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Sustainable U.S. Marine Aquaculture Expansion in the 21st Century

Front Cover: SeaStation Net Pen, photo courtesy of OceanSpar LLC.

Back Cover: (l-r) Top row: Mature mussels at 15m depth; Five-tiered lantern net used for open water oyster culture (see Cheney et al. paper); New Aquapod cage design being outfitted for deployment (photo courtesy Barry Costa-Pierce). Middle row: Moi harvest (photo courtesy Cates International, Inc.); Upper section of scallop spar at deployment in surface mode (see Cheney et al. paper); 20-ton capacity multi-cage feeder developed by the University of New Hampshire (UNH), Ocean Spar and the Aquaculture Engineering Group (see Langan paper). Bottom row: Small offshore cage with copper alloy netting after a 120-day deployment at the UNH experimental offshore site (see Langan paper); SeaStation cage being outfitted for submerged deployment off New Hampshire (photo courtesy Richard Langan); diver using a hydraulic net cleaner on a SeaStation cage installed at Keahole Point (see Loverich paper).

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Guest Editor: John S. Corbin

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COMMENTARY

Marine Stock Enhancement, a Valuable Extension of Expanded U.S. Marine Aquaculture

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The National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce defines aquaculture as, "the propagation and rearing of aquatic marine organisms in controlled or selected aquatic environments for any commercial, recreational, or public purpose." According to NOAA, the definition covers all production of finfish, shellfish, and other marine organisms, excluding marine mammals, for

- human consumption and other commercial uses,
- wild stock enhancement,
- rebuilding populations of threatened or endangered species, and
- restoration of marine habitat (NOAA, 2010).

The term aquaculture, more commonly called fish farming, generally conjures up visions to seafood-loving Americans of acres of fish ponds, hanging baskets of oysters in estuaries, coastal mud flats teeming with clams, and more recently large sea cages floating on the ocean or submerged in the depths. This commentary briefly addresses the "other aquaculture," encompassed by the words in the NOAA definition, "propagation or rearing … for … recreational or public purpose." Specifically, it focuses on the current status of marine aquaculture as a tool for stock enhancement of nonsalmonid, marine species, saving threatened and endangered species, and marine habitat restoration. These are increasingly important activities that are not fully appreciated in many circles of government or by the public.

Wild Stock Enhancement Is Not a New Idea

It is noteworthy that alarms were being raised over the decline in U.S. fish populations as early as the late 1800s, when the American population was around 44 million people. Consider this statement by Spencer Baird, the first Commissioner of the newly formed U.S. Fish and Fisheries Commission (USFFC), who was appointed by President Ulysses S. Grant in 1871.

> *A few years ago, in view of the enormous abundance of fish originally existing in the sea, the suggestion of a possible failure would have been considered idle; and the fisheries themselves have been managed without reference to the possibility of a future exhaustion. The country has, however been growing very rapidly…. The object of those engaged in the fisheries has been to obtain the largest supply in the shortest time….Spencer Baird, USFFC, 1871 (Stickney, 1996).*

Enter aquaculture. Almost coincident with the establishment of the USFFC was the establishment of the American Fish Culturists Association, which later became today's American Fisheries Society. The association suggested in 1872 that the United States should "take part in the great undertaking of introducing or multiplying shad, salmon, and other valuable food-fishes throughout the country, especially in waters over which its jurisdiction extended, or which were common to several States, none of which might feel willing to incur expenditures for the benefit of the others" (Stickney, 1996).

Thus began a large-scale, long-term, multistate effort by the federal and state governments to use aquaculture technologies to address the often unanticipated impacts on wild fish and shellfish populations of society's efforts to meet the economic and social needs of the expanding U.S. population. Among the applications of aquaculture technologies were mitigation of dam construction on salmon runs, restoration of shellfish beds from periodic flooding, demand for increased recreational fishing opportunities (particularly public use of newly constructed reservoirs), and addressing overfishing of coastal and ocean species, such as cod (Stickney, 1996).

The magnitude of the effort can be illustrated by examining a compilation of all state and federal hatcheries in 1937 that lists 79 federal hatcheries

and 381 state hatcheries, representing all 48 states. These facilities released millions of eggs, larvae, and early stage juvenile fish and shellfish each year (Stickey, 1996). Today, 70 national fish hatcheries remain under the National Fish Hatchery System (NFHS), the U.S. Fish and Wildlife Service, and the Department of the Interior that focus on several freshwater species, including lake trout, cutthroat trout, paddle fish, sturgeon, and freshwater mussels. These facilities are located in 35 states and can produce more than 60 different, freshwater, and anadromous species (NFHS, 2010). The NFHS, along with numerous state and private sector hatcheries, supports a nationwide freshwater recreational fishing economy that in 2006 encompassed an estimated 25 million anglers, generated 433 million fishing days, and accrued $26 billion of expenditures (U.S. Department of Commerce and US Department of the Interior, 2007).

Importance of U.S. Marine Stock Enhancement

Commercial Fisheries

Although freshwater stock enhancement is a well-established practice in the United States, marine stock enhancement fell out of favor with government fisheries managers in the 1960s and 1970s, when it was considered a waste of public resources. Marine stock enhancement consists of three basic types:

1. restocking, or the release of juveniles into wild populations to restore severely depleted spawning biomass or reproductive capacity;
2. stock enhancement, or the release of cultured juveniles into wild populations to augment the natural supply and optimize harvests by overcoming recruitment limitations; and
3. sea ranching, or the release of juveniles in the marine and estuarine environments for harvest at a larger size, without concern for spawning biomass (Science Consortium for Ocean Replenishment [SCORE], 2010).

After over 70 years of stocking marine species without clear signs of success (i.e., the release of millions of eggs, larvae, and early stage fish and shellfish that were too fragile for survival, without adequate assessment techniques to accurately gauge results), the United States closed most of its marine hatcheries. Instead, fisheries managers focused on controlling catch rates through regulation and habitat protection (Leber, 2004).

America's commercial fisheries provide a significant amount of seafood each year, with 2008 catch values equaling approximately 3 mmt (6,600 million pounds), valued at $4.2 billion. Despite this harvest, the United States still imports 84% of the seafood consumed (NOAA, 2010). In general, fishery yields have remained relatively flat since the early 1990s (National Marine Fisheries Service [NMFS], 2009).

Of greater concern, despite diligent management efforts by the NMFS that are making steady progress, overfishing remains a threat to the sustainability of seafood supply from domestic capture fisheries. Aquaculture for stock enhancement can be an effective way to address this ongoing threat. A 2008 report on the status of 531 individual U.S. fish and shellfish stocks and stock complexes noted that there are two broad categories defined: stocks "subject to overfishing" and those stocks "subject to being overfished." According to NMFS, a stock that is subject to overfishing has a fishing mortality (harvest) rate above the level that provides for maximum sustainable yield, and a stock that is subject to being overfished has a biomass level below a biological threshold specified in its fishery management plan. Of the 251 stocks or stock complexes with previous overfishing determinations, 41 (16%) were subject to overfishing in 2008. Similarly, of 199 stocks with previous overfished determinations, 46 (23%) were overfished (NMFS, 2009).

Given the increasing challenges in sustainably managing U.S. marine fisheries, renewed interest in marine stock enhancement has been growing steadily. One reason is the documented successes demonstrating that releases of hatchery-produced marine fish and shellfish can augment and rebuild wild populations that are subject to yearly fishing pressure and occasional man-made and natural disasters. Perhaps the most recognizable U.S. success involves the multimillion dollar commercial salmon industry in Alaska. Hatchery techniques for salmon have been around for nearly 100 years and were widely applied when fisheries experienced record low wild stock runs in the 1960s and 1970s. Currently, Alaskans have invested in 36 hatcheries, 31 of which are owned and/or operated by private nonprofit corporations that released 1.4 billion juvenile fish in 2009, while in that year, 45 million adult salmon from releases in previous years returned to streams statewide. Of the 148 million fish harvested by the fishery, an estimated 28 million or 19% originated from the Alaska enhancement program (White, 2010).

Indeed, enhancement programs for the anadromous (a salt water fish that returns to fresh water to spawn)

salmon have enjoyed strong federal and Congressional support for the past 50 years, with the dual targets of increased sport fishing opportunities and active management of stocks for commercial fishing. Over time, support for enhancement of U.S. Pacific salmon fisheries diversified with federal, state, industry, and NGO contributions. Currently, public and private support for stocking Pacific salmon is substantial, with the annual total from various publically mandated programs estimated at well over $63 million in 2004 (Leber, 2004).

Another successful, large-scale example is from Japan and its efforts to build domestic fisheries yields. In the late 1970s, fisheries officials realized that due to a variety of reasons, including the establishment of Exclusive Economic Zones around the world, Japan's distant water fishing fleet could not meet the future demand for seafood by its population. At that time, the government began investing heavily in marine aquaculture technologies with the goal of enhancing fisheries around the main islands.

Today the program involves about 80 species of marine fish and shellfish. Progress in the main targeted fisheries has been impressive, with estimates showing 50% of the Kuruma prawn catch, up to 75% of red sea bream, almost all of the scallop harvest and up to 40% of the flounders originating from hatcheries. Techniques used to support hatchery releases include habitat restoration, predator removal, and behavioral conditioning. Coastal fishing communities made a strong commitment to the program (SCORE, 2010).

Recreational Fisheries

Marine recreational fishing also provides a significant amount of seafood for the American diet. In 2008, almost 12 million anglers spent $30 billion on nearly 85 million marine recreational trips on the Atlantic, Gulf, and Pacific Coasts and around Hawaii. The total marine catch was conservatively estimated at nearly 464 million fish, of which almost 58% were released. Total harvest weight was estimated at 112, 217 mt (248 million pounds) (NMFS, 2008).

In theory, greater stocking of important coastal sport fishing species, in combination with other fishery management techniques, could help sustainably maintain and expand the availability of these species to resident and tourist anglers alike. Expected future growth in the number of recreational salt water anglers and the increase in fishing pressure on available fish could be more successfully managed by adding marine stock enhancement to the "tool box." Moreover, the economies of coastal communities would benefit from a stable and more robust fishing economy.

U.S. Research and Development Efforts

The Consortium Approach

A growing need for increased research to better understand the complex interactions between enhancement and the marine ecosystem has been recognized by many U.S. fisheries and aquaculture professionals in recent years. Proponents of more research and demonstration projects highlight a lack of measurable results during the previous 100 years of public sector fisheries enhancement efforts, which focused on hatchery production and release magnitude (numbers of animals) and not cost and benefit analysis. Supporters also highlight the emergence of advanced aquaculture technologies for mass production of stock and better understanding of the ecological requirements of receiving waters as well as a new generation of cost-effective, high-tech marking techniques (e.g., coded wire tags and genetic markers), and sophisticated monitoring capabilities. These improvements and others to the state of the science provide a solid foundation on which to build greater U.S. capabilities.

These issues were brought into sharp focus by publication of a seminal paper by Blankenship and Leber in 1995, entitled "A Responsible Approach to Marine Stock Enhancement." This publication led to the 2001 establishment of a scientist-initiated national partnership of research institutions called the Science Consortium for Ocean Replenishment (SCORE). SCORE, partially funded and sponsored by NOAA since 2002, is built on a different enhancement model than past efforts. It is a more comprehensive, holistic, and responsible approach to utilizing and understanding aquaculture as a tool for fisheries enhancement and ecosystem management (SCORE, 2010).

SCORE is focused on advancing the science needed to further develop and responsibly manage marine stock enhancement. Member scientists conduct concurrent, multidisciplinary research activities in coastal areas of the United States—the Gulf of Mexico, the Eastern Atlantic Ocean, and Western Pacific Ocean—incorporating all of the principles of the responsible approach conceptualized by Blankenship and Leber. These principles can be briefly summarized as follows:

1. prioritize and select target species and assess reasons for wild population decline,
2. develop a management plan for each species that fits into regional plans,

3. define quantitative measures of stocking success,
4. use genetic resource management,
5. implement a disease and health management plan for stock,
6. consider ecological, biological, and life history patterns and requirements in forming objectives and tactics,
7. identify individual released hatchery fish to quantitatively assess impacts on wild stock abundance,
8. use an empirical process to define optimal release strategies, e.g., release location, timing, and numbers,
9. identify economic objectives and policy guidelines and educate stakeholders, and
10. use adaptive management to refine production and stocking plans (Blankenship and Leber, 1995).

SCORE is composed of five "Principal Partners": Mote Marine Laboratory (MML), Florida; University of New Hampshire, Atlantic Marine Aquaculture Center; University of Southern Mississippi, Gulf Coast Research Laboratory; Hubbs-SeaWorld Research Institute (HSWRI); and NOAA/NMFS Northwest Fisheries Science Center (SCORE, 2010).

Nationwide, a modest amount of research is underway on marine finfish and shellfish aquaculture (e.g., closing the life cycles and mass rearing of economically important species) and release of cultured fish and shellfish for responsible stock enhancement. SCORE lists active participants representing 7 NOAA fisheries and aquaculture organizations, 4 Sea Grant groups, 9 state conservation and natural resource agencies, 1 Northwest Indian Fisheries Commission, and 13 university and private research laboratories (SCORE, 2010). States with the greatest funded nonsalmonid fish and shellfish research programs focused on enhancement are Florida, California, Texas, Connecticut, Maryland, Mississippi, New Hampshire, North Carolina, South Carolina, Virginia, and Washington (Leber, 2004). Several examples of stock release projects that are underway are as follows:

- MML, Florida: The MML program focus is on basic and applied research designed to resolve critical uncertainties about stocking efficiency and effectiveness and whether and how stocking can be best used as a fishery management tool in marine and estuarine ecosystems. Model species chosen are two of Florida's most popular game fish; red drum, *Sciaenops ocellatus*, and the common snook, *Centropomus undecimalis*. The Red Drum Program, conducted between 2000 and 2004, released more than four million juveniles, consisting of three size groups, into two rivers systems feeding Tampa Bay. Extensive assessment of the impacts of these releases continues, including fish survival, growth, and movement (MML, 2010).
- HSWRI, California: The White Sea Bass Restoration Project was established to reintroduce white sea bass, *Cynoscion nobilis*, to California coastal waters. Once an important game fish and commercial food fish, the white sea bass have virtually disappeared, with populations 10% of what they were 50 years ago. California Fish and Game funded HSWRI to propagate white sea bass and grow them to juvenile size (6 cm or about 3 inches), when the fish are transported to one of 15 grow-out facilities along the Coast that are operated by various nonprofit groups and volunteers. Fish are grown for 3 to 4 months to about 30 cm (1 ft) in net pens located in sheltered waters and harbors, when they are released to the wild at this larger size to increase survival. To date, millions of fish have been released and evaluation studies, including movement, are ongoing (SDOF, 2010; HSWRI, 2010).
- Texas Parks and Wildlife Department (TPWD): In the 1970s and early 1980s, a series of extreme winters, combined with commercial and recreational overharvest, had decimated red drum populations along the Texas coast. TPWD responded in 1983 by building its first marine hatchery and stocking coastal bays. TPWD has expanded the release program to three hatcheries and stock releases are now considered an essential management tool for red drum populations along the Texas coast. Annually, some 25 million juvenile marine fish, representing two species, red drum and spotted sea trout, *Cynoscion nebulous*, are released and today both fish populations are considered stable by fishery scientists (TPWD, 2010).

Species Preservation and Ecosystem Restoration

Marine aquaculture technologies can be developed to produce a variety of organisms that could help preserve endangered aquatic species and restore damaged marine ecosystems. Bottlenecks exist in closing the life cycle of many species of interest, for example, a food small enough for first feeding of some marine fish, but research is underway on a few species, largely at public and private aquariums.

Many of the larger aquariums, for example, the Georgia Aquarium, have breeding programs for the rarer aquatic species they have on display so that they do not have to continuously capture wild specimens. In this context, some aquaria are also working with threatened and endangered organisms to develop propagation technology that could be used to restock and rebuild populations that are or could be in crisis and view this as an important role in the 21st century (Garibaldi, 2001). For example, the Seattle Aquarium (2010) carries out genetics research on the leafy seadragon, an endemic species of Australia that is endangered. The Waikiki Aquarium (WA) was the first facility to culture the Chambered Nautilus, considered a living fossil and threatened by overfishing for its beautiful shell (WA, 2010).

Cultured organisms could also be used to restore ecosystems damaged by natural and man-made disasters. For example, the WA currently has the oldest and largest collection of living corals in the United States. The aquarium has regularly been asked to use its Hawaiian coral stock to help the State in reestablishing coral colonies damaged by ship groundings (WA, 2010).

Conclusions

Clearly, releasing aquaculture produced stock to enhance wild populations of fish and shellfish and restore distressed ecosystems or habitats could be a valuable tool to incorporate into existing fishery and habitat management approaches. Moreover, the United States has a growing cadre of capable researchers and research institutions that are developing mass rearing hatchery technologies for species of economic and ecological importance. A few state stocking programs using the responsible approach are demonstrating the positive influences of wild stock enhancement today.

Research Funding Needs

The United States should take full advantage of its leadership position in this emerging, modernized field and the active collaboration of federal, state, university, and private research organizations pursuing responsible marine stock enhancement. The potential as a useful management tool is evident and the scientific literature is growing (Bell et al., 2008). However, uncertainties with large-scale application remain and increased federal research funding is needed (Mote, 2010; SCORE, 2010). Importantly, research dollars spent on closing the life cycles and creation of mass production hatchery technologies for economically significant marine species will have a twofold benefit. Hatchery technologies can be applied by the private sector for commercial farming, such as sea cage culture in the EEZ, and by public purpose government and private agencies to produce fish and shellfish for stock enhancement of recreational and commercial fisheries.

A partial "wish list" by experts in the field of responsible stock enhancement indicates further research needs include greater use of genetic stock identification, comparison of natural levels of diseases and parasites between hatchery and wild fish, release–recapture studies to optimize release strategies and more precise measurement of fish population sizes to document contribution rate, stock behavioral studies, ecological and wild stock impact studies, better tracking technologies, such as use of hydroacoustics to monitor movements of hatchery fish and locate older released fish, better understanding and evaluation of ecosystem carrying capacity and its effects on success rate, and greater application of cost and benefit analysis to enhancement approaches compared with alternative management approaches (Leber, 2004; Lorenzen, 2008).

Hatchery Infrastructure Needs

Rapid advancement in the culture technology for marine species is expected in the next decade because of increasing global reliance on aquaculture to meet the growing need for basic aquatic protein (Food and Agriculture Organization, 2009). Looking ahead, should increased U.S. efforts in marine aquaculture research be successful and governments want to scale-up enhancement efforts, adequate federal or state hatchery infrastructure does not appear to be available or planned that can take advantage of the anticipated research breakthroughs.

A cursory look at federal facilities reveals the NFHS in the U.S. Fish and Wildlife Service is focused on and fully engaged in producing freshwater and anadromous species. NOAA is primarily engaged in research and not mass production of marine stock. Further, only a few coastal states have any significant infrastructure for mass production of marine fish and shellfish species (e.g., Texas and Connecticut) and most with enhancement programs currently focus on biological and ecological research (Leber, 2004). Given this sobering assessment, what options do governments and the commercial and recreational fishing public, which they serve, have to implement increased wild stock enhancement efforts?

At least three options could be considered: (1) build a totally new nationwide federal hatchery system for marine species, (2) partner with interested states to build a significant number of state-run marine hatcheries, and (3) incentivize the business environment to encourage private for-profit and nonprofit companies to build marine hatcheries to produce stock for sale to the government and the public. It is not possible to elaborate on these policy options in this brief commentary but to state that applicable model programs (though some not in fisheries) for all these approaches are available for study, for example, Alaska's nonprofit private hatchery program for salmon.

Priority Support

Finally, with the new administration in Washington, DC, policies and plans are currently being developed for broader ocean management and use as well as specifically for commercial aquaculture in the EEZ (Council on Environmental Quality, 2009a, 2009b; NOAA, 2009). These efforts should include priority consideration of investing in greater U.S. understanding and use of marine aquaculture as a tool for responsible fisheries and ecosystem management. The United States should plan for and encourage greater infrastructure capabilities to mass produce marine fish, shellfish, and other species (e.g., blue crab, *Callinectes sapidus*) to help address America's growing demand for seafood and the potential requirements to rebuild and restore critical marine habitat impacted by continued coastal development and global climate change.

Valuable impacts on society extend beyond fostering healthy and productive marine ecosystems and reducing America's increasing reliance on seafood imports to fill demand. They can include greater development and diversification of the commercial fishing, recreation, and tourism-based economies of coastal communities as well as expanding the important social and cultural benefits to the public at-large of preserving America's marine fishing heritage.

References

Bell, J., Leber, K., Blankeship, H., Loneragan, N., Masuda, R. 2008. A new era for restocking, stock enhancement, and sea ranching of coastal fisheries resources. Reviews Fish Sci. 16(1-3):1-9.

Blankenship, H., Leber, K. 1995. A responsible approach to marine stock enhancement. Am Fish Soc Symp. 15:162-175.

Council on Environmental Quality. 2009a. Interim Report of the Intergency Ocean Policy Task Force. Washington DC: IOPTF, CEQ, 38 pp.

Council on Environmental Quality. 2009b. Interim Framework for Effective Coastal and Marine Spatial Planning. Washington DC: IOPTP, CEQ, 32 pp.

Department of the Interior. 2007. 2006 National Survey of Fishery, Hunting, and Wildlife-Associated Recreation. Washington DC: U.S. Fish and Wildlife Service, DOI, 168 pp.

Food and Agriculture Organization. 2009. The Status of World Fisheries and Aquaculture 2008. Rome: United Nations, FAO, 176 pp.

Garibaldi, L. 2001. The changing role of the aquarium in the 21st Century. Bull I'Institut Oceanographic (Monaco), 20:2.

Hubbs-SeaWorld Research Institute. 2010. Website: HSWRI [www.hswri.org] (Accessed April 2010).

Leber, K. 2004. Marine stock enhancement in the USA: Status, trends, and needs. In: Stock Enhancement and Sea Ranching, Developments, Pitfalls, and Opportunities, pp. 11-24. Ames, Iowa: Blackwell Publishing.

Lorenzen, K. 2008. Understanding and managing enhancement fisheries systems. Reviews Fish Sci. 16(1-3):10-23.

Mote Marine Laboratory. 2010. Website: MML [www.mote.org] (Accessed April 2010).

National Fish Hatchery System. 2010. Website: NFHS: [www.fws.gov/fisheries/nfhs/] (Accessed April 2010).

National Marine Fisheries Service. 2008. Fisheries of the United States 2008. Silver Spring, MD: NMFS, U.S. Department of Commerce. 101 pp.

National Marine Fisheries Service. 2009. 2008 Status of U.S. Fisheries. Washington, DC: NMFS, NOAA, U.S. Department of Commerce. 28 pp.

National Oceanic and Atmospheric Administration. 2009. Website: News [www.noaasnews.noaa.gov/stories 2009/] (Accessed Dec. 2009).

National Oceanic and Atmospheric Administration. 2010. Website: NOAA, Aquaculture Program [http://aquaculture.noaa.gov/] (Accessed April 2010).

San Diego Oceans Foundation. 2010. Website: SDOF [www.sdoceans.org] Accessed April 2010).

Science Consortium for Ocean Replenishment. 2010. Website: SCORE [www.stockenhancement.org] (Accessed April 2010).

Seattle Aquarium. 2010. Website: SA [www.seattleaquarium.org/] (Accessed April 2010).

Stickney, R. 1996. Aquaculture in the United States. New York: John Wiley and Sons, Inc., 372 pp.

Texas Parks and Wildlife Department. 2010. Website: TPWD [www.tpwd.state.tx.us] (Accessed 2010).

Waikiki Aquarium. 2010. Website: WA [www.waqarium.org] (Accessed April, 2010).

White, B. 2010. Alaska Salmon Enhancement Program 2009 Annual Report. Anchorage, Alaska: Alaska Department of Fish and Game, 53 pp.

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