Oregon Sea Grant
Coastal and Ocean Issues Workshop

Aquaculture

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Introduction

Aquaculture can be viewed in its broadest sense as the culture of aquatic organisms. This activity may be focused on the culture of traditional or new aquaculture species for food or other products, endangered species for restoration and conservation, or ornamental species for public and private aquaria. The basic principles of aquatic husbandry are similar across all industries.

Most global aquaculture efforts focus on food production. Aquaculture already supplies about 25 percent of fish and shellfish consumed by humans. It is estimated that aquaculture production will have to double by 2035 to meet future demands, assuming that human populations will increase by 50% in this time period and yields from capture fisheries remain at current levels of 80 to 100 million tons per year.

The need to increase support for aquaculture development in the US has recently been recognized by the US Department of Commerce, through a new national funding initiative. Primary goals of the program are to increase the value of annual domestic aquaculture production from the present $900 million to $5 billion in 2025 and to increase aquaculture employment from 180,000 to 600,000.

Marine aquaculture in the Pacific North-West (PNW) is most concentrated in Washington State as a result of the large areas of protected waters of Puget Sound, Willapa Bay and Gray's Harbor. Annual production of salmon aquaculture in Puget

Sound is valued at about $30 million. Annual oyster, clam and mussel aquaculture production in Washington is valued at about $73 million.

Aquaculture development in Oregon is limited by a scarcity of protected coastal areas, highly variable estuarine salinities, high winds and wave action. Oyster culture is presently the main commercial marine aquaculture activity in Oregon with annual sales of 5 million pounds worth about $4 million. Apart from commercial aquaculture production, there is a large state salmon hatchery program for enhancement and restoration of salmon stocks. Such hatcheries benefit both recreational and commercial salmon fisheries in coastal and offshore waters. Oregon also provides goods and services to the global aquaculture community, such as feeds, various technologies and consulting services.

The West Coast aquaculture industry is struggling due to deterioration in water quality, conflict with other users for space and increasing scrutiny by environmentalists and oversight by regulatory agencies. Land-based, recirculating systems and offshore, on-bottom or cage-culture systems are the most likely ways in which US aquaculture will rapidly expand, according to the U.S. Department of Commerce. Oregon is well placed to develop these types of aquaculture. Land and labor prices are lower in Oregon than in other states, climate and seawater temperatures are very equitable and coastal waters are highly productive due to upwelling. Aquaculture could play a greater role in the future economy of Oregon's coastal communities as forestry and capture fisheries continue to decline and residents look for alternatives to tourism as a source of income.

Policy

The new national aquaculture mission of the Department of Commerce is “to create sustainable economic opportunities in aquaculture in a manner that is environmentally sound, and is consistent with applicable laws and Administration policy”. To facilitate Oregon’s role in this expansion of the aquaculture industry it is important to coordinate state policies and agencies in order to have well defined responsibilities, while at the same time stream-lining the permitting process. This is being accomplished at the national level by the Joint Sub-Committee on Aquaculture, an interagency committee for coordination of aquaculture policy and support among federal agencies. In the Western region, there is a newly formed Pacific Aquaculture Caucus with the mission to “promote economically viable and environmentally sound aquaculture for the Pacific coastal region through good public policy and science”. Active participation in this Caucus by appropriate state agencies and entrepreneurs should be encouraged to provide regional coordination and identify opportunities.

An evaluation of existing policy constraints to aquaculture and stock enhancement should be undertaken to provide direction in developing policy guidelines that will foster aquaculture development. A review of policies and approaches adopted by other states with successful aquaculture industries, such as Florida and Maine, could provide direction in developing a supportive regulatory program. For example, on Florida’s Gulf coast near Cedar Key, a job retraining program developed after an initiative banning gill nets was passed, enabled out-of-work fishermen to become clam farmers with several

hundred earning more than $40,000 per year and helping to revive a very depressed rural economy. In addition to identifying constraints, this policy analysis and development should include an economic evaluation of recommendations and requirements as they relate to environmental issues such as siting, effluent management and aesthetics. Continued research and dissemination of information on aquaculture will assist state, tribal and local governments in developing policy and regulations based on the best available science.

Education and Outreach

There is a great need to provide unbiased education about aquaculture to the public at large, and in particular, the environmental community, regulatory agencies and policy makers. Aquaculture has the potential to increase employment opportunities, diversify local economies, increase the availability of fresh fish and shellfish and help to maintain biodiversity through conservation and enhancement hatcheries. Opportunities to integrate aquaculture and tourism should be investigated with the goal of diversifying rural economies and enhancing recreational opportunities for visitors. Educational efforts should include these societal benefits when evaluating the economic viability and sustainability of aquaculture. Domestic aquaculture production can also contribute to reducing the nation's $6 billion dollar annual foreign trade deficit in edible seafood.

There are concerns about aquaculture development that include environmental interactions influencing water quality and biodiversity. These concerns must be addressed using a science-based approach. In order to efficiently target educational efforts, a survey should be conducted to identify the current range of public opinion and knowledge of aquaculture in Oregon. Appropriate educational programs can then be tailored to increase public awareness of the opportunities available.

Research is the foundation of any educational program and there are enormous research needs to develop new aquaculture species and insure that the industry expands in a fashion that is both economically and environmentally sound. To provide the funding base for this research, Sea Grant should leverage funds with those of other agencies for long-term, coordinated marine aquaculture research supporting a portfolio of research projects to reduce risk and enhance the potential for success.

The use of system-level approaches in aquaculture education, research and development require effective collaboration and communication between subject matter specialists and stake holders from a wide range of fields. Granting entities can promote system-level thinking through the specific objectives and collaboration criteria of their proposal requests. This systems approach also needs to be incorporated in aquaculture education. At Oregon State University, existing courses relevant to aquaculture include fish biology and disease (mainly oriented towards fishery science), water quality and treatment (oriented towards civil and chemical engineering), resource economics, and two courses specific to aquaculture. These courses are offered by a range of departments, lack a unifying entity and most must be re-interpreted in an aquaculture context. Additional courses are needed to address health management for aquatic organisms and aquaculture engineering. Some mechanism is needed to provide overall coordination of aquaculture

education in the Oregon University system. Oregon Sea Grant could facilitate this by providing a venue for exchange of ideas and collaboration via an annual symposium in collaboration with other state and federal agencies.

One means of delivering information would be to increase course offerings at junior colleges and universities and establish internships in cooperation with local farms, aquaria and research institutions. An aquaculture technical certification program similar to one offered by Mt. Hood community college could be developed to provide well-trained technicians (http://www.mhcc.cc.or.us/catalog/programs/fish.htm). To reach a widely distributed audience, internet-based aquaculture courses for high schools, colleges and continuing education would help to ensure a knowledgeable public and a steady supply of well-trained aquaculturists for an expanding industry.

Technology transfer can provide an excellent opportunity for Oregon producers to benefit from research conducted in other states and nations. For example, net pen designs and recirculating systems engineering developed in other regions could be readily applied to aquaculture production in Oregon. Similarly, research advances achieved by Oregon's scientists in areas of expertise related to molluscan broodstock selection and fish health management provide examples of opportunities for technology transfer from Oregon to other regions. Technology transfer should also be expanded to include the ornamental industry where considerable benefits could be realized by applying improved techniques for shipping, health management and water treatment in both private and public aquaria.

To effectively manage and support the aquaculture industry it would be desirable to establish a GIS-based catalogue of West Coast aquaculture production. This would include information on economic impacts, geographical conditions, production systems and species, products, markets and other economic and sociological data. This endeavor could be undertaken in collaboration with other West Coast Sea Grant programs and the Pacific Aquaculture Caucus.

Aquaculture and the environment

Develop Environmental Codes of Practice

Aquaculture has received increasing criticism from environmental groups and is subject to an increasingly complex and unpredictable regulatory environment that threatens its long-term economic survival. Regulations on effluents from aquaculture facilities and potential designation of shellfish growing areas as essential habitat for protected salmon populations are examples of environmental issues that have significant potential impact on aquaculture.

Environmental Codes of Practice need to be developed for aquaculture that will result in an environmentally sound industry with greater regulatory stability. The Pacific Shellfish Growers Association is already developing Codes for the West Coast shellfish industry and a similar exercise needs to be undertaken by other aquaculture industries. Oregon Sea Grant should play a role in facilitating this process in conjunction with the Pacific Aquaculture Caucus.

Regulatory agencies should be encouraged to explore the potential value of incentive-based programs to promote implementation of Environmental Codes of Practice. Such incentive-based programs would reward aquaculture industries that adopt the Codes of Practice by reducing regulatory oversight and monitoring.

Restoration and enhancement

In Oregon and the PNW, there are extensive hatchery programs for salmon enhancement and restoration. Interactions among populations of wild and hatchery-reared salmon in rivers and the marine environment are poorly understood. Competition for food and space, the effects on genetic diversity of wild salmon populations and potential transfer of diseases among hatchery and wild populations are important research areas that need to be addressed.

Based on historical information, there were extensive native oyster beds in Oregon's estuaries at the time of European settlement. These beds have been destroyed by overfishing and increased sedimentation. Oysters play an important role in enhancing benthic communities by providing habitat for small fish and invertebrates that become additional food sources for migrating salmon smolts. Restoration efforts should be implemented by planting native oysters in Oregon's estuaries with consideration of genetic and ecological effects.

Red abalone were once numerous in Oregon's southern coastal waters. A hundred-year storm in 1964 and overfishing have severely impacted populations, resulting in very small numbers of scattered adults with no evidence of recruitment. Aquaculture-based restoration of these populations would enhance recreational abalone fishing and perhaps lead to future commercial harvests.

Reduce impacts of negative environmental conditions on aquaculture

Harmful blooms of noxious and toxic phytoplankton species are becoming more common and widespread. Paralytic shellfish poisoning (PSP) and amnesic shellfish poisoning (ASP) have severely impacted shellfish harvesting in Oregon and the PNW, while blooms of *Heterosigma carterae* and *Chaetoceros* species have caused high mortalities of pen-farmed salmon in Puget Sound. Methods need to be developed to allow prediction, detection and reduction in the harmful effects of these algal species.

Shellfish culture in Oregon and the PNW is severely impacted by water pollution, especially fecal wastes from leaking septic systems, stormwater runoff outfalls and other non-point sources. In many localities, watershed councils have taken the lead in identifying failing septic systems and facilitating repairs.

Shellfish culture in Oregon's coastal estuaries is severely limited by expansive burrowing shrimp populations. Burrowing shrimp soften the substrate, causing both cultured and naturally-occurring bivalves to become suffocated by sediment. Very little is known about the biology of burrowing shrimp, considering their abundance and ecological

importance. A better understanding of burrowing shrimp biology would assist in developing effective, environmentally sound methods needed to control their invasion into productive oyster grounds and ecologically valuable habitats, such as eel grass beds.

Recent invasion of the green crab (*Carcinus maenas*) into Oregon's waters is of great concern to shellfish aquaculturists. A West Coast Aquatic Nuisance Plan needs to be developed to facilitate monitoring and control of invasions by aquatic nuisance species and to educate the public about potential risks. Further research needs to be conducted on the biology and ecology of the green crab in West Coast estuaries and how its invasion affects shellfish aquaculture.

New species and technologies

Develop and evaluate new culture technologies

The recent initiative by the US Department of Commerce to significantly boost aquaculture in the US has focused on the development of offshore net-pen and land-based recirculating systems. Recirculating systems may prove to have more promise in Oregon. Such systems may be economically valuable for rearing high-value species that cannot be grown in Oregon's estuaries due to salinity fluctuations, conflicts with other users or the need to avoid escapement risks.

Depending on the species cultured, it will be necessary to develop reliable, recirculation aquaculture systems suited to Oregon conditions that are economically viable and have minimal impact on the environment. Specialized culture techniques may be required for rearing endangered or threatened species for restoration purposes.

Develop the aquaculture of new high-value species

The aquaculture potential of many indigenous species of fish and shellfish are largely unknown in Oregon and the PNW including sablefish, ling cod, rockfish, Pacific halibut and other flatfish, geoduck, rock scallop, abalone and many ornamental species. As a first step, a survey of potential aquaculture species should be undertaken, to include data on production biology, economics, marketing and potential environmental impacts of culture. After determining the most promising species, development of aquaculture production methodologies should follow.

Feeds

It is likely that feed companies will need to increase and develop new products and production techniques as a result of the projected rapid growth of aquaculture in the US. The need to reduce the dependence on marine fish, such as herring, as a source of protein and highly unsaturated fatty acids (HUFA) in feed formulation has been recognized by the industry for many years. Alternative, vegetable or single-cell sources of proteins and HUFA need to be developed.

Feeds specifically designed for captive salmon broodstock programs need to be developed, as currently available diets are not optimal. Diets and methods for diet delivery also need to be developed for rearing new marine fish species, especially during their larval stages as this is a critical obstacle in marine fish culture. In addition, abalone

aquaculture could expand dramatically on the West Coast if inexpensive artificial diets were developed that replaced kelp as a food source.

Genetics

There is currently a genetic improvement program for Pacific oysters based in Oregon. Similar programs should be implemented on the West Coast for Manila clams and mussels which are both important aquaculture species in Washington State and could be produced throughout the region. Restoration initiatives for red abalone would require genetic evaluation and monitoring to ensure that genetic diversity among recovering populations is sufficient to sustain viable populations in the future. Further, genetic research will be necessary to ensure that supplementation initiatives have minimal and only positive effects upon natural population structure.

A better understanding of the genetic structure of Oregon's salmon stocks need to be achieved in order to ensure that restoration efforts by state and regional hatcheries are effective. Genetic interactions between hatchery reared fish and wild fish need to be determined and hatchery-rearing techniques modified, if necessary, to achieve desired effects.

Health management and biotechnology

Oregon has a strong reputation in fish health management and disease prevention. Development of vaccines, diagnostic tools and other products serves not only Oregon's aquaculture industry but also industries outside of the state. Sensitive indicators of stress and disease need to be developed for early detection of culture problems together with effective vaccines and other treatments to reduce risks of disease outbreaks.

System-level design and analysis

Whatever the type of aquaculture, it is a complex, multi-disciplinary enterprise with a number of demands and impacts on natural and human resources. Therefore, the research, development, and engineering of aquaculture production systems require "system" or "farm" level perspectives and contexts, in order to support the best possible decision-making and to produce the best results.

Research regarding new species and system designs cannot be properly rationalized or implemented without a system-level context, starting from potential markets and working backwards towards production methods. Resource impact assessments, informed engineering, and sound business plans are needed, again requiring system-level analyses. Aquaculture for food fish production is not viable if (1) it costs more to produce and ship a unit of fish than the market will support, (2) the market is undeveloped or made unreasonably competitive by over supply, or (3) impacts on related resources are unacceptable. While such statements seem obvious, many aquaculture enterprises over the last thirty years have failed for these reasons. Aquaculture for fishery enhancement must also consider economic viability, in order for it to be rationalized to the paying public, as well as genetic conservation concerns

Marketing and sales
A large-scale study of shellfish consumption indicating regional, ethnic, age and gender characterization of consumers would be very useful to the shellfish industry to help them focus marketing efforts. In addition, labeling aquaculture products as "organic" would enhance their value and expand markets.

Aquaculture will become more profitable if greater emphasis is placed on the development of value-added products and marketing. Market opportunities for high valued products such as eel, abalone, urchins and sablefish need to be explored. Oregon is well positioned to facilitate these efforts due to the expertise found at the OSU's Seafood Laboratory and Seafood Consumer Center in Astoria and the Seafood Innovation Center in Portland.