Summary of the 2008 NOAA National Symposium on Shellfish & the Environment

Prepared by the
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NOAA National Symposium on
Shellfish & the Environment

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Background

On June 9–10, 2008, the National Oceanic and Atmospheric Administration's Aquaculture and Habitat Conservation programs hosted the *2008 National Symposium on Shellfish and the Environment* in Warwick, Rhode Island. Organized by Dr. Sandy Shumway of the University of Connecticut, the symposium was designed to address important issues regarding shellfish aquaculture in the United States. Three key themes were discussed:

- Educating the public on the benefits of shellfish aquaculture;
- Bringing clarity and consistency to regulations for this industry, and
- Refinement of best management practices essential for the growth and success of the shellfish industry.

Topics included carrying capacity, eutrophication, water quality, habitat, invasive species, genetics, aquatic animal health, social aspects, gear/harvest impacts, and cumulative impacts.

U.S. Senator Jack Reed of Rhode Island was a featured speaker on the first day of the symposium. In his remarks Senator Reed highlighted the proactive approach the Ocean State is taking to ensure a sustainable aquaculture industry and protect the marine environment. Other speakers included scientific and policy experts from the United States, Canada, and Europe who addressed a range of topics focused on policy, regulation, and the environmental effects of shellfish culture. Participants included growers and representatives from the U.S. shellfish industry, non-government organizations, researchers, and federal and state officials. NOAA's representatives included Tim Keeney, Deputy Undersecretary for Oceans & Atmosphere; Brian Pawlak, Deputy Director of the NOAA Office of Habitat Conservation; and Dr. Michael Rubino, Manager of the NOAA Aquaculture Program.

This summary includes a synthesis of the top three themes that emerged from the discussions held at the symposium, followed by highlights of the presentations given by each of the invited speakers. The information generated by the symposium will be used to facilitate public policy and resource management discussions and decisions for shellfish aquaculture in the United States, and to inform research priorities.

Top Three Themes from the Symposium

The following points emerged as the top three themes from the breakout sessions held at the NOAA National Shellfish Symposium.

- *The need for improved understanding of the interactions, both positive and negative, of shellfish aquaculture and the environment.* Better information and analysis will allow for refinement of Best Management Practices (BMPs) that are essential to a sustainable aquaculture industry. Participants emphasized that BMPs should be standardized, recognizing that practices, environments, and species vary regionally.

- *More vigorous education and outreach efforts are critical to the future of U.S. aquaculture, including the need to increase public knowledge and understanding of the beneficial effects of sustainable shellfish farming.* Throughout the symposium, the value of and need for increased education and outreach to the public was raised as the most important next step. Participants emphasized that Sea Grant agents, industry members, environmental NGOs, and other stakeholders need to engage in more extensive local education and outreach (e.g., school programs/visits, oyster gardening, and food festivals) to improve public understanding of shellfish aquaculture. Potential solutions included targeting public education campaigns to riparian landowners and educating the public specifically on the environmental and economic benefits of shellfish aquaculture.

- *Shellfish aquaculture policies and regulations on all levels are often fragmented and confusing limiting restoration aquaculture and commercial shellfish farming*. Proposed solutions included coordinated coastal land use planning to keep shellfish beds, restore beds, to protect natural environmental features, and make room to establish areas dedicated for shellfish aquaculture. Policies and regulations should take into account local knowledge and experience, as well as the need for consistency and predictability. Proposed solutions included coordinated coastal land use planning to keep shellfish beds, restore beds, to protect natural environmental features, and establish areas dedicated for shellfish aquaculture.

Syntheses of the Breakout Discussions

Participants at the symposium were randomly assigned to participate in breakout groups to discuss issues of particular importance and relevance to shellfish aquaculture in the United States. Each participant had the opportunity to participate in two of the four breakout discussions.

The following text summarizes the major points recorded and highlighted in the four breakout sessions that focused on:

1. Eutrophication/Carrying Capacity/Water Quality
2. Genetics/Invasives/ Disease
3. Habitat and Gear/Education
4. Societal Interactions/Engagement

1. Eutrophication/Carrying Capacity/Water Quality

This session focused on the ecosystem interactions of shellfish aquaculture and the environment. Discussions highlighted the need for:

- A common language and understanding as well as quantitative definitions regarding key metrics, values, and terminology for shellfish aquaculture. A standard starting point for comparisons. For example, should current operations be compared to present values, historic values, or something else? And, at what scale (temporal and/or spatial) must effects be analyzed?
- Improved data collection practices and methods to provide species-specific data on benthic impacts, sedimentation, harvesting impacts, nutrient removal capabilities, and other factors.
- Considering source data from industry as well as research.
- Data and information on water quality that is easily accessible to researchers, regulators, and the public in useful formats, such as bibliographies or a web-based information
- Implementation of a meta-analysis of existing data to help answer questions and identify information gaps related to water quality.

2. Genetics/Invasives/Disease

This session highlighted issues of genetic management and husbandry, non-native introductions, and the potential role of farmed shellfish as vectors for disease or parasites. A central question was: Should farmed species be domesticated (much like modern agriculture) to produce lineages that are very different than wild stocks, or should broodstock be managed to maintain genetic diversity as found in abundant wild stocks? Responses to this question included the view that although domestication would allow for “genetic improvement,” such as disease-resistant strains of shellfish, faster growth, higher meat yields, and other desirable traits, the chance of interbreeding wild and farmed stocks should be carefully considered to address the possibility of gene pool effects.

Reflecting the discussions held in the water quality session, participants in this session emphasized that researchers and regulators need clear a definition of what constitutes an invasive species. Discussion here focused on the need to establish common reference points for the time and/or spatial scales that are considered; boundary lines for native species; intentional and accidental introductions; recognition of species and strains; and how regulators and others establish a baseline for what originally existed in an area.

The importance of scientific expertise was highlighted as a key component for evaluating benefits, risks, and other issues. This discussion also included consideration of non-biological risks and public perception of the use of sterile and triploid stocks in shellfish aquaculture.

The discussions in this session also addressed:

- The need for better understanding of shellfish disease, either through increased federal funding of research and/or the establishment of disease testing centers with standardized testing protocols.
- Additional research to develop more reliable methods for ensuring sterility of stock.
- Using introduced species as a regional and species-specific decision.

3. Habitat and Gear/Education

The discussions concerning habitat and gear noted there are observed benefits to the environment from shellfish aquaculture and that current research showing the ecosystem benefits of shellfish aquaculture is well-recognized and accepted by industry. Several recommendations on future directions for research and regulation were discussed. Those included:

- Further quantifying the benefits and interactions of shellfish aquaculture with the environment, including the positive effects of structure as refugia and habitat, the relationship between gear and increased biodiversity of native species, and the reduction of turbidity in the water column, which aids eelgrass and other vegetation.
- An economic valuation of ecosystem services provided by shellfish aquaculture.

Habitat disturbances inherent in shellfish harvest methods were also discussed. Suggestions for next steps included an assessment of the frequency and magnitude of disturbances, and recovery time from habitat disturbances such as trampling by humans, harvesting, dredging, structure removal, and others. Because the effects and impacts of harvest methods differ depending upon gear and harvest infrastructure, a comparative gear analysis of habitat disturbances was also discussed.

As highlighted earlier, the need for more public education and outreach regarding the benefits of shellfish aquaculture was a common element in every discussion held at the symposium. In addition to the numerous calls for public education across breakout groups and topics, participants emphasized the need for better information flow to regulators to help streamline the permits process. Suggestions included providing regulators and permit writers with:

- Additional training regarding shellfish aquaculture.
- Better access to resources that provide the best, most recent science and research.
- A *Permit Writer's Guidebook* with region-specific supplements.

4. Societal Interactions/Engagement

As with the other breakout sessions, public education and outreach was most often identified as the best way to engage and interact with the interested public regarding shellfish aquaculture. Key messages in any education effort should include:

- Shellfish require clean water and help to improve water quality through filtration.
- Clean water improves the quality of life for people living along the coasts.

Participants noted that large-scale direct marketing campaigns are a necessary step in the public education process. Such marketing could highlight the positive benefits of shellfish aquaculture and feature farms and farmers, not just products. The use of celebrity chefs was also suggested.

Other suggestions for societal engagement included:

- Connecting with Community Supported Agriculture (CSA) frameworks, or other networks that highlight local food sources to the community.
- Pursuing eco-labeling and/or sustainable certifications to promote the sustainability of their product.
- Conducting a public opinion survey to help broadly identify the thoughts and values surrounding shellfish aquaculture.
- Training regulators in conflict resolution.

List of Presentations

- **Shellfish Culture in the Realm of Ecosystem-based Management**, Dr. Jon Grant, Dalhousie University
- **Chronic Effects of Eutrophication on Bivalve Shellfish,** Dr. JoAnn M. Burkholder, North Carolina State University
- **Ecosystem Interactions with Intensive Mussel Aquaculture: Research Applications,** Dr. Peter Cranford, Department of Fisheries and Oceans, Canada
- **Mussel Farming as a Tool for Remediation of Coastal Waters: Experiences from Sweden,** Dr. Odd Lindahl, Kristineberg Marine Biological Station, Sweden
- **Marine Invaders and Aquaculture: Sources, Biodiversity, Impacts and Consequences,** Dr. Dianna Padilla, Stony Brook University
- **Genetics of Shellfish, Wild and Farmed,** Dr. Dennis Hedgecock, University of Southern California
- **Effects of Environment and Culture Techniques on Shellfish Disease Severity and Prevalence,** Dr. Roxanna Smolowitz, New England Aquarium
- **Importance of Bivalve Molluscs: The Habitat They Generate and Associated Ecosystem Services,** Dr. Loren Coen, Sanibel-Captiva Conservation Foundation
- **Assessing the Impacts of Shellfish Aquaculture Harvest: Lessons Learned,** Dr. Bradley P. Harris (University of Massachusetts, Dartmouth), Dr. Kevin D. E. Stokesbury (University of Massachusetts, Dartmouth), and Dr. Edward P. Baker (University of Rhode Island)
- **Case Studies–Perspective: Education and Engagement**, Dr. Gary Jensen and Dr. Jeff Silverstein, U.S. Department of Agriculture (USDA)
- **World Wildlife Fund Molluscan Shellfish Dialogues**, Colin Brannen, World Wildlife Fund-U.S.
- **Shellfish Aquaculture and the Sustainable Seafood Movement,** Dr. George H. Leonard, The Ocean Conservancy
- **Thoughts on the Environmental Concerns with Molluscan Shellfish Aquaculture Development**, Dr. Gary H. Wikfors, NOAA Northeast Fishery Science Center – Milford Lab

Summaries of the Individual Presentations

Throughout the course of the symposium experts in the field of shellfish aquaculture and the environment provided presentations to facilitate and inform the discussions. Below are the abstracts of the presentations, and following each abstract is a brief synthesis of the presenter's key points.

Shellfish Culture in the Realm of Ecosystem-based Management
Dr. Jon Grant, Dalhousie University

Ecosystem-based management (EBM) is a developing concept, applied largely to conservation of harvest fisheries. For aquaculture, it can have a more detailed meaning in terms of management, since the location and biomass of culture species is controlled. Aquaculture may have a variety of interactions with the ecosystem, since high biomasses of herbivorous bivalves are emplaced within the trophic web. These include seston depletion (the uptake of plankton by the shellfish primarily for feed) via filtration and eutrophication (nutrient pollution) via biodeposition. There is a sustainable level of shellfish culture, estimable by ecosystem modeling, but in any management scenario, goals must be defined—an often deficient aspect of EBM. Management variables include levels of nutrients and oxygen, biodiversity, and habitat conservation. The options for mechanisms of controlling coastal ecosystems are limited, however; discharges of contaminants and nutrients can be regulated and, in the case of aquaculture, biomass is controlled to limit potential localized organic loading. There are various examples of models applied to these problems, but a reasonable progression is to start simple (box or index models) and proceed to more complex models (fully coupled physical-biological) if necessary. In any event, the science is sufficient to reliably yield a variety of predictions related to aquaculture management at the ecosystem level.

Highlights from the Presentation:

- Aquaculture can be a natural part of coastal ecosystems and can be made sustainable by understanding its interaction with the system.
- The point above is an essential aspect of now-popular ecosystem-based management.
- It is important to define goals for ecosystem management as they relate to water and sediment quality, coastal resource use, biodiversity, etc.
- Dominant effects of bivalve culture include seston depletion and localized organic deposition.
- Predictive tools are essential in managing this process, likely based in ecosystem modeling.
- Models are of several types, including box models and fully coupled physical-biological simulations.
- Models of marine systems must include a biogeochemical component as well as an explicit physical oceanographic model.
- Simpler models are best for initial approaches, leading to more complex models if required.
- Aquaculture may be fully integrated into EBM with reliable output from ecosystem-level models.

Ecosystem Interactions with Intensive Mussel Aquaculture: Research Applications

Dr. Peter Cranford, Department of Fisheries and Oceans, Canada

Aquaculture is the only realistic means of resolving the growing disparity between seafood production and demand. Although shellfish aquaculture in Canada is highly diverse in structure, capital, and material infrastructure, the most rapid development has occurred with mussel culture. Ecosystem science is regarded in Canada to be the foundation for the development of effective area-wide strategies that promote the sustainability of the aquaculture industry. Ecosystem interactions with bivalve culture are highly complex as a result of potential effects on suspended particles, particularly in terms of food resources; sediment geochemistry and benthic habitat; nutrient cycling; and benthic and pelagic population and community dynamics. The number of fundamental ecosystem processes potentially influenced by mussels, and the complexity of their interactions, make it difficult to predict the effects of the culture on many ecosystem properties without resorting to a model. A combination of multidisciplinary field research and ecosystem modeling in intensively farmed Prince Edward Island (PEI) coastal embayment has been conducted to investigate ecological consequences of mussel filter-feeding, feces deposition, excretion and harvesting, and interactions between aquaculture and coastal eutrophication (nutrient pollution). This research has provided Canadian decision-makers with comprehensive science advice and is being used to develop approaches for assessing the capacity of ecosystems to support the future growth of the industry.

Highlights from the Presentation:

- A recurring bottleneck to the establishment of an operational framework for managing aquaculture is the need to define an "unacceptable" impact.
- While science has an important role in advising managers and policymakers on the ecological consequences related to available management options, this decision needs to be made within an integrated framework that recognizes important linkages between ecological and socioeconomic systems.
- An important consequence of developing an effective science-based management framework for aquaculture is that it will increase public confidence and reduce negative driving forces on industry. To achieve this goal, the development of a management framework should be inclusive, with diverse stakeholder participation, transparency, and communication.
- Ecosystem research results have been used to make recommendations on indicators (measures of habitat and ecosystem status) and thresholds (predetermined impact limits used to trigger management actions) for use in assessing shellfish aquaculture impacts on marine habitat and to develop monitoring frameworks for assessing habitat effects of shellfish aquaculture.
- A habitat assessment framework was recommended for shellfish aquaculture. The framework is based on a tiered monitoring approach recognizing that an increased risk to fish habitat requires an increased monitoring effort.
- Ecosystem modeling provided the means for a quantitative assessment of the capacity of intensive mussel aquaculture to ameliorate impacts from excess nitrogen enrichment from land-use.

Chronic Effects of Eutrophication on Bivalve Shellfish

Dr. JoAnn M. Burkholder, North Carolina State University

Although intensive shellfish aquaculture can cause localized degradation of water quality in some poorly flushed coastal regions, bivalve aquaculture in many areas is a minor contributor of pollutant loadings compared to land-based sources. In contrast, major, pervasive nutrient pollution from many urban and agricultural sources is seriously affecting shellfish populations and shellfish aquaculture, and these impacts are expected to increase with rapidly expanding coastal development. The National Research Council has reported that 60 percent of the coastal rivers and bays in the United States are moderately to severely degraded by nutrient pollution, mostly from land-based urban and agricultural sources. Coastal population growth worldwide and associated nutrient pollution are rapidly increasing. The acute, obvious effects of urban and agricultural nutrient pollution, often accompanied by microbial pathogens, are fish kills and high-biomass algal blooms. Much more serious chronic impacts, however, include long-term shifts in nutrient supplies; increased "dead zones" of low-oxygen bottom water; loss of critical habitat such as seagrass meadows; stimulation of harmful algal species that are low in food quality; reduction of shellfish recruitment and grazing; and increased shellfish physiological stress, disease and death. Increasing temperatures from present warming trends caused by climate change can interact with pollution to weaken shellfish hosts and facilitate pathogen attack. Considering that shellfish aquaculture is vital to meeting the seafood demands of the rapidly increasing global human population, there is a pressing need for resource managers and policymakers to increase protection of shellfish aquaculture operations from land-based nutrient pollution.

Highlights from the Presentation:

- Relative to land-based pollution sources, shellfish aquaculture contributes little to eutrophication (nutrient pollution) except in localized, poorly flushed areas along U.S. coasts. Aquaculturists should continue to strive to minimize these impacts.
- There is a pressing need for resource managers and policymakers to increase protection of shellfish aquaculture operations from land-based nutrient pollution.

Mussel Farming as a Tool for Remediation of Coastal Waters: Experiences from Sweden

Dr. Odd Lindahl, Kristineberg Marine Biological Station, Sweden

Nutrient emissions from agriculture, rural living, the atmosphere and many other diffuse sources increase coastal primary production leading to increased biomass in both filamentous algae and phytoplankton. Because phytoplankton is the main feed for mussels, mussel farming and harvest are been recognized as possible measures to improve coastal water quality. A cost-efficient and environmentally friendly way of taking care of diffuse nutrient emissions is the cultivation of mussels through the long-line farming method. When the mussels are harvested, a known amount of the nutrients are recycled back from sea to land, mainly in the form of valuable seafood or marine protein. One kg of live mussels will remove 8.5 to 12 g of nitrogen, 0.6 to 0.8 g of phosphorous, and about 40 to 50 g of carbon.

The ecosystem service provided by mussel farming has been recognized by Swedish environmental authorities as a possible measure to improve coastal water quality. The main principle is the implementation of nutrient trading as a management tool. This imposes demands on those who emit the pollution through emission quotas, which are traded and bought by the emitter. The seller is a nutrient harvesting enterprise (e.g., a mussel farmer).

For example, in one trial between 2005 and 2011, the community of Lysekil, Sweden, was permitted to continue to discharge nitrogen from the sewage treatment plant, presupposing that the same amount of nitrogen was “harvested” and brought ashore by 3,900 tons of farmed blue mussels. The annual cost of $230,000 for Lysekil was far below the price for nitrogen removal in the sewage treatment plant. This payment goes to a mussel farming enterprise which has been contracted for the removal of 39 tons of nitrogen from the recipient waters annually. This is estimated to correspond to 100 percent nitrogen treatment of the discharges from the sewage treatment plant.

Highlights from the Presentation:

- Shellfish farming is a cost-effective, flexible, and environmentally friendly measure for combating eutrophication (nutrient pollution) and improving coastal water quality.
- Shellfish farming is a sustainable way of producing healthy seafood while also recirculating nutrients from sea to land.
- Nutrient trading is a useful management tool that connects environmental economy (nutrient discharges) with market economy (shellfish farming enterprises).
- In the sea, shellfish farming has the same effect as open landscape feeding on land. Thus, “mussel farming - clear water feeding” will be a new slogan.

Genetics of Shellfish, Wild and Farmed
Dr. Dennis Hedgecock, University of Southern California

Use of non-native species, reductions in biodiversity, and gene flow between domesticated farmed and wild stocks are potential genetic impacts of shellfish aquaculture. Although global shellfish culture is based on non-native species (e.g., the Pacific oyster *Crassostrea gigas* and the Manila clam *Ruditapes philippinarum*), the aquaculture industry, at least in Europe and North America, is not currently a major vector of new shellfish introductions. On the other hand, interactions of wild and farmed shellfish stocks deserve greater attention and research support at a global scale. Aquaculture in general, and shellfish culture in particular, lack domesticated strains and rely largely on hatchery propagation of wild stocks. The legendary high fecundity of bivalve molluscs (females can typically spawn tens of millions of eggs at one time) creates a risk that hatchery-propagated shellfish stocks could dilute the genetic diversity of wild populations and possibly elevate the frequency of harmful mutations. Continued farming of wild, native species will raise rather than lower these risks over time. Moreover, farming wild animals is a less efficient food production system than one based on domesticated stocks with improved traits, increased production efficiency, and reduced environmental and energy footprints. Yet use of genetically divergent domesticated stock might also increase the risks of detrimental effects on the genetics of wild populations. Farming triploid bivalves, which are largely sterile, essentially eliminates genetic interactions with wild shellfish. However, since tetraploid bivalves are used to generate triploid seed and tetraploids are self-fertile, the bio-security of tetraploid stocks becomes a new issue for study. Research on developing and improving domesticated shellfish for aquaculture and on improved methods for eliminating interaction with wild populations (bio-security) should have high priority for research leading to sustainable management of shellfish resources.

Highlights from the Presentation:

- Research on developing and improving domesticated shellfish for aquaculture and on improved methods for eliminating interaction with wild populations (biosecurity) should have high priority for research leading to sustainable management of shellfish resources.
- Although non-native species are widely used in shellfish aquaculture, as in agriculture, shellfish aquaculture is probably not currently an important vector of new introductions.
- Interactions of wild and farmed shellfish deserve greater attention because they could be detrimental to both.
- Farming of wild stocks may, over time, increase the likelihood of detrimental interactions.
- Farming of domesticated stocks permits genetic improvement but may elevate the risk of detrimental interactions with wild stocks.
- Farming of triploid domesticated shellfish, which are effectively sterile, permits genetic improvement while greatly reducing or eliminating negative interactions with wild stocks; containment of fertile tetraploids is an issue deserving closer attention.

Marine Invaders and Aquaculture: Sources, Biodiversity, Impacts and Consequences
Dr. Dianna Padilla, Stony Brook University

Aquaculture – both private commercial and public stock enhancement – is a leading source of introduced non-native species in marine and estuarine waters, second only to shipping. Many initial introductions are historic, but new introductions—the aquaculture species themselves and associated macro- and micro-species, including agents that cause disease—continue to invade and spread on shores around the world. Aquaculture escapees, especially bivalves, can have large ecological impacts on shores, hybridizing with and displacing important native species. Safe introductions (i.e., introductions that do not escape and spread) are rare. The time lag between when a species is first introduced and when it begins to spread is unpredictable, and can be short (a few years) to very long (>75 years). Our ability to predict the impacts of invaders is poor, but many can have devastating impacts on local populations of commercially and ecologically important species and communities, including marine reserves and protected areas. For example, the Pacific oyster, *Crassostrea gigas*, is now a major introduced species spreading on shores in North America, Australia, and Europe. Many marine invaders impose significant negative impacts on aquaculture species (e.g., disease, bloom forming harmful algae, and direct fouling) and the aquaculture industry (e.g., through fouling gear). Due to the substantial ecological harm and economic costs that can be caused by introduced species and the unpredictable nature of predicting which species will be invaders, when they will spread, and what impacts they will have, a risk-averse strategy will be the safest course when considering new aquaculture introductions. All safeguards should be in place to ensure that non-native species are not transferred or likely to escape culture through aquaculture practices.

Highlights from the Presentation:

- Aquaculture is the second leading source of non-native introduced species in marine systems.
- Invaders include aquaculture species themselves as well as associated macro- and micro-species, including disease causing agents.
- Spread can occur decades after initial introductions, and the timing and impacts of spread are often impossible to predict.
- Care must be taken to prevent the introduction and spread of non-natives through aquaculture, including consideration of new aquaculture species and aquaculture locales for non-native species.

Effects of Environment and Culture Techniques on Shellfish Disease Severity and Prevalence

Dr. Roxanna Smolowitz, New England Aquarium

Disease is the result of the interaction of three factors: host susceptibility, agent virulence, and environmental conditions. Elimination or modulation of any one of these factors can decrease or increase the occurrence of disease in a host. When disease occurs in a molluscan population, our lack of understanding of why the disease happens and how, causes us to treat the disease as though it is a black box. But because disease is a combination of factors, if we logically think about the factors and then begin our investigations on the pathogenesis by examining important factors, we can develop an understanding of the disease as well as methods to prevent or manage around it. Factors important in disease occurrence are summarized below.

Highlights from the Presentation:

- Host susceptibility (i.e., poorly conditioned animals and genetic lack of disease resistance).
- Agent virulence (i.e., new or mutated agent in the environment; change in the base population level of agents, such as increased density of the agent; direct vs. indirect infections).
- Environmental conditions (i.e., density of the host; pollution; decreased water quality; decreased nutrients; and temperature/salinity/pH changes of the water).

Importance of Bivalve Molluscs: The Habitat They Generate and Associated Ecosystem Services
Dr. Loren Coen, Sanibel-Captiva Conservation Foundation

Aquaculture is making an ever-increasing contribution to meeting the worldwide demand for shellfish, as native wild stock (captured) populations decline. At the same time, recently we have become more aware of the ecosystem services provided by native bivalves as habitat, biofilters, and shoreline stabilizers. These bivalves occur as reef-forming, aggregation-forming, or shell-accumulating species. Given the significant decline in native species populations, the loss of all critical (nursery) habitats, and the increasing worldwide contribution of cultured native and non-native species, we need to examine and critically evaluate their value and impacts. These include positive and negative, direct and indirect, biotic and abiotic effects in estuarine and marine systems. For the United States these impacts currently vary by location of habitat (intertidal vs. subtidal), extent of cultured vs. natural acreage, and 3) by latitudinal/geographical differences (e.g., western Atlantic/Gulf of Mexico vs. Eastern Pacific).

Highlights from the Presentation:

- Aquaculture can provide enhanced habitat for natural communities.
- Culture of native species can reduce the fishing pressure on native wild stock.
- Methodologies to assist with native species restoration should be used (e.g., Olympia oyster).
- Sustainable practices need to be investigated, developed, and implemented.
- Greater emphasis needs to be placed on quantifying the impacts, both positive and negative, of large-scale bivalve aquaculture.

Assessing the Impacts of Shellfish Aquaculture Harvest: Lessons Learned

Dr. Bradley P. Harris, University of Massachusetts – Dartmouth; Dr. Kevin D. E. Stokesbury, University of Massachusetts – Dartmouth; and Dr. Edward P. Baker, University of Rhode Island

As the shellfish industry expands, growers, managers, and permitting agencies will face increasing pressure to demonstrate that harvest activities are environmentally benign. Drawing causal connections between environmental changes and harvest activities requires a formal experimental design and representative sampling at appropriate temporal and spatial scales. The Before-After Control-Impact (BACI) experimental design provides a framework for testing these harvest-impact hypotheses. We conducted a BACI assessment of sea scallop (*Placopecten magellanicus*) dredge harvest and found that changes in the epibenthic community were similar between the control and impact areas. Further, annual substrate composition changed more than epibenthic faunal composition, indicating high levels of natural disturbance—which may explain why harvesting did not alter the benthic community.

Lessons learned and guidelines for conducting a BACI study include:

- Use a pilot study to select the temporal and spatial sampling scales.
- Select a sampling design adaptive to new technologies.
- Incorporate/anticipate spatial and temporal variability.
- Use sampling techniques that develop your intuition of the ecosystem (automation can kill intuition).
- Start as simply as possible and build a mosaic.

Most importantly, absolute measures sampled in the units of the expected impact are required to explain changes in a population, community, or ecosystem due to harvest activities.

Highlights from the Presentation:

- Cause and effect hypotheses require experimental design; the BACI design is ideal for testing the connections between harvest activities and environmental changes.
- Establish the appropriate temporal and spatial sampling scales.
- Anticipate spatial and temporal variability; natural disturbance provides a context for determining if harvest activities have adverse impacts.
- Avoid collecting relative samples; absolute measures, sampled in the units of the hypotheses, are required to explain anthropogenic changes in a population, community, or ecosystem.

Case Studies–Perspective: Education and Engagement
Dr. Gary Jensen and Dr. Jeff Silverstein, U.S. Department of Agriculture

The advancement of shellfish aquaculture depends on the generation of new discovery information and access to our collective knowledge system supported by public investments in science, technology and education, and private sector innovations. The United States has two university-based programs with an informal education mission founded on science. Numerous land-grant universities and sea grant institutions—in partnership with the USDA Cooperative State Research, Education and Extension Service and the NOAA National Sea Grant Office, respectively—have programs aimed at assisting the U.S. farmed shellfish sector. These same university programs also support research projects and interact with federal research partners—the USDA Agricultural Research Service and NOAA.

The winds of change are affecting shellfish aquaculture businesses. This situation implies new approaches and actions by the shellfish aquaculture community focused on the transition from science to practice. This presentation highlighted several case studies as examples of the benefits of research-extension integration, engagement, and education: seafood Hazard Analysis and Critical Control Point (HACCP) alliance for education; aquaculture effluents task force; national organic aquaculture work group; and Viral Hemorrhagic Septicemia (VHS) education alliance. Each case study is based on scientific information generated from highly relevant solution research and mobilizing expertise across states and institutions with a common purpose to address an industry-critical issue or need. To leverage resources, engage broader extension expertise, and strengthen state-federal partnerships, the USDA Cooperative State Research, Education and Extension Service and NOAA's National Sea Grant Office established the National Aquaculture Extension Steering Committee. This interagency action has resulted in new collaborations and projects to support the aquaculture extension community and its educational role of advancing industry development.

Highlights from the Presentation:

- If it is not business as usual in the industry sector, federal and state research and educational programs should seek effective approaches that take full advantage of our knowledge system, expertise, and limited resources through effective collaborations and partnerships.
- There are numerous examples of participatory processes, engagement, and strategic actions that have addressed complex regional and national issues that can serve as models for other applications and issues.
- New tactics and bold steps may be required to reach a desired future state, including development of effective collaborations and partnerships that may extend outside of the United States.

World Wildlife Fund Molluscan Shellfish Dialogues
Colin Brannen, World Wildlife Fund-U.S.

Through a series of roundtable discussions known as 'Aquaculture Dialogues', the World Wildlife Fund (WWF) works with seafood farmers, retailers, NGOs, scientists, and other aquaculture industry stakeholders worldwide to develop global standards for certifying aquaculture products. Certification is understood to mean that the product is grown and harvested in an environmentally and socially responsible way. The goal of aquaculture certification standards is to minimize key environmental and social impacts associated with seafood farming. Dialogues are under way for 12 marine and freshwater species, including tilapia, salmon, shrimp, molluscs, trout, and pangasius.

Highlights from the Presentation:

- Currently, more than two dozen standards or certification programs for aquaculture exist. Most are ineffective at helping make the global aquaculture industry more sustainable.
- The standards created by WWF's Aquaculture Dialogues will be created by a broad and diverse set of stakeholders, based on consensus, developed through a transparent process, science-based, measurable, and performance-based.
- The WWF Aquaculture Dialogues build from previous work done by the organization, including the Forestry Stewardship Council, the Marine Stewardship Council, Protected Harvest, and the Climate Savers Program.
- To date, the WWF Molluscan Dialogues have attracted 235 participants from nine countries.

Shellfish Aquaculture and the Sustainable Seafood Movement
Dr. George H. Leonard, The Ocean Conservancy

Sustainability is the intersection of the environmental, economic, and societal sectors. Presently, the sustainable seafood movement, of which farmed seafood products is a part, is generally focused only on the environmental aspects of this concept. The sustainable seafood movement includes four components: eco-certification, consumer education, single species campaigns, and partnerships among businesses and NGOs.

Highlights from the Presentation:

- Several key issues contribute to overall environmental sustainability, including use of marine resources for feed; impacts of escaped fish; amplification and retransmission of disease and nutrient pollution; and other habitat impacts.
- Shellfish farming is generally viewed favorably because it requires no supplemental feed, has limited pollution impacts, and lower risks of escapes because animals are generally sedentary.
- Going forward, the shellfish industry needs to be concerned with questions of science and society.
- Important questions remain to be answered surrounding the local impacts of harvest methods as well as broader questions of what scale of farming is compatible with overall ecosystem health and function.
- Addressing the societal questions is likely to pose the toughest challenge. For example, much of the current controversy surrounds issues of what people see – or are willing to look at – from their waterfront property (this is also known as ‘viewshed’), property rights, and the future use of habitats which can be viewed as public trust resources.
- Geoduck farming is one example of the broader need for a national dialogue on the future role of aquaculture in our nation’s coastal and ocean ecosystems.
- As competing interests in our nation’s oceans grow—including interest in aquaculture—a multi-stakeholder approach holds promise for resolving these inevitable conflicts and for crafting a forward-looking vision for both sustainable ocean economies and the healthy ocean ecosystems on which they depend.

Thoughts on the Environmental Concerns with Molluscan Shellfish Aquaculture Development

Dr. Gary H. Wikfors, NOAA Northeast Fishery science Center – Milford Lab

Concerns about possible environmental impacts of shellfish aquaculture range from changes in ecosystem structure and function to pollution and multi-user conflicts. These concerns often are viewed as proscriptive, for example, when people say, “We can’t let that happen.” However, we live with many of these environmental changes as consequences of other human activities. Many examples are from land-based, agricultural production of human foods, but environmental modifications in the marine environment to accommodate recreation, capture fisheries, and transportation of goods are ubiquitous. It is unrealistic to expect farming of any kind to not modify the surrounding environment; nevertheless, concerns about impacts often are presented as barriers.

Assumptions underlying tacit intolerance of potential shellfish–aquaculture impacts on coastal areas can be questioned. Most coastal waters where shellfish aquaculture expansion can occur are not pristine wilderness areas; most are highly impacted by other human activities. In fact, a major concern is whether coastal areas have sufficient environmental quality to sustain shellfish growth. The perception of shellfish aquaculture as an industrial activity that will benefit a few at the expense of the general populace is challenged by the reality that shellfish farming often is local, place-specific food production consistent with the current movement toward local foods and community-supported agriculture. Thus, changing perceptions about environmental and societal aspects of shellfish farming are revealing this activity to be consistent with the ecosystem services desired by human communities from their coastal seas. The way forward for molluscan shellfish aquaculture is complex but achievable.

Highlights from the Presentation:

- Put perceived risks in a realistic context.
- Question the assumptions underlying barriers.
- Recognize evolution of societal values.
- Benefit from the opportunity to do it right/better.

Appendix 1

MONDAY, JUNE 9, 2008

8:00 - 8:15 a.m.	**Welcome** Dr. Sandra Shumway, University of Connecticut
8:15 - 8:45 a.m.	**Opening Remarks** Timothy R. Keeney, NOAA Deputy Undersecretary for Oceans and Atmosphere Dr. Michael Rubino, Manager, NOAA Aquaculture Program Brian Pawlak, Deputy Director, NOAA Office of Habitat Conservation

Eutrophication/Carrying Capacity/Water Quality

8:45 - 9:00 a.m.	Dr. Jon Grant (Dalhousie University) · *Shellfish Culture in the Realm of Ecosystem-Based Management*
9:00 - 9:15 a.m.	Dr. Peter Cranford (Fisheries and Oceans Canada) · *Ecosystem Interactions with Intensive Mussel Aquaculture: Research Applications*
9:15 - 9:30	Open Question Period
9:30 - 9:45 a.m.	Dr. JoAnn Burkholder (North Carolina State University) · *Chronic Effects of Eutrophication on Shellfish*
9:45 - 10:00 a.m.	Dr. Odd Lindhal (Sweden's Kristineberg Marine Biological Station) · *Shellfish Farming as a Tool for Remediation of Coastal Waters*
10:00 - 10:15 a.m.	Open Question Period

Genetics/Invasives/ Disease

10:45 - 11:00 a.m.	Dr. Dianna Padilla (State University of New York - Stony Brook) · *Marine Invaders, Biodiversity & Aquaculture: Sources, Impacts & Consequences*
11:00 - 11:15 a.m.	Dr. Dennis Hedgecock (University of Southern California) · *Genetics of Shellfish, Wild and Farmed*
11:15 - 11:30 a.m.	Dr. Roxanna Smolowitz (New England Aquarium) · *Effects of Environment & Culture Techniques on Shellfish Disease Severity & Prevalence*
11:30 a.m. - 12:00 p.m.	Open Discussion with Entire Group

MONDAY, JUNE 9, 2008 (continued)

12:00 - 12:30 p.m.	Guest Speaker – U.S. Senator Jack Reed (Rhode Island)
Afternoon Breakouts	(Facilitated Discussions)
1:30 - 2:15 p.m.	Eutrophication/Carrying Capacity/Water Quality
2:15 - 3:00 p.m.	Invasives/Genetics/Disease
3:30 - 5:00 p.m.	Summary Presentations and Discussion
5:00 p.m.	Adjourn

TUESDAY, JUNE 10, 2008

8:00 - 8:15 a.m. **Day 2 Welcome**
Dr. Sandra Shumway, University of Connecticut

Habitat and Gear/ Education/ Societal Interactions/ Engagement

8:15 - 8:30 a.m. Dr. Loren Coen (Sanibel-Captiva Conservation Foundation)
- Importance of Bivalve Molluscs: The Habitat they Generate and Associated Ecosystem Services

8:30 - 8:45 a.m. Dr. Kevin Stokesbury (University of Massachusetts - Dartmouth)
- Impacts of Shellfish Aquaculture Harvest Methods

8:45 - 9:00 a.m. Open Question Period

9:00- 9:15 a.m. Dr. Gary Jensen (USDA-CSREES)
- Case Studies and Perspectives: Education and Engagement in Aquaculture

9:15 -9:30 a.m. Colin Brannen (World Wildlife Fund)
- Molluscan Dialogues Revisited

9:30 - 9:45 a.m. Dr. George Leonard (Ocean Conservancy)
- Shellfish Farming and the Growing Sustainable Seafood Movement

9:45- 10:00 a.m. Open Question Period

10:30 - 10:45 a.m. Dr. John Hargreaves (Baton Rouge, Louisiana)
- BMPs & Environmental Management Systems in Shellfish Aquaculture

TUESDAY, JUNE 10, 2008 (continued)

10:45 - 11:00 a.m.	Dr. Gary Wikfors (NOAA, Northeast Fisheries Science Center) · Thoughts on the Environmental Concerns with Molluscan Shellfish Aquaculture Development
11:00 - 11:15 a.m.	Dr. Susan Stonich (University of California - Santa Barbara) · Societal Issues Associated with Shellfish Aquaculture
11:15 a.m. - 12:00 p.m.	Open Discussion with Entire Group
Afternoon Breakouts	(Facilitated Discussions)
1:30 - 2:15 p.m.	Gear and Harvest/ Education
2:15 - 3:00 p.m.	Societal Interactions/ Engagement
3:30 - 5:00 p.m.	Summary Presentations and Discussion
5:00 p.m.	Adjourn