture FMP, the first time that a regional fishery management council has approved a comprehensive regulatory program for offshore aquaculture in the U.S. EEZ. The Office of Management and Budget is currently reviewing a Final Rule to implement the Aquaculture FMP. The Aquaculture FMP authorizes NMFS to issue permits to culture species managed by the Gulf of Mexico Fishery Management Council, with the exception of shrimp and corals. We expect final regulations to be effective sometime in 2016.

2. Latest Topics in U.S. Aquaculture

2.1 New Draft NMFS Marine Aquaculture Strategic Plan

NMFS is in the process of developing a new strategic plan intended to guide marine aquaculture activities within NMFS, including activities at the headquarters Office of Aquaculture and activities within Regional Offices and Fisheries Science Centers. The plan identifies mission and vision statements and four strategic goals:

Goal 1: Regulatory Efficiency: Develop coordinated, consistent, and efficient regulatory processes for the marine aquaculture sector

Goal 2: Tools for Management: Encourage environmentally responsible marine aquaculture using best available science

Goal 3: Technology Development and Transfer: Develop technologies and provide extension services for the marine aquaculture sector

Goal 4: Informed Public: Improve public understanding of marine aquaculture

A copy of the draft strategic plan can be found at:
http://www.nmfs.noaa.gov/aquaculture/homepage_stories/21_draft_strategic_plan.html.

2.2 NOAA Strategic Research Planning

In 2014, The White House Office of Science and Technology Policy released a National Strategic Plan for Federal Aquaculture Research (Federal Plan). The Federal Plan directs partner agencies, including NOAA, to improve coordination and implement nine strategic research priorities. As a first step, NMFS will inventory and assess its aquaculture science program through a rigorous peer-reviewed process. This "Aquaculture Science Review" will be finalized in 2016.

2.3 Update on in NOAA Aquaculture Research

In 2015, to evaluate and make information on NOAA internal research projects available to the general public, a new interactive aquaculture research map was developed that will be updated annually. Selected projects of interest are described below. Further details on these and other internal projects are provided on the map noted below.

A link to the story map can be found at:
http://www.nmfs.noaa.gov/storymap/aquaculture/aquaculture_research.html.

2.3.1 Advancing Culture Methods and Technologies for Candidate Aquaculture Species

NOAA continues to refine culture methods for key existing and emerging aquaculture species around the country. Research efforts include:

- NMFS Northwest Fisheries Science Center: sablefish (*Anoplopomo fimbria*), Olympia oyster (*Ostrea conchaphila*), and seaweeds
- NMFS Southwest Fisheries Science Center: California yellowtail (*Seriola lalandi*) and abalone (*Haliotis* spp.)
- NMFS Northeast Fisheries Science Center: eastern oyster (*Crassostrea virginica*), bay scallops (*Argopecten irradians*), microalgae for shellfish hatcheries, black sea bass (*Centropristis Striata*), and scup (*Stenotomus chrysops*)
- National Ocean Service (NOS) National Centers for Coastal Ocean Sciences (NCCOS) Beaufort Laboratory: red porgy (*Pagrus pagrus*) and grey triggerfish (*Balistes capriscus*)

Key Examples:

NOAA has identified sablefish as a candidate species for the Pacific Northwest due to market characteristics, such as a high price-point, white flesh, and limited production from wild harvest. Scientists at the NMFS Northwest Fisheries Science Center have made significant advancements in the aquaculture technologies for sablefish in the last several years, having investigated key research topics, including the effects of temperature; viability of using all female sablefish; effectiveness of hormonal treatments, sterilization, and immersion vaccination; and optimizing tank design, environmental conditions, and feeds composition. NOAA is working to build partnerships with the interested private sector and tribal parties to transfer sablefish farming technology. One Pacific Northwest tribal group and one private sector partner are interested in farming this species, if financial and permitting barriers can be overcome.

Scientists at the NMFS Southwest Fisheries Science Center have continued to advance aquaculture technologies for California yellowtail, a species with high potential for commercial culture in the U.S. Scientists have undertaken several genetic and genomics projects for this species that aim to improve production efficiency in commercial operations, as well as evaluate effects of proposed commercial operations on wild stocks. NOAA has partnered with California Sea Grant and Hubbs-SeaWorld Research Institute to develop new land-based tank technologies to improve larval rearing. NOAA scientists and partners have an opportunity to transfer these technologies to the private sector through an offshore aquaculture project, Rose Canyon Fisheries, which has been proposed for the Southern California Bight.

2.3.2 Developing Tools for Managing Marine Aquaculture

NOAA has continued to develop synthesis documents and refine tools for managers around the country. Research efforts include:

- NMFS Northwest Fisheries Science Center: Development and testing of a genetics risk model (OMEGA) focused on the impact of escapes from marine aquaculture and studies on the habitat value of shellfish farms.
- NMFS Pacific Islands Fisheries Science Center: Development of a GIS tool for aquaculture siting in the tropical Pacific (Marine Mapper) using exclusion mapping and a unique prioritization algorithm.

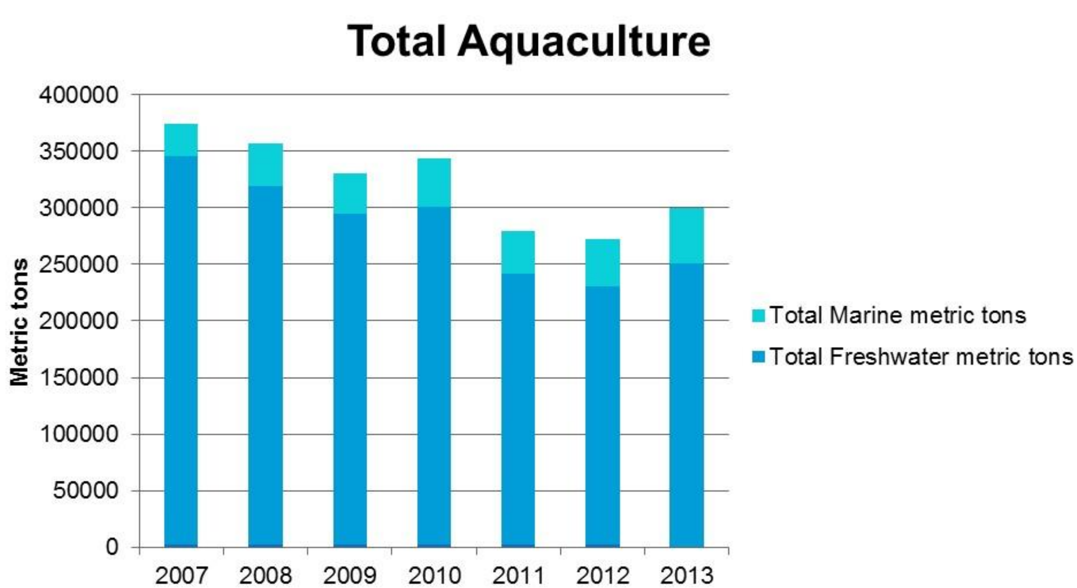
- NOS NCCOS Beaufort Laboratory, NMFS Northeast Fisheries Science Center, and NMFS Greater Atlantic Regional Fisheries Office: Development of a framework to determine risk to marine mammals and turtles posed by aquaculture gear and mitigation strategies.
- NOS NCCOS: Testing and refinement of models for benthic and water column nutrient impacts, Best Management Practices (BMP) for offshore marine fish culture, ecological management of shellfish farms (FARM model), habitat value of shellfish farms (HIA), and viewscape issues (CanVis) posed by marine aquaculture.

Key Examples:

Since the adoption of the R&D plan, NOAA has released two comprehensive synthesis documents, "Marine Cage Culture and the Environment"(Price and Morris 2013) and "Environmental Performance of Marine Net-Pen Aquaculture in the United States" (Rust et al. 2014) that demonstrate that net-pen finfish aquaculture has manageable impacts on the marine environment. NOAA has also refined ecological forecasting models, including AQUAMODEL and DEPOMOD, through field testing and model validation methods and has applied them in management settings. In 2014, the NOS NCCOS Beaufort Laboratory developed models to forecast benthic monitoring requirements for aquaculture operations in several key regions of the U.S. (i.e., the Gulf of Mexico, California, Hawaii, and Washington State) so that coastal managers will have high confidence in siting and management of marine aquaculture.

3. Production Trends

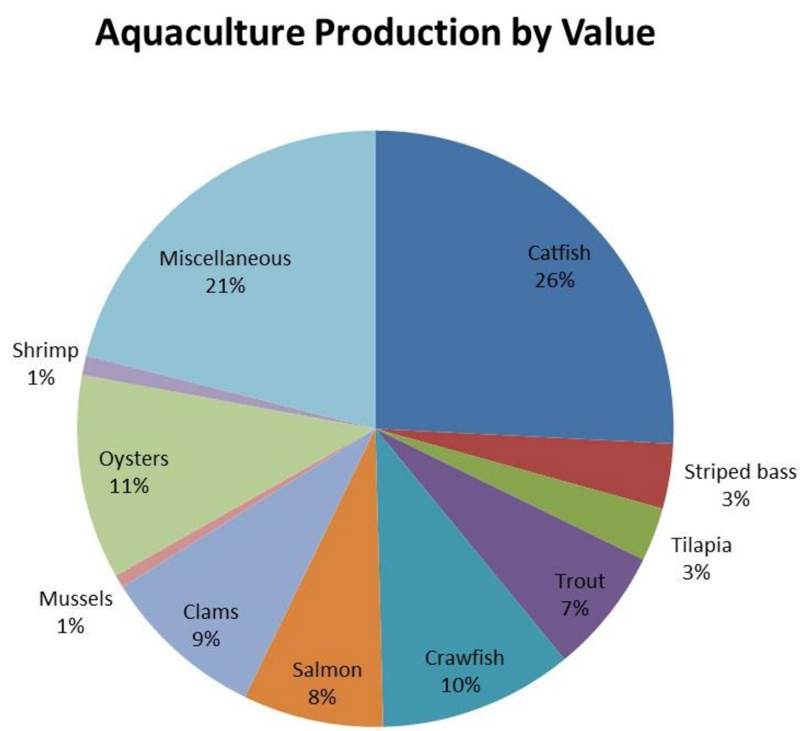
The most current year for which aquaculture production data is available is 2013. The U.S. remains a relatively minor producer of aquaculture, ranking 14th globally in aquaculture production. In 2013, total U.S. marine and freshwater aquaculture production was 300,242 mt valued at $1.4 billion, an increase of $140 m and 30,692 mt from 2012. However, total U.S. aquaculture production actually decreased 12% by volume between 2010 and 2013, although value increased by 7% over the same time period.



The U.S. produces far more wild caught seafood than it does seafood from aquaculture. However, because of the focus on high-value food species, aquaculture yields 25% of the value of U.S. commercial wild catches, while volume is only 7% of the wild catch.

The main species for aquaculture production in the U.S. are trout, tilapia, catfish, crawfish, shrimp, salmon, oysters, mussels, and clams. Other U.S. production includes baitfish, ornamental/tropical fish, alligators, algae, aquatic plants, scallops, crabs, and marine and freshwater fish. Most of U.S. aquaculture consists of freshwater species (84% by volume), including catfish, crawfish, and trout. Marine species make up a small proportion of aquaculture production by volume. However, marine species make up a disproportionately large part of the value of aquaculture in the U.S. Shellfish, in particular, are produced in relatively smaller quantities but are high-value products.

The U.S. remains a large market for seafood, including aquaculture products. In 2013, the U.S. imported over 90% of its seafood, and it has been estimated that over 50% of U.S. seafood imports are produced from aquaculture.

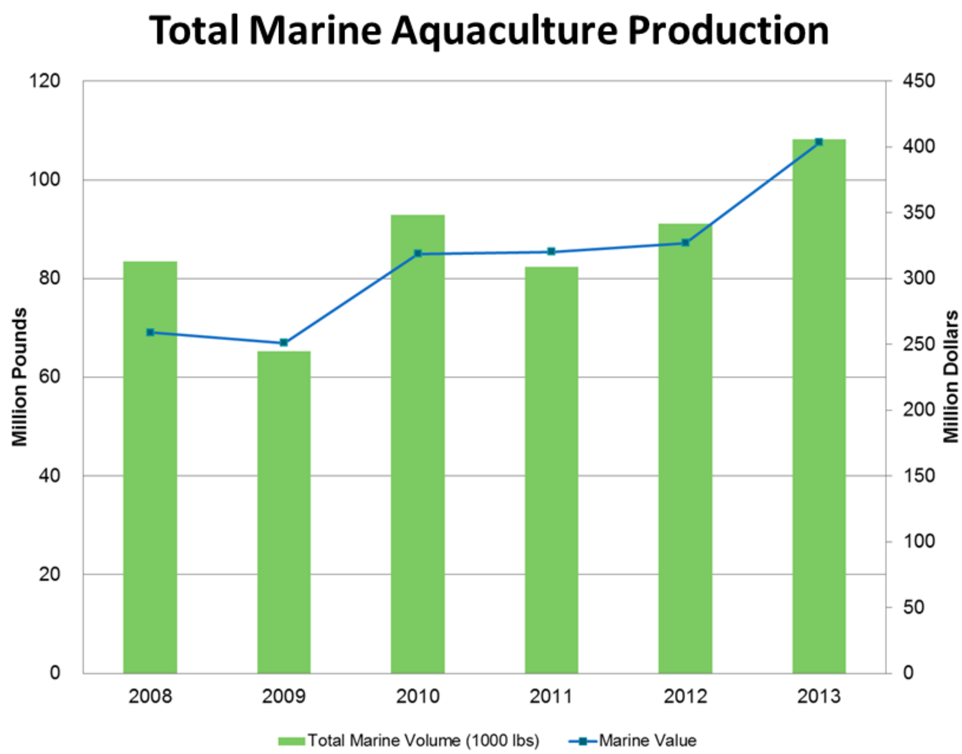


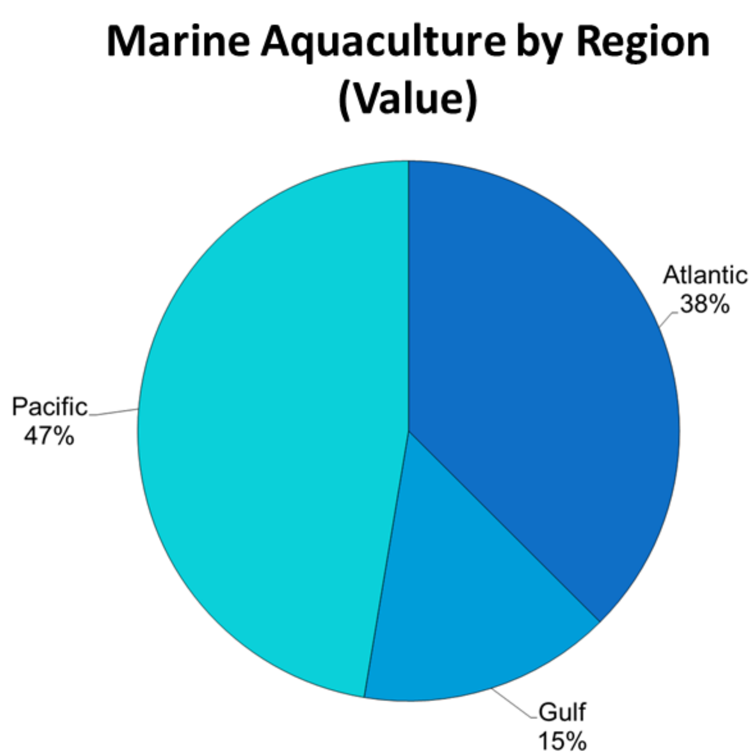
3.1 Marine Aquaculture[1]

In 2013, U.S. marine aquaculture accounted for 49,113 mt of seafood valued at $403 m. Major U.S. marine species are Atlantic salmon (*Salmo salar*), mussels (mainly blue mussels, *Mytilus edulis*), clams (mainly hard clams *Mercinaria mercinaria*, Manila clam *Venerupis philippinarum*, and geoduck

[1] We define Marine Aquaculture in this section as marine and anadromous species cultured in the marine environment (e.g. oceans, bays, salt-water estuaries) and marine and anadromous species cultured on land facilities (e.g. recirculating systems)

Panopea generosa), and oysters (mainly *Crassostrea gigas* and *Crassotrea virginica*). Marine aquaculture production in the U.S. has been increasing steadily in recent years, with an average growth rate of 5% per year by volume over the last five years (2008-2013). Regionally, the Pacific states produce 47% of marine aquaculture production by value, which includes primarily shellfish and salmon from Washington State. The Atlantic states are the second largest marine aquaculture producing region at 38% of production.



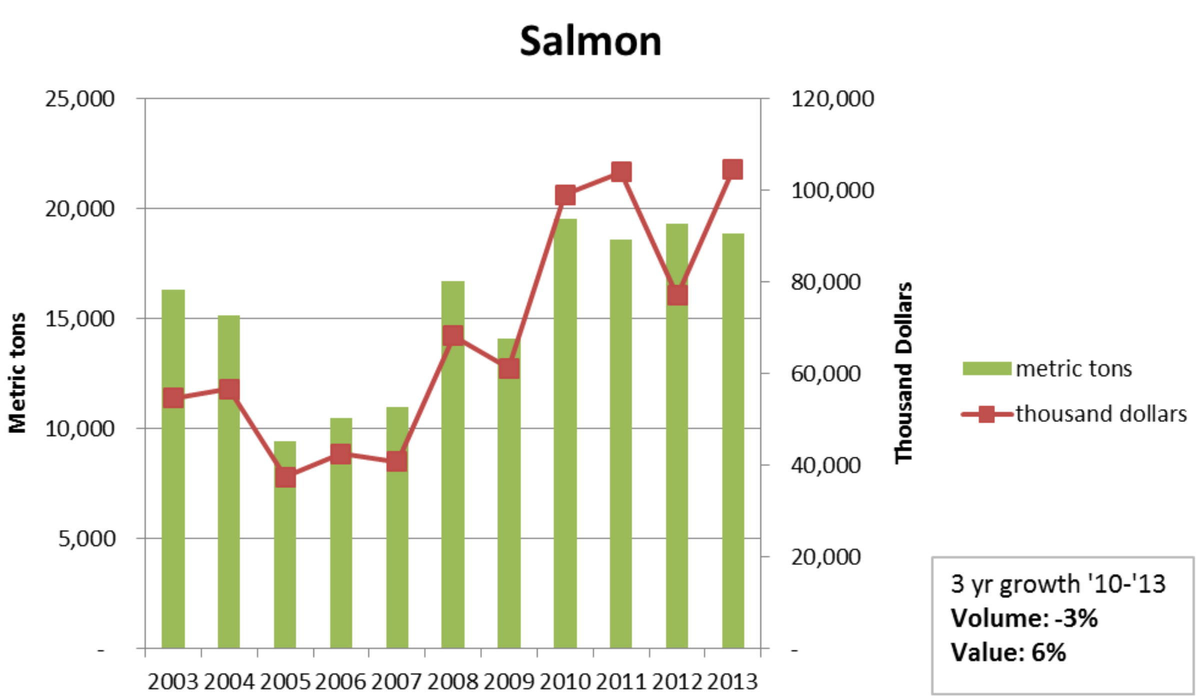


Atlantic salmon are grown in Maine and Washington State. Salmon from hatcheries are raised in land-based tanks until they reach 40-120 grams, at which time they are transferred to marine net-pens for grow-out. The U.S. produces a relatively small amount of farmed salmon relative to what it consumes. In 2013, U.S. growers produced 18,866 mt of Atlantic salmon, with a farm-gate value of $105 m. By comparison, the U.S. imported $2.56 billion worth of salmon products in 2013, the large majority of which are produced from aquaculture.

Over the three year period from 2010-2013, U.S. salmon production by aquaculture decreased 3% by volume but increased 6% by value. Salmon production increased for much of the 2000s, attributed to existing farms increasing efficiency in existing facilities. The 2010-2013 plateau in salmon aquaculture production indicates that existing operations may be at or close to maximum production efficiency on existing sites. Access to new aquaculture sites and a complicated, time consuming permitting process is a significant barrier to expanding salmon production in the U.S. In Washington State, for example, the last new aquaculture site permitted for salmon was in 1996 (Washington Department of Ecology, personal communication).

Production of farmed salmon is significant, however, compared to wild harvests in the State of Washington. From only 21 acres of aquaculture sites, farmed salmon made up an average of 36% of all commercial salmon landings in the six years between 2008 and 2013 (Icicle Seafoods, personal communication).

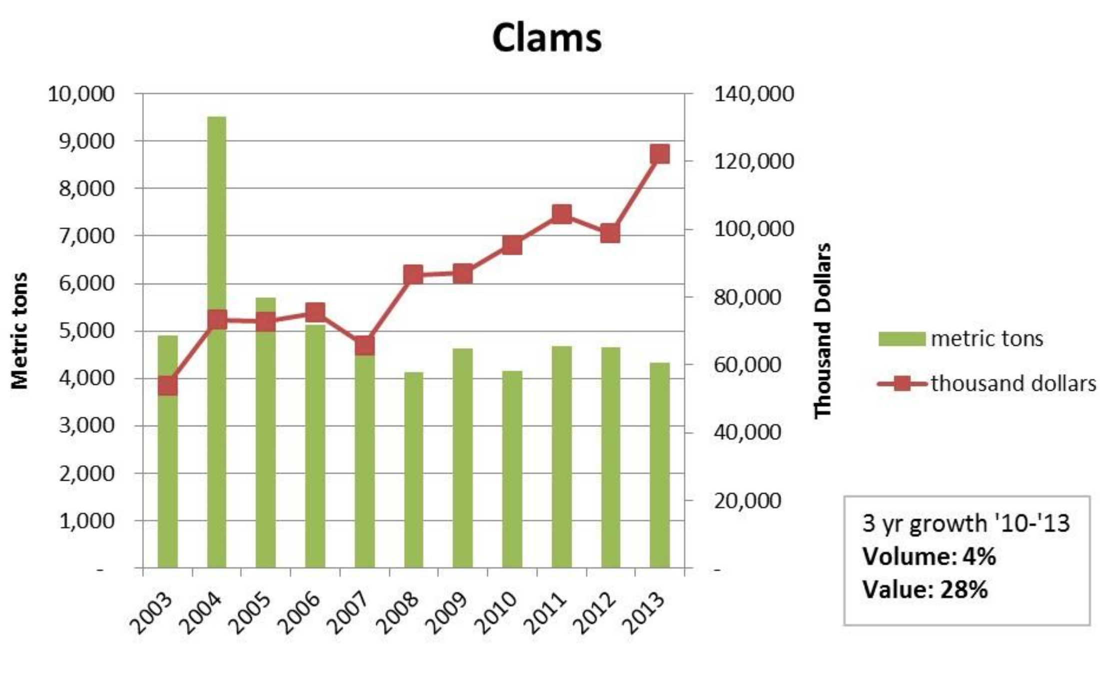
The U.S. has a robust stock enhancement or sea ranching program for Pacific salmon on the west coast of the continental U.S. and Alaska. Outside of Alaska, most (sometimes greater than 80%) of the salmon caught in “wild-capture” salmon fisheries were spawned in a hatchery. Value and landings from these enhanced fisheries are not included in these statistics.



Clam culture in the U.S. is largely for hard clam (*Mercinaria mercinaria*) and Manila clam *Venerupis philippinarum*), with some native geoduck clams (*Panopea generosa*) grown in the Pacific Northwest. Hard clam culture in the U.S. involves seed production, nursery stage, and final grow-out. Producers rely on seed from hatcheries. During the nursery stage, juvenile clams are placed in a protected environment where they can grow to a size that confers optimum success for survival once they are placed into a natural setting for grow-out. Once juvenile clams are 7-15 mm, they are moved into the final grow-out system until they reach a harvest size of 50 mm. For grow-out, clams are placed into different structures (e.g., trays, pens, and bags) and secured to the substrate in intertidal or subtidal areas. Harvesting occurs by either collecting the trays/bags or by raking the substrate.

Geoduck seed are produced in hatcheries, and juveniles are raised in the hatchery until they reach about 5-12 mm in size. Geoduck are kept in a nursery where they grow large enough for survival outdoors. Geoduck are then planted on intertidal beaches in PVC pipes. The pipe is placed in the sediment about 30 cm deep, with 10 cm left at the surface. Juvenile geoducks are very susceptible to predation, and the pipe protects them until they are large enough to evade predators on their own. On many farms, a net is placed over all of the tubes to provide further protection from predators. Two to three juveniles are placed into each pipe. While protected, the geoduck will grow and burrow itself into the sediment. After 1-2 years, the netting is removed, since the geoducks are large and deep enough to be safe from predators. The grow-out stage can take 4-7 years, during which geoduck will reach a harvest size of two pounds (~1 kg). Geoduck are primarily exported to Asian markets, particularly China and Hong Kong. In late 2013, China prohibited imports of U.S. geoducks and other shellfish due to concerns over elevated arsenic and paralytic shellfish poisoning toxin levels. This prohibition adversely affected U.S. revenues from shellfish. The trade issue has now been resolved and the trade ban was removed.

In 2013, U.S. growers produced 4,324 mt of clams (meat weight) valued at $122 m farm-gate. Clam production was relatively stable from 2010-2013, increasing by just 4%. Over the same time period, however, the value of the clam aquaculture industry increased by 28%.

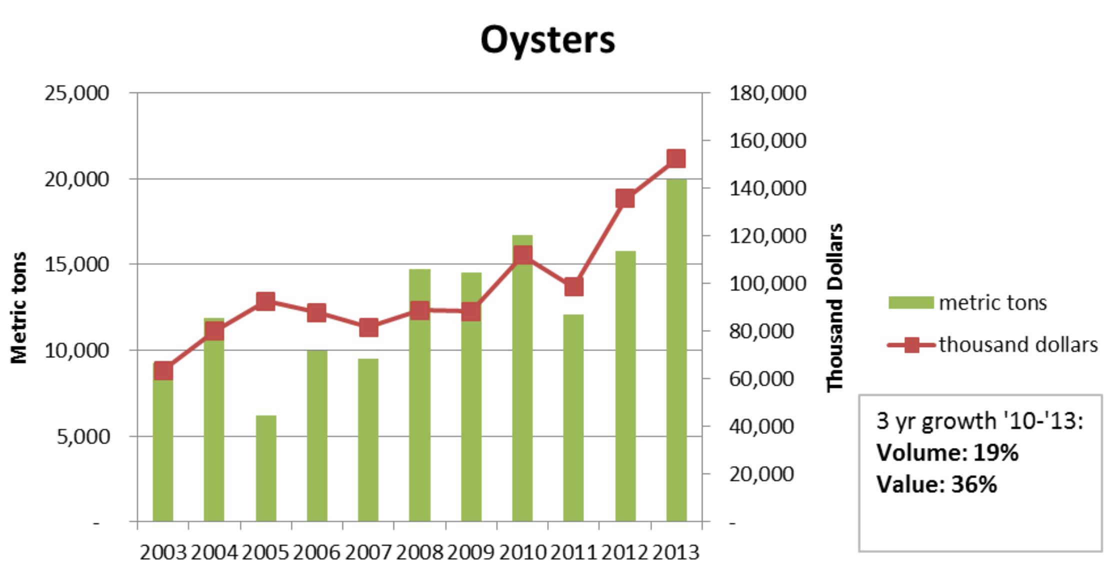


Oyster culture in the U.S. mainly consists of two species. The Pacific oyster *(Crassostrea gigas)* is the predominant oyster grown on the west coast, and the Virginia oyster (*Crassotrea virginica)*, which is the only oyster raised on the east coast. On the west coast, other species are raised in smaller numbers, such as the Kumamoto oyster (*Crassosetrea sikamea*), the native Olympia oyster (*Ostreola conchaphila*), and the Virginia oyster. The majority of oyster farms rely on hatchery production of seed, though wild seed collection also occurs.

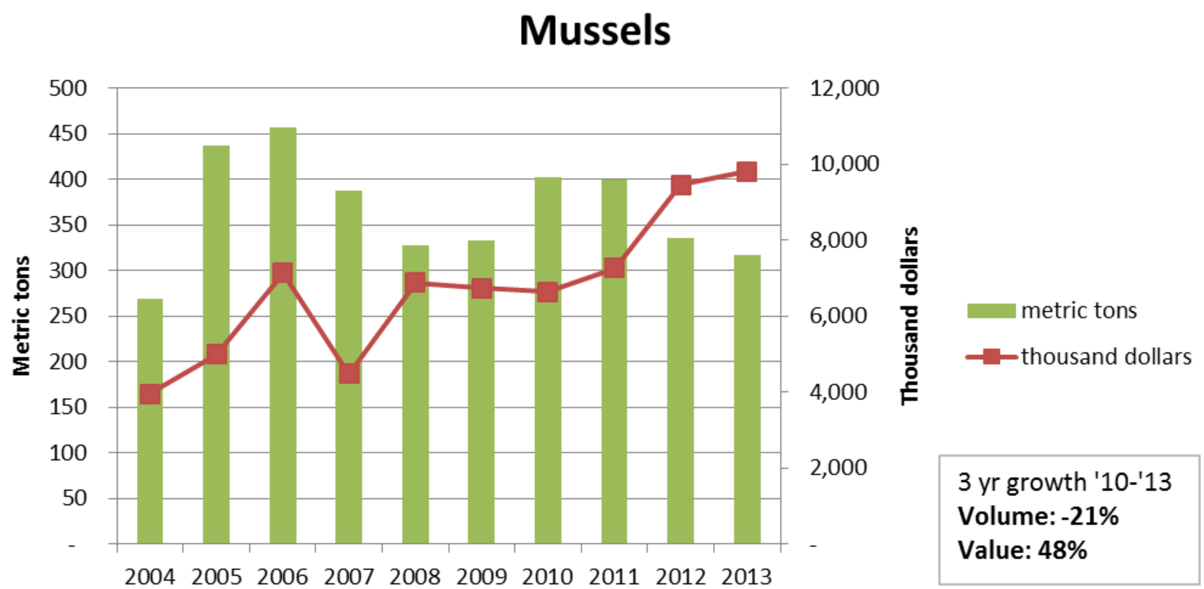
Oysters are grown by on-bottom, off-bottom, or suspended-culture techniques. On-bottom culture is used when a site has a suitably firm substrate in an intertidal or sub-tidal area. This method is used extensively in the State of Washington and the southeastern U.S. Off-bottom culture requires seed to be put into cages, mesh bags, or trays, which are attached to ropes and frames for growth to market size. This method is becoming increasingly used in the U.S. to grow oysters for the raw, or "half-shell," market. It is used extensively in the northeast region but is also becoming more common in other regions.

U.S. growers produced 19,963 mt of oysters (meat weight) in 2013 valued at $152 m farm-gate. U.S. oyster aquaculture production is demonstrating a strong upward trend. From 2009-2012, the U.S. oyster culture industry increased 19% by volume and 36 % by value. Development of triploid oysters, which substantially decreases grow-out time, is allowing growers to increase production on their existing leases, and because triploids are sterile, marketable oysters can be harvested year-round. Strong growth of the oyster culture industry is occurring particularly the Chesapeake Bay, where new aquaculture permits are being issued. The states of Virginia, Massachusetts, and Rhode Island reported record aquaculture oyster production in 2013.

Nationwide, the effects of shellfish aquaculture on eelgrass populations is key management issue. NOAA continues research on this topic. On the west coast of the U.S., the use of pesticides to control burrowing shrimp is another key management issue. On the east coast, food safety is a major focus of shellfish regulation and management (e.g., prevention of infection by *Vibrio* spp.). NOAA research continues on assessing the ecological benefits of shellfish aquaculture, improving culture methods, and treating and managing disease.



Mussels are farmed either on- or off-bottom. On-bottom mussel farming involves seeding sea bottom areas and dredging mussels for harvest. There are several methods of off-bottom farming, including longline culture and raft culture. Despite large potential opportunity for mussel culture in Alaska, along the west coast, and in the northeast, the U.S. mussel aquaculture industry remains small, with the majority of mussels consumed in the U.S. coming from overseas (Canada and New Zealand). New operations in the U.S. have been hampered by a cumbersome permitting process. In 2013, U.S. growers produced 317 mt of mussels (meat weight) worth $9.8 m farm-gate.

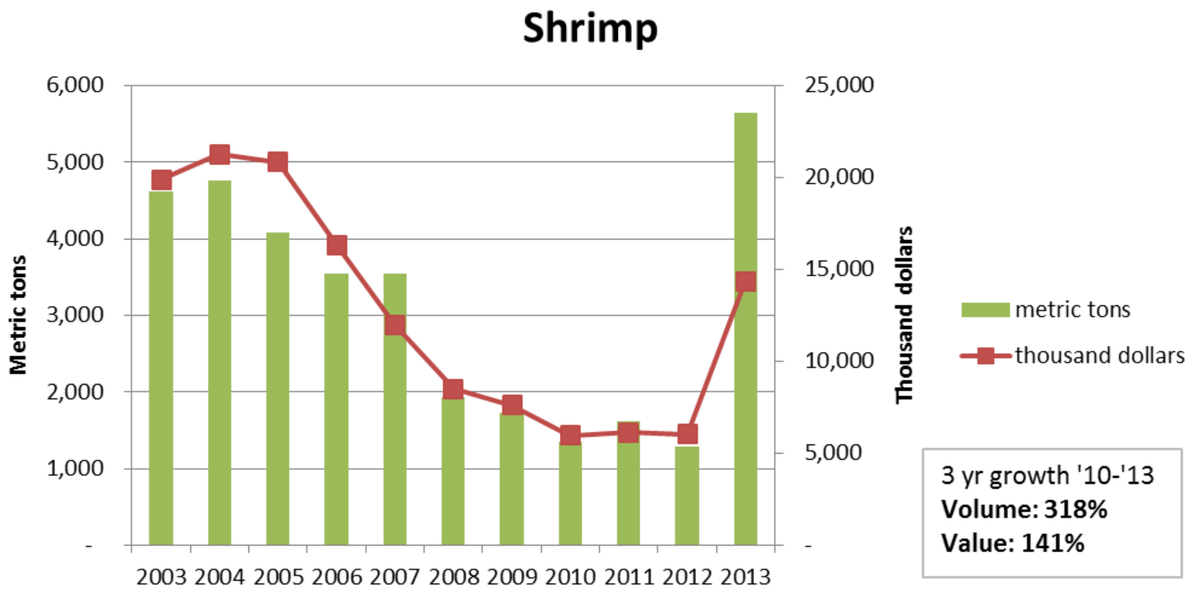


Shrimp is the number one seafood species group consumed by Americans, but the U.S. produces relatively little shrimp compared to what it consumes. Shrimp produced in the U.S. are primarily wild-caught. In 2013, U.S. growers produced 5,643 mt of shrimp valued at $14 m dollars farm-gate. By comparison, in the same year, U.S. commercial fishermen landed $592 m worth of wild shrimp.

A small amount of marine and freshwater shrimp species are grown in ponds, tanks, and recirculating systems. Pacific whiteleg shrimp (*Litopenaeus vannamei*) is the most commonly cultured marine shrimp species in the U.S. and worldwide. U.S. farmed shrimp are cultured in ponds primarily in Texas, though small operations in recirculating systems have been developed in Indiana, Oregon, Texas, Massachusetts, and elsewhere. The culture of the freshwater Malaysian prawn (*Macrobrachium rosenbergii)* in land-based systems is increasingly popular in the mid-western and southern U.S. USDA data shows an increase in shrimp aquaculture volume and value in 2013 over 2012 estimates. Future data collections will indicate whether a real increase in shrimp aquaculture production is occurring in the U.S. or whether this a result of differing data sources. The price of shrimp increased in 2013, likely because of low production in overseas markets due to disease outbreaks.

Of note, the U.S. has significant shrimp aquaculture businesses that support the global shrimp aquaculture industry. Operations in Hawaii sell specific pathogen free broodstock overseas.

Significant privately owned shrimp research and breeding programs also exist in Florida. Revenues and production from these businesses are not included in the figures provided here.



Other marine finfish are cultured, but due to issues, such as the small number of farms, consistent data are not available. To protect the privacy of businesses, the USDA ARS cannot report detailed statistics when there are so few farms, it would be possible to identify individual farms from the data. Species in the early stages of commercialization or in research and development include sixfinger threadfin (*Polydactylus sexfilis*, commonly known in Hawaii as moi), cobia (*Rachycentron canadum*), almaco jack (*Seriola rivoliana*), Atlantic cod (*Gadus morhua*), California yellowtail (*Seriola lalandi*), red drum (*Sciaenops ocellatus*), sablefish (*Anoplopoma fimbria*), California flounder (*Paralichthys californicus*), summer flounder (*Paralichthys dentatus*), yellowfin tuna (*Thunnus albacares*), and Florida pompano (*Trachinotus carolinus*).

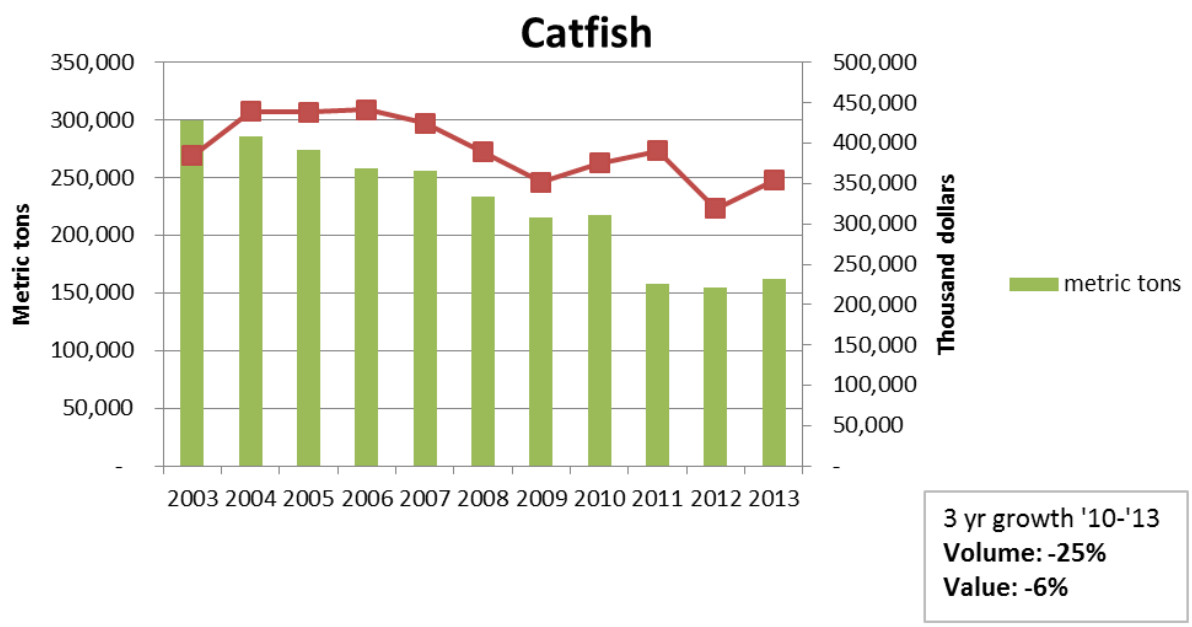
There are several ongoing experimental and commercial land-based marine finfish culture operations. Notably, barramundi (*Lates calcarifer)* has been commercialized in a large land-based facility in Massachusetts. Several non-native species of sturgeon (*Acipenser baeri* and *Acipenser gueldenstaedtii*) have been cultured commercially in Florida (e.g. MOTE Marine Laboratory/Healthy Earth). White sturgeon (*Acipenser transmontanus*) and are also cultured in the Pacific Northwest.

Additionally, work to commercialize cobia (*Rachycentron canadum*) and black sea bass (*Centropristis striata*) is ongoing. Baitfish culture for marine recreational fishing is a growing area of interest, as well, and ornamental fish culture operations exist in Hawaii, Florida, and other states.

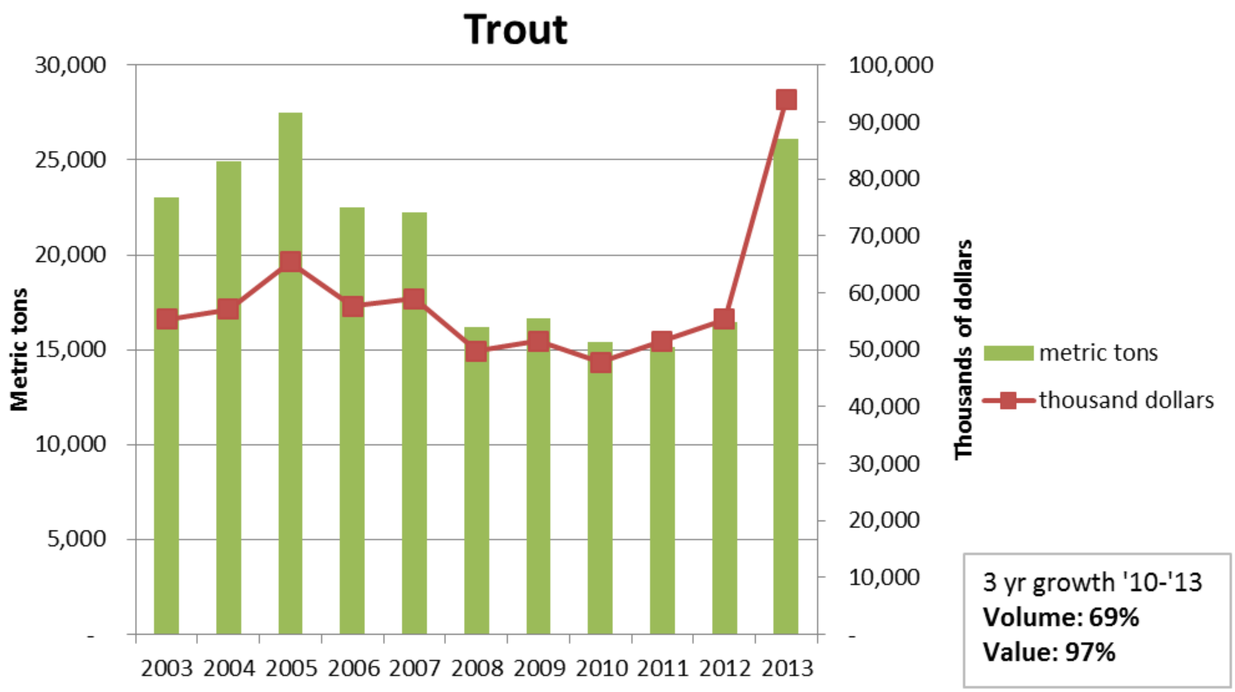
3.2 Freshwater Aquaculture

Freshwater species account for about 84% of US aquaculture production by volume. Freshwater aquaculture produced 251,128 mt valued at $681 m in 2013. Major U.S. freshwater aquaculture species are channel catfish (*Ictalurus punctatus*), rainbow trout (*Oncorhynchus mykiss*), hybrid striped bass (*Morone saxatilis* crossed with *Morone chrysops*), and tilapia (*Oreochromis spp*.). Farmed freshwater shellfish includes the crawfish (*Procambarus clarkii*). U.S. freshwater aquaculture showed a consistent decreasing trend in production from 2009-2012 but rebounded slightly in 2013 due to reported increases in catfish and trout production.

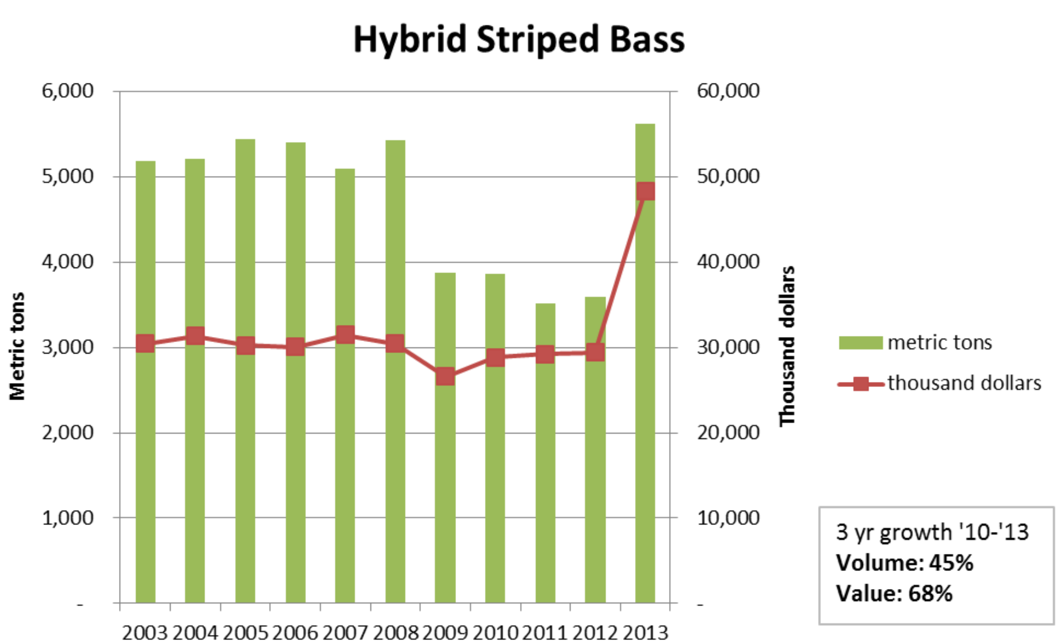
Channel catfish are the predominant aquaculture species in the U.S. The majority of catfish culture occurs in the southeastern U.S. In recent years, growers have begun producing channel-blue catfish hybrids (*Ictalurus punctatus* crossed with *Ictalurus furcatus*) because they have shown potential for greater survival, faster growth, and shorter production cycles than purebred channel catfish. Catfish are grown primarily in embankment or levee ponds, where the earth that is removed to dig the ponds is used to build levees or embankments to encircle the ponds. Ponds range in size from 0.04 km^2 and 2 m deep to 0.1 km^2 and 1 m deep. In 2013, U.S. growers produced 162,560 mt of catfish valued at $354 m farm-gate, a slight increase in production from 2013 levels. Three year production trends from 2010-2013, however, decreased 25% by volume and 6% by value. This decline is consistent with a slight declining trend over the last 10 years. By and large, U.S. producers are finding it difficult to compete with imported aquaculture products of similar species.



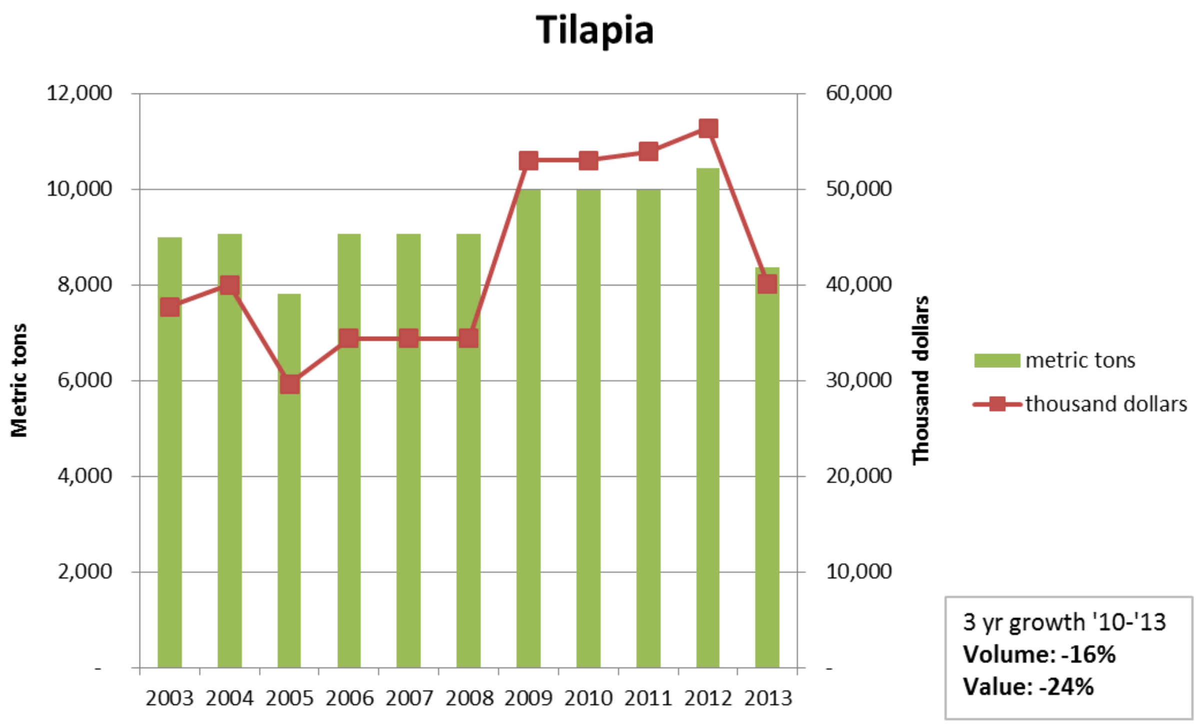
Rainbow trout (*Oncorhynchus mykiss*) are predominantly raised in raceways, though some farms use ponds, recirculating systems, or net-pens. Raceways, also known as flow-through systems, are essentially artificial streams. Gravity flows water through concrete raceways, and the water is often filtered to remove waste products before being released. The majority of rainbow trout are produced in the state of Idaho. Steelhead trout, a sea-run rainbow trout, can be raised in net-pens in rivers or the marine environment. Steelhead trout are currently farmed in Washington State and New Hampshire. U.S. growers produced 26,067 mt of trout in 2013 valued at $94 m farm-gate. Trout production showed an upward trend from 2010-2013, increasing 69% by volume over the time period. Over the same time period, trout production increased 97% by value. The U.S. has a robust system of public and private trout hatcheries that produce "stocker" trout that are released into public and private waters primarily for recreational fisheries. The value of these hatcheries and recreational fisheries are not included in these statistics.



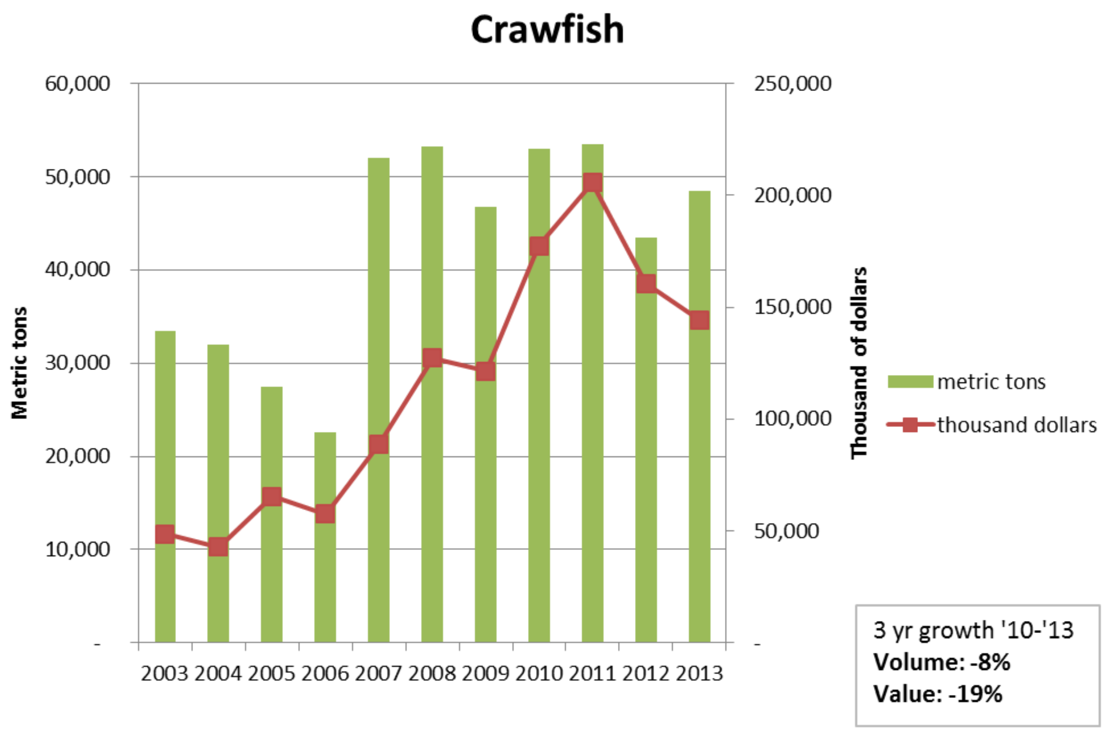
Hybrid striped bass are produced in hatcheries by fertilizing female white bass (*Morone chrysops*) eggs with sperm from male saltwater striped bass (*Morone saxatilis*). This hybrid is sometimes called a sunshine bass. Hybrid striped bass have greater tolerance to extremes in temperature and dissolved oxygen than either of its parental lineages and is thus better suited for pond culture. The majority of hybrid striped bass producers are in the southern region of the U.S. and raise their fish in freshwater ponds. Tanks and cages are also used for hybrid striped bass production. In 2013, U.S. growers produced 5,622 mt of hybrid striped bass worth $48 m at the farm-gate.



Tilapia are grown in recirculating systems or ponds. Tilapia produced in the U.S. are primarily sold to live or fresh markets to receive a higher price and compete with imports that are primarily imported frozen. In 2012, U.S. growers produced 8,359 mt of tilapia, valued at $40 m farm-gate. The three-year trend in U.S. tilapia production showed a moderate decrease of 16% by volume from 2010-2013. Over the same period, the value of U.S. tilapia production decreased by 24%. In the U.S., there is increasing investment interest in land-based production of tilapia in urban centers and as a component of aquaponics.



Crawfish are the predominant freshwater shellfish cultured in the U.S. and are cultivated and in several southern states. Louisiana dominates the aquaculture and wild harvest crawfish industry. Crawfish are grown in shallow ponds 20-60 cm deep, and the ponds are flooded and drained each year. Crawfish in the U.S. primarily forage for plant material pre-existing in the ponds. In order to provide crawfish with enough plant material to feed upon, they are often double-cropped or rotated with field crops, most commonly rice but also soybeans and sorghum. In 2013, U.S. growers produced 48,500 mt of crawfish worth $144 m at the farm-gate. The three-year trend in crawfish production from 2010-2013 was a decrease of 8% by volume and 19% by value.



7) Annotated Bibliography

Lowther, A. (editor). 2015. Fisheries of the United States 2014. Current Fishery Statistics No. 2014. National Marine Fisheries Service Office of Science and Technology.

The annual Fisheries of the United States is the official published source of fisheries statistics for the U.S. The 2015 report gives preliminary 2014 data on U.S. commercial fisheries. U.S. aquaculture statistics lag a year behind and are reported for 2013. Summary statistics are also provided on U.S. production of processed fishery products, domestic supply and per capita consumption, foreign trade, and world fisheries production.

Kapetsky, J.M., Aguilar-Manjarrez, J. & Jenness, J. 2013. A global assessment of potential for offshore mariculture development from a spatial perspective. FAO Fisheries and Aquaculture Technical Paper No. 549. Rome, FAO. 181 pp.

The FAO produced this document to highlight that mariculture, specifically offshore aquaculture, offers significant opportunities for sustainable food production but is underutilized worldwide. The report states that offshore aquaculture could foster development of many coastal communities, especially in regions with limited freshwater and arable land. This report measures and compares the current status and potential for offshore mariculture development from a spatial perspective for all maritime nations, and identifies nations with high but unrealized offshore potential.