Guest Editorial

Shellfish aquaculture — In praise of sustainable economies and environments

Sandra E. Shumway[1], Chris Davis[2], Robin Downey[3], Rick Karney[4], John Kraeuter[5], Jay Parsons[1], Robert Rheault[6], Gary Wikfors[7]

We write to extol the virtues of filter-feeding bivalve shellfish – clams, mussels, oysters and scallops – to give them their due as key players in ecologically sustainable aquaculture in the marine environment and as environmentally sensitive monitors and water purifiers. Shellfish are successfully farmed throughout the world and shellfish culture represents a legitimate use of the marine environment for sustainable food production. An equally compelling case can be made for the primary grazers such as abalone and sea urchins.

In recent years it has become all too common for the press and some scientific literature to focus only on the negative aspects of man's use of the environment. Unless we as humans decide to eat substantially less seafood, which is contraindicated by the latest in health and nutrition research, aquaculture is here to stay; seafood production is a key to our present and future food supply. Worldwide, the demand for seafood continues to surpass supplies of wild-caught fish and shellfish, and appetites for these products are growing steadily at a time when the world is increasingly looking to the sea to provide food. Promoting ecologically sustainable shellfish culture is promoting sound resource stewardship and a clean environment. There is a critical need worldwide to bring ecological balance to some forms of aquaculture and an urgent challenge to foster aquaculture as an environmentally sound and socially acceptable practice in the United States. Marine/estuarine shellfish culture is an optimally environmentally sustainable form of aquaculture.

In 1999, bivalves represented nine percent of total world fishery production, and 27 percent by volume or 18 percent in value of total world aquaculture production. World bivalve production (capture + culture) has increased continuously and substantially over the past half century, rising from approximately one million tons in 1950 to about 11 million tons in 1999. This growth is primarily due to aquaculture (Anderson 2002). As the global population continues to grow, demand and production of food, especially seafood from aquaculture will continue to be an essential element in the future of our food security.

Unfortunately and quite unfairly, aquaculture has become an all inclusive term, especially when used by special interest and advocacy groups to rail against the perceived impacts of some coastal farmers on the environment. All aquaculture is not created equal and should not be treated as such. The various attributes and intricacies of different forms of aquaculture need to be understood. Aquaculture is a broad term that encompasses the farming of many aquatic species such as fish, shellfish and seaweeds, not only for food but also for medicinal and nutraceutical purposes. Filter-feeding bivalves have unique requirements for growth compared to other aquaculture-reared organisms such as fish and seaweeds and, consequently, they have different interactions and impacts on the coastal waters, habitats and food webs in which they are grown. Given this fact, these various attributes and potential beneficial interactions amongst the various species under culture need to be considered on their own merits in order for the continued sustainable aquaculture production of seafood. Cultured shellfish are one of the few forms of marine aquaculture to get a solid thumbs up of approval for ecological stewardship from the Audubon Society, Monterey Bay Aquarium's Seafood Watch and Eco-Fish. The broad-brush approach of lumping all aquaculture impacts together is too simplistic an approach to what is actually a complex set of issues.

Molluscan shellfish aquaculture is, by definition, a 'green' industry. Shellfish growers are committed to water quality – quality of their product and quality of the environment – from the day the molluscs spawn to the day the finished product is eaten by the consumer. Shellfish grown in approved, certified waters provide a safe, nutritious, healthy food source. In addition, the act of shellfish feeding (biofiltering) improves water quality by removing particulates and some unwanted nutrients from the water column.

Shellfish feed at the base of the food chain - as first-order consumers they are vegetarians. Filter-feeding bivalve molluscs are an essential link between the bottom-dwelling aquatic communities and phytoplankton production in the water column. Shellfish are highly efficient water filters that directly remove particulate material thus reducing turbidity and both directly and indirectly removing nitrogen and other nutrients. Via this process, these highly efficient water purifiers remove or reduce organic matter, nutrients, silt, bacteria and viruses, and improve clarity and light transmission which, in turn, improves the condition of critical habitat, including survival of critical habitat species such as seagrasses and other submerged vegetation. Thus they provide a net gain for the environment. As with any living organism, too many shellfish in a given area can result in an unbalanced ecosystem, as has been demonstrated by intense mussel raft culture operations in Spain. The phenomenon of overstocking has not been documented in U.S. shellfish aquaculture operations to date, however. Clearly, it is in shellfish growers' best interest to guard against overstocking their farms, which would result in slower growth and reduced production of their valuable crops. Working in concert with Mother Nature is always preferable to the shellfish farmer.

It is important to emphasize that as opposed to other forms of aquaculture, or agriculture for that matter, none of the food consumed by bivalve shellfish is added to the environment. They feed entirely on naturally occurring particulates in the water column. While much of the food and nutrients captured by shellfish are returned to the environment as undigested waste or feces, some is assimilated and used for growth and reproduction. What is not assimilated falls to the bottom and becomes food for deposit feeders including many of the worms and crustaceans that, in turn, are used as food by predatory fish. Increased biodeposition of organic matter in sediments leads to increased bacterial denitrification that can help to remove nitrogen (N) from estuarine systems over-enriched with nutrient pollution (see Kaspar *et al*. 1985).

Filter-feeding molluscs not only remove N from the water column, but also incorporate a high proportion of it into their tissues. When the molluscs are harvested, the N is removed from the system. Shellfish are approximately 1.4 percent nitrogen and 0.14 percent phosphate by weight. This may not seem like much, but when those shellfish are harvested, substantial amounts of nutrients are permanently removed from the water. A weekly harvest of only about 200 oysters can compensate for the nutrient inputs of a typical waterfront homeowner on a properly functioning septic system (Rice *et al*. 2001). A commercial weekly harvest of ~10,000 oysters contains about 13.6 kg of nitrogen and 1.4 kg of phosphate, and can result in the removal of about 100 kg of N per year! In simple terms, an oyster farm of about 1 ha can compensate for the nitrogenous wastes of 40-50 coastal inhabitants. As an added benefit, the associated bacteria in sediments of an oyster bed can remove 20 percent or more of the N in oyster wastes, using the same process that is used in modern wastewater treatment plants (see Newell *et al*. 2003). Shellfish feeding can also help to control or even prevent harmful algal blooms by removing the cells before the algae accumulate to environmentally detrimental levels. Data indicate the importance of bivalves as modulators of suspended materials and nutrient cycles in ecological systems. The effects are a primary reason that programs designed to rehabilitate our estuarine and nearshore water such as the Chesapeake Bay Program in the USA are encouraging hundred to thousand fold (or more) increases in the numbers of bivalves in the system.

Public health standards under which shellfish aquaculture operates demand clean waters and commercial shellfish harvest can only take place in growing waters that have been certified under the National Shellfish Sanitation Program (NSSP), a stringent set of standards adopted by all shellfish producing states and operated under the Food and Drug Administration. These standards include monitoring for fecal coliform level, which is used as an indicator for human activity and the potential for pathogenic bacteria in the water; *Vibrios*; harmful algal toxins; heavy metals and other contaminants. The NSSP standards fostered the first estuarine/marine monitoring programs, and are the most stringent of all our water quality classifications, far exceeding those required for swimming. They are also one of the few environmental monitoring programs where failure to meet water quality standards causes an immediate closure of the water to harvest. These bans remain in effect until water quality monitoring indicates the area once again meets standards. As a result, the presence of molluscan aquaculture often results in increased awareness and monitoring of environmental conditions of estuaries and coastal waters. Shellfish growers can not tolerate the discharge of untreated sewage near their farms and regularly monitor other potentially harmful inputs to the local areas. The contamination of areas for shellfish culture or harvest has often provided the political impetus for improvement in sewage treatment plants, or programs to fix local septic systems. Even the courts are upholding the environmental benefits of shellfish culture. Recently, Taylor Shellfish in the state of Washington's Puget Sound was sued by a group of waterfront homeowners who claimed that the cultured mussels were polluting the water. The court found in favor of Taylor Shellfish stating: "...feces and chemicals exuded from the live mussels have not been shown in the record significantly to alter the character of Puget Sound waters, and the record suggests instead that the mussel-harvesting operations generally purify the waters."

Shellfish aquaculture is sustainable farming at its best, including the latest in hatchery and nursery technology, stocking, crop-tending/density management, and integrated pest management. Growers recognize the need to be stewards, of the environment to maintain clean growing waters and ensure their own future viability. Many aquaculture organizations have or are developing Environmental Codes of Practice, including Best Management Practices, to ensure that as the industry develops, it maintains a responsible environmental record. Examples can be found in the USA, Chile, New Zealand, Ireland and Canada.

Shellfish culture is a winning proposition on several fronts, and by its very nature in most cases meets the National Organics Standards Board's criteria required for 'organic' aquaculture (NOSB 1996) – which calls for "an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity." According to the NOSB, farming practices should be based on "minimal off-farm inputs and on management practices that restore, maintain and enhance ecological harmony." Shellfish farming embraces all these principles.

Further, due to the sedentary nature of shellfish, they are not prone to escape. They are farmed in well defined areas, intertidally or subtidally, either directly on the substrate or suspended from rafts or stakes, often with protective netting, or on racks. Shellfish culture also promotes and enhances biodiversity by creating structure and habitat for other marine species. Shellfish beds provide a larger variety and biomass of associated invertebrates and finfish than a similar area without shellfish.

On the West Coast, the native oyster (*Ostrea conchaphila*, "Olympia" oyster) came close to the point of extinction in the mid 1900's, due to a combination of over-harvest and pollution from pulp mills that dumped toxic wastes directly into the marine waters. The Japanese oyster (*Crassostrea gigas*) was introduced by enterprising oyster farmers during that period, providing the farmers with a hardier oyster and allowed the industry to continue. Armed with the knowledge of how pollution can destroy growing areas, shellfish farmers become first in the line of defense in enacting laws and protecting and restoring water quality to keep their industry alive. As a result, water quality has been restored in many of the bays where the native oysters were once prolific, and restoration efforts, that have included the latest in hatchery technology to maintain and promote native broodstock used to recolonize beaches, are bringing about a resurgence in native oyster populations.

The structures used in aquaculture (racks, cages, nets, ropes, trays and lines), and in particular shellfish aquaculture, act like reefs and provide habitat and protection for a myriad of other organisms, frequently serving as nursery grounds for fish and other shellfish, such as juvenile lobsters. They provide protection from predators for juvenile fish and crustaceans, increased surface area for fouling (a benefit for many microorganisms and grazers, although not a benefit to the growers), and an increased food supply for other organisms.

Shellfish culture additionally can reduce the negative impacts from bottom disturbance that would occur if the area had been used instead for harvest of wild stocks. The increased density on shellfish farms means less environmental impact and disturbance for equal yield compared to wild harvest. Growers will typically plant at densities that are ten to several hundred times those found in beds that are open to wild harvesting. Farmers who rely on mechanical harvesting will therefore disturb a proportionately smaller area to harvest the same biomass. Moreover, culture areas are the same year after year and typically are only disturbed when the crop reaches harvest size, whereas wild harvesters work the same grounds many times a year.

Aquaculture represents an important opportunity for economic activity and social cohesion in coastal, rural areas, providing family wage jobs in rural areas that are often otherwise economically depressed. Aquaculture is an activity that occurs in and on the water and can, in part, provide an ideal occupational alternative for displaced fishermen. Its development can preserve the character and ambience of seaside fishing communities, utilize the local acquired knowledge and skills of the coastal folk, and allow the local denizens to remain economically and culturally tied to the marine environment.

Odum (1989) stated that, "......modern aquaculture should adopt a new strategy, a model of community-based, ecologically sustainable aquaculture." Polyculture of shellfish on salmon leases has been demonstrated to be a viable option by many studies (see Parsons *et al*. 2002) and seaweed culture is a net consumer of dissolved nutrients from the water column. It is possible that by integrating the culture of shellfish and seaweeds with marine finfish culture a more ecologically balanced approach can be achieved for the sustainable development of seafood. Aquaculture is where the future growth of seafood will come and we believe that shellfish are the key to an ecologically sustainable venture.

Shellfish are one of the best candidates for ecologically sustainable aquaculture. Farming of shellfish not only provides a high quality, high value, sustainable harvest from the ocean, it also provides jobs and social and economic development, all while providing tangible benefits to the marine environment. A productive shellfish farm means a healthy and equally productive surrounding environment – let's give the lowly molluscs their due!

Notes

[1]Department of Marine Sciences, University of Connecticut, 1080 Shennecossett Road, Groton, Connecticut 06340 USA.

[2]Pemaquid Oyster, P.O. Box 302, Waldoboro, Maine 04572 USA.

[3]Pacific Coast Shellfish Growers Association, 1120 State Avenue NE, PMB #142, Olympia, Washington 98501 USA.

[4]Martha's Vineyard Shellfish Group, Oak Bluffs, Massachusetts 02557 USA.

[5]Rutgers University, Shellfish Research Laboratory, P.O. Box 687, Port Norris, New Jersey 08349 USA.

[6]Moonstone Oysters, Wakefield, Rhode Island 02879 USA.

[7]NOAA National Marine Fisheries Service, 212 Rogers Avenue, Milford, Connecticut 06460 USA.

References

Anderson, J.L. 2002. Aquaculture and the future: Why fisheries Economists should care. Marine Resource Economics 17: 133-151.

Kaspar, H.F., P.A. Gillespie, I.C. Boyer, and A.L. MacKenzie. 1985. Effects of mussel aquaculture on the nitrogen cycle and benthic communities in Kenepuru Sound, Marlborough Sounds, New Zealand. Marine Biology 85: 127-136.

Newell, R.I.E., J.C. Cornwell and M.S. Owens. 2003 Influence of simulated bivalve biodeposition and microphytobenthos on sediment nitrogen dynamics: A laboratory study. Limnology and Oceanography 47, pp. 1367-1379.

Odum, E.P. 1989. Input Management of Production Systems. Science 243: 177-181

Parsons, J.G., S.E. Shumway, S.Kuenstner and A. Gryska. 2002. Polyculture of sea scallops (*Placopecten magellanicus*) suspended from salmon cages. Aquaculture International 10: 65-77.

Rice, in: Tlusty, M.F., D.A. Bengston, H.O. Halvorson, S.D. Oktay, J.B. Pearce and R.B. Rheault, JR. (Eds) 2001. Environmental impacts of shellfish aquaculture: filter feeding to control eutrophication. Pp. 76-86 In: Marine Aquaculture and the Marine Environment: A meeting for the Stakeholders in the Northeast. Held January 11-13, 2001 at the University of Massachusetts Boston. Cape Cod Press, Falmouth, MA.