



CRMC Working Group on Aquaculture Regulations

Report on the Deliberations of the Group
and
Suggestions to Guide Future Development

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Executive Summary

As the aquaculture industry in Rhode Island increased by double digits, albeit from a very small base, concerns grew about the possible environmental and social impacts. This increasing concern has resulted in the Coastal Resources Management Council reconvening the CRMC Working Group on Aquaculture Regulations. The working group first met in 2000. This first series of meetings focused upon Narragansett Bay. During the series of meetings that took place during 2008, due to the special nature of the Rhode island salt ponds along the southern coast the group decided to begin with a focus on this fragile ecosystem. The group comprised of representatives from a wide range (environmental NGO's, fishing industry, aquaculture industry, academics, legislature and regulators) of users of the state's submerged lands. This report is the outcome of these proceedings.

The group has made a number of suggestions that will allow the continued growth of the aquaculture industry while protecting the environment and decreasing the possible conflicts with other user groups. Specifically the group was looking at the salt ponds. The most wide ranging recommendation of the group was a limit on the area allowed to be occupied by aquaculture in any water body of 5%. This limit was arrived at by studying the available peer-reviewed scientific literature on ecosystem carrying capacity. The research was conducted in other parts of the world and adapted to RI specific conditions. A further recommendation was that funding for research specific to Rhode Island waters be applied for to arrive at specific ecosystem carrying capacities for local conditions. The recommendation has been followed and a NOAA grant to conduct a modeling study has been won.

Discussion of the working group resulted in recommendations included regulatory changes in the CRMC regulations governing aquaculture. These changes clarify the regulatory approach taken by the CRMC when permitting aquaculture leases. An important product of the group include a continuation of the charting project began during the first round of working group meetings in 2000-2001. The charting project began with the charting of the uses of Narragansett Bay and the waters of Rhode Island Sound. During this round of meetings the project was continued to chart the coastal salt ponds along RI's south shore. During the public process it was noted that there is a continued need to educate the public about the specifics of aquaculture regulations. As a result of these questions the group authored a Frequently Asked Question flyer to be distributed to the public in an effort to answer these questions.

The products of the working group are extensive, reflecting the wide range of expertise and experience of the members of the group. The long term result is the increased communication fostered between the organizations will affect the regulatory environment for a significant time to come. The CRMC recognizes that public participation in the permitting process, while not always pretty or comfortable, is an essential long term imperative in an effective regulatory environment. The Council thanks all of the participants for the time spent assisting the agency in carrying out its duties to protect the unique Rhode Island environment.

Introduction

The Rhode Island Coastal Resources Management Council's regulatory approach to aquaculture has been driven by the dual goals of protecting the public trust while at the same time encouraging a sustainable aquaculture industry that respects the traditions of the state. In the past decade the Rhode Island aquaculture industry has been growing at double digit rates. This growth has been cause for concern by various user groups of the state's public trust lands and the waters above them.

In response to this concern the CRMC's Working Group on Aquaculture regulations was formed. The CRMC believes that including as many user groups as practical in the regulatory process is essential to achieving a lasting consensus on the issues.

The working group was first formed in 2000 and met until 2001, when the participants decided the issues had been explored to everyone's satisfaction. This series of meetings did result in changes in CRMC regulations and increased communication between the industries and regulators. This series of meetings focused upon Narragansett Bay. This increased communication served the process well until 2007. The current series of meetings has focused upon the salt ponds along the state's southern shores. The working group is made up of representatives from:

NGOs: Save The Bay, Salt Pond Coalition, Sierra Club;
Industry representatives: RI Farm Bureau; Ocean State Aquaculture Association, RI Shellfishermen's Association, RI Saltwater Anglers Association, RI Marine Fisheries Council
Academia: University of Rhode Island, Roger Williams University,
United States Department of Agriculture, RI State legislators
Regulatory agencies: RI Department of Environmental Management, Division of Fish & Wildlife; RI Department of Health; RI Coastal Resources Management Council.

The working group has been meeting monthly for the past nine months. These meetings have resulted in a number of deliverables including a report on the biological impacts of aquaculture in Rhode Island and suggested changes in the state's regulations concerning aquaculture.

The working group process has resulted in suggested changes that have been extensively discussed and agreed upon by a majority of the working group members. This report will cover a number of areas:

- 1) Outline the recent history of aquaculture development in Rhode Island.
- 2) Cover the current regulatory requirements for aquaculture permitting in Rhode Island.
- 3) Report on the working group's goals.
- 4) Explain why the suggested changes agreed upon by the working group were arrived at.
- 5) Detail these changes and findings of the working group.

The next step is for the suggested changes to be submitted to the regulatory agencies charged with responsibility for aquaculture in Rhode Island. The agencies, mostly CRMC but also including DEM, will then have to submit the suggestions to the established process of regulatory change.

The Current State of Aquaculture in Rhode Island

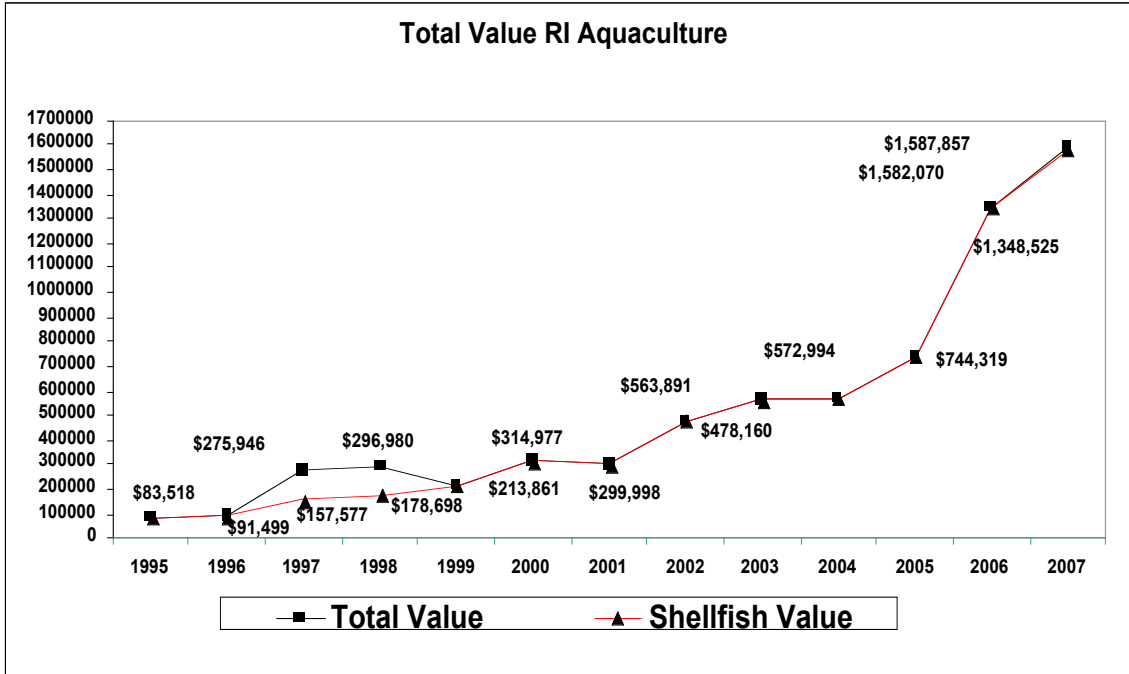
The Aquaculture Industry in Rhode Island

Aquaculture has a long history in Rhode Island waters. The first oyster lease granted by the state was in 1798. At the peak of production in 1911 1,394,983 bushels of oysters were landed along with 1,331,192 gallons of shucked oyster meats were sold. Its value, adjusted for inflation, would be worth \$135 million. However, because of various causes the aquaculture industry declined for a peak of more than 20,000 acres in 1911 to less than 10 acres in 1999. Since 1999 the aquaculture industry in Rhode Island has enjoyed robust growth, albeit from a very small base, growing from 10 acres in 1999 to 123 acres in 2007. The industry has grown from a farmgate value of \$83,518 in 1999 to \$1,587,857 in 2007. Compared to other industries aquaculture is a small but dynamic industry.

Table 1

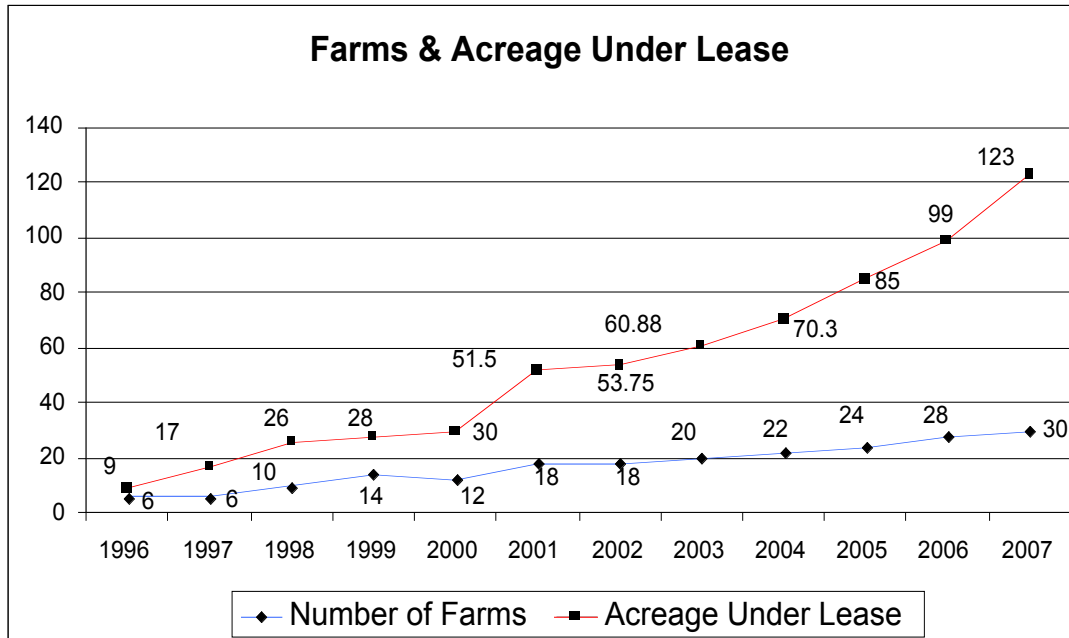
Year	Change in Farmgate Value from Previous Year
995-1996	9.6%
996-1997	72%
997-1998	13%
998-1999	20%
999-2000	47%
000-2001	-4.7%
001-2002	59%
002-2003	16.5%
003-2004	1.6%
004-2005	29.9%
005-2006	81.2%
006-2007	17.75%

Table 1. The percent change of the farmgate value of aquaculture shellfish production in Rhode Island. See



Graph 1

In 2007 total Rhode Island aquaculture production increased 18 percent. The total value indicated for the years 1997 and 1998 includes a retail ornamental finfish operation that was in business for those two years only. In all other years up to 2006 100 percent of Rhode Island aquaculture production is in shellfish. The two numbers for 2007 reflect the total value of all aquaculture products (the larger number) and the total shellfish value (the lesser number).



Graph 2

Two new leases were established during 2007, and a couple of existing farms expanded. Farm totals for 2007 are 123 acres under cultivation and 30 permit holders (not including commercial viability, educational and research permits).

At the same time the growth in Rhode Island's aquaculture industry was taking place there have been unprecedented pressure being put on the natural ecosystems that make up Rhode Island's marine environment. One of the major contributing factors to this pressure is population change. In the decade of 1990 to 2000 the population of the Washington County, where all of the environmentally fragile salt ponds are located, rose by 12.3% to a total of 124,019 residents. This growth is projected to continue with an estimated population in 2030 of 151,104. This is a 21% increase from the population in 2000. This increase in population puts pressure on all of the industries that depend on a clean marine environment and access to this environment. For example the quahog fishery has decreased from 8,000 metric tons landed in 1988 to 2,000 metric tons in 2006.

At the end of 2006 the aquaculture industry leased a very small amount of the state's submerged lands.

Total in all RI waters = 110 acres

This equals 0.037% of total State waters

Salt ponds = 5,387 acres/55 acres aquaculture = 1.0%

Narragansett Bay = 87,723 acres/55 acres of aquaculture = 0.062%

Combined Salt Ponds and Narragansett Bay = 0.12%

As there was concern about the expansion of aquaculture in the salt ponds it is also educational to look at the amount of aquaculture in the ponds.

Ninigret Pond = 0.25%

Winnepaug Pond = 1.91%

Potters Pond = 1.81%
Pt. Judith Pond = 2.54%

The CRMC has been enthusiastic in supporting traditional shellfishing industry participants who wish to transition into, or augment their traditional fishing income, by joining the aquaculture industry. As a result the percentage of aquaculture leases held by shellfishermen is significant: 57% of leases in the salt ponds and 39% of all aquaculture leases through out the state.

The Current Aquaculture Permitting Process in Rhode Island

The CRMC permitting process is multi faceted and strives to include stakeholder input. All applications must meet the requirements stated in the Coastal Resources Management Program (CRMP) "Red Book," the section pertaining to aquaculture is Section 300.11. As outlined in the CRMP the process, for commercial marine aquaculture farms, includes a two part process.

The first part of the permitting process involves the applicant determining a suitable location for the proposed farm. Advice given to prospective applicants involves informing them about the possible conflicts and a suggestion that once they think a suitable site is identified that they make personal contact with local officials (harbor master, conservation commission, etc.) and fishing interests in that area to determine any possible conflicts before an application is made.

Once the applicant has identified a possible site the first formal step is an application to the CRMC to hold a preliminary determination (PD) meeting. The application package includes the following required components:

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1. Application Fee: \$25.00
 2. Photos of the project site and adjacent area (minimum size 3" x 5" maximum size 8" x 10")
 3. Four (4) copies of the completed application form. Be complete and concise in the description of the work proposed. The written description must completely describe all work proposed on the submitted site plans. This concise written description is essential in order to put the project out to public notice and expedite the processing of the application.
 4. Location map. Four (4) copies: Use a NOAA nautical chart to accurately delineate the site location. The location map must include a map scale, a north arrow (indicate magnetic or true north) and an accurate latitude-longitude coordinate for the site. The location map must be 8" by 11".
 5. Site plans. Four (4) copies of all plans are required. All plans must include applicant's name, date of preparation, scale and north arrow (indicate magnetic or true north). Complete site boundary lines must be shown on the plan view. All corners of the site must be accurately delineated in latitude-longitude coordinates and shown on the plans. Be sure to include appropriate scale and distance from the site to the nearest shoreline.

The proposed gear layout must be shown on the plan view. Depth contours must also be shown on this site plan view for the proposed lease area at mean low tide. Be sure to show **all** of the proposed gear (cages, racks, netting, etc.) within the site. A separate sheet depicting a typical cross-section view (from deepest to shallowest portions) of the entire site at the same scale as the plan view which includes the gear layout. Mean high and mean low tide

elevations must be indicated on the cross section view plan.

Detailed drawings of the proposed gear (cages, racks, nets, etc.) showing typical dimensions must be provided on an 8_ by 11" sheet. Applicant must show depth of water covering the gear at mean low tide for the shallowest portion of the site.

The PD meeting is a staff level meeting between various federal, state and local regulators, various industry representatives and the applicant. The list of invitees is extensive:

- 1) U.S. Coast Guard, Captain of the Port, MSO Providence;
- 2) Ocean State Fishermen's Association;
- 3) National Marine Fisheries Service, Habitat Conservation Division;
- 4) RI-Department of Health, Office of Food Protection;
- 5) RI Shellfishermen's Association;
- 6) U.S. Army Corps of Engineers;
- 7) RI Saltwater Anglers Association;
- 8) RI Department of Environmental Management, Office of Technical and Customer Assistance,
- 9) RI DEM Division of Fish and Wildlife,
- 10) RIDEM Division of Water Resources.
- 11) The town where the application is located. The town representatives usually include the harbor master, members of the planning staff, conservation commission members, harbor commission and the like depending on the town.
- 12) Other fishing groups as necessary depending on the proposed applications location.

The PD process requires that the applicant submit a full application for the proposed farm. This application is sent to all of the invited participants before the meeting is held. Before the PD meeting talks place the DEM Division of Fish and Wildlife (F&W) has conducted a survey of the area to determine quantities of commercially harvestable shellfish in the proposed farm area. The proposed farm site is also reviewed for possible Submerged Aquatic Vegetation (SAV) interactions using charts of known eelgrass habitats. The PD meeting is designed to identify any issues or conflicts with existing regulations and uses. All of the participants have the chance to offer their input on the application. After the meeting the CRMC Aquaculture Coordinator is required to submit a report within 30 days to the applicant. This report summarizes the meeting and itemizes any suggestions or additional requirements the applicant was informed of during the meeting. This ends the PD process. It is strongly suggested that the applicant take into account the results of the PD process when proceeding to the next step, but it is not required that the applicant make the suggested changes. In the last 8 years all applicants have heeded the suggestions arising from this process. The CRMC considers the PD process a success. The PD meetings bring the stakeholders into the process at an early stage, thus helping weed out unsuitable applications. As a result of these meetings applications have been modified or dropped. This keeps unsuitable applications from proceeding to the next step of the permitting process, which is the full commercial application.

The next step in the permitting process is more involved and includes more input from the public. Once a full application is received it is sent to the same participants as the PD application was: U.S.

Coast Guard, Captain of the Port, MSO Providence; Ocean State Fishermen's Association; National Marine Fisheries Service, Habitat Conservation Division; RI-Department of Health, Office of Food Protection; RI Shellfishermen's Association; U.S. Army Corps of Engineers; RI Saltwater Anglers Association; RI Department of Environmental Management, Office of Technical and Customer Assistance, Division of Fish and Wildlife and the Division of Water Resources. The town where the application is located is also given notice of the application. Additionally the application is sent to the Shellfish Advisory Panel (SAP) of the MFC, and then to the full MFC for an opinion. The application is also sent out for 30 days public notice. While the 30 day notice does have an end date where comments can be accepted, in practice the CRMC will accept comments up to the morning of the Coastal Council hearing. Comments received that late in the process are copied and handed out to the Coastal Council members at the time the application is heard.

During the 30 day comment period a meeting is held with the U.S. Army Corps of Engineers under the auspices of the programmatic general permit (PGP). At this meeting representatives from the Corps, US National Marine Fisheries Service, US Environmental Protection Agency, US Fish & Wildlife Service, and representatives from the RI DEM F&W and Water Quality Divisions. Also during this period the SAP meets to consider any recommendations on the proposal to the MFC. At all of these meetings the CRMC Aquaculture Coordinator is present to give a brief review of the proposal, issues connected with the proposal and to answer any questions that might arise.

Before any application can proceed to the Coastal Council for a hearing the following permits, permissions, advisory opinions are required:

- 1) US Army Corps permit,
- 2) DEM Water Quality permit,
- 3) Advisory opinion from MFC,
- 4) DEM F&W advisory opinion,
- 5) Report to the Coastal Council from the CRMC Aquaculture Coordinator,
- 6) Any comments received from the public.

Once all of the requirements are met the proposal then can be scheduled to be heard by the Coastal Council. The Coastal Council receives the application package in the meeting agenda at least a week before the hearing, thus allowing the Council members time to review the application. The Council meeting is an open meeting and subject to the open meetings law, thus the meeting and agenda is advertised. Additionally authors of any specific comments received are individually notified of the meeting. At the Coastal Council meeting the application is presented to the Council by the CRMC Aquaculture Coordinator, the council is then free to ask the aquaculture coordinator or the applicant questions pertaining to the application. The Council then hears from interested parties, and if it wishes can ask questions of these parties.

The Council is then free to vote on the application. The Council can approve the application as presented, change the proposal if it sees the needs to or vote not to grant the application in any form. If the Council votes to not grant the proposal the applicant has a right to appeal. If the Council approves the application in any form, there are a number of further requirements of the applicant before an aquaculture assent can be issued. Additionally the aquaculture lease holder also has a continuing list of regulatory requirements over the full life span of the lease.

An aquaculture assent is valid for 15 years. This time span has been legislatively mandated. The aquaculture assent has a number of standard requirements in addition to specific requirements for any particular farm. Before an applicant can receive an aquaculture assent to begin establishing a farm there are three necessary requirements:

- 1) A lease must be signed between the applicant and the CRMC. This lease must be notarized.
- 2) A lease fee for the remainder of the calendar year must be received.
- 3) A performance bond must be posted with the CRMC as the payee in case of default.

The lease fee charged by the State of Rhode Island is one of, if not the, highest in the country. The fee is \$150.00 per year for the first acre of a lease and \$100.00 per year for each additional acre. The performance bond is required to give the state to funds necessary to ensure the farm site is returned to its pre-farm condition in case of the lease holder abandoning the site. The minimum amount is \$5,000.00. The largest bond currently required is \$40,000.00. Once these requirements have been met an aquaculture assent is granted.

Yearly the aquaculture assent holder must submit a report, on a form supplied by the CRMC. This information is garnered to keep track on the aquaculture industry in Rhode Island and disseminated in a yearly CRMC aquaculture report. The assent holder must also keep the performance bond current and supply the CRMC with proof of that yearly. Additionally all requirements of the CRMP as to marking of the lease, etc. must be maintained. The CRMC visits each aquaculture site at least once a year to ensure these requirements are met.

It is clear from the previous description of the requirements places on the industry that aquaculture is one of the most regulated activities taking place in the states submerged lands. Any use of the states public trust lands needs to be conducted in such a way that the public trust is upheld.

CRMC Working Group on Aquaculture Regulations

The need for a planned approach

The Rhode Island aquaculture industry is a small but dynamic industry which has been growing quickly, albeit from a very small base. As the sector of the industry that cultures shellfish in the states waters continues to grow there will be natural limits of the use of the public trust submerged lands.

The natural constraints to growth of the marine aquaculture industry in Rhode Island are based on the fact that as the smallest state the amount of public trust lands for aquaculture farms is limited. Add to this natural limit the conflicting uses of navigation, recreational users, commercial harvesting of natural resources and pollution closures the area for sustainable aquaculture development in Rhode Island is limited. Thus the need for a planned approach in governing and guiding the industry's growth is needed.

In 2007 perceived increased competition between the traditional fisheries and aquaculture came to a head with the Rhode Island Marine Fisheries Council (MFC) refusal to offer an opinion on any new aquaculture proposals until an aquaculture development plan was in place. In the Rhode Island Coastal Resources Council (CRMC) Management Program an advisory opinion is solicited on any aquaculture proposal from the MFC. This refusal to offer an opinion was consequently amended to where the MFC did offer opinions on all pending applications while an aquaculture plan was being written.

Before this impetus for planning the CRMC considered the permitting process as outlined in the Coastal resources Management Plan to be a *de facto* guide to aquaculture development in Rhode Island. This approach has worked suitably until the now. A plan that takes into consideration a longer range outlook is now considered necessary and desirable.

The state has been actively building an enabling environment for sustainable aquaculture development. The Rhode Island Coastal Resources Management Council is the lead agency for permitting of aquaculture in the state. This includes leasing of the states submerged lands and land based aquaculture where the lease of public lands is not required.

The Working Group

During the past year the CRMC Working Group on Aquaculture regulation has begun meeting again due to questions arising about the lack of a long term plan for aquaculture development. The group first formed in 2000 and met until 2001, when the participants decided the issues had been explored to everyone's satisfaction. This series of meetings did result in changes in CRMC regulations and increased communication between the industries and regulators. This increased communication served the process well until 2007.

In early 2007 questions arose as to the increased aquaculture leasing in the salt ponds. The questioning came from the Rhode Island Marine Fisheries Council (MFC) and the RI Department of Environmental Management (DEM) Division of Fish & Wildlife. After a series of communications between the CRMC and the MFC, the MFC decided to withhold all opinions on aquaculture leases until a plan was in place. CRMC regulations require the agency to solicit opinions on all aquaculture leases from the council and the DEM director. It was plain to all concerned that communication had broken down. Thus the CRMC decided to reconvene the working group in the hope that communication could be restored. It was also important to note that the first series of working group meetings were concerned with Narragansett Bay and had not considered the salt ponds. This round would focus on the salt ponds.

The CRMC, as the lead agency for aquaculture permitting in Rhode Island, has solicited input from various user groups, including but not limited to the local town officials, state and federal regulatory agencies, fishing industry groups (both commercial, recreational and aquaculture) and the general public. The CRMC strongly believes that communication between creditable and responsible stakeholders improves the regulatory environment towards developing a sustainable aquaculture industry.

Towards the end of having a sustainable aquaculture industry in Rhode Island the CRMC has taken the input from the Working Group on Aquaculture Regulation and other user groups to define a plan for aquaculture development. In the smallest state it is imperative that all of the stakeholders work together to accomplish the goal of sustainable exploitation of our marine resources. The working group began meeting in the spring of 2007. The group was made up of representatives from:

- NGOs: Save The Bay, Salt Pond Coalition, Sierra Club;
- Industry representatives: RI Farm Bureau; Ocean State Aquaculture Association, RI Shellfishermen's Association, RI Saltwater Anglers Association, RI Marine Fisheries Council
- Academia: University of Rhode Island, Roger Williams University
- US Department of Agriculture, State legislators
- Regulatory agencies: Department of Environmental Management Division of Fish & Wildlife, RI Department of Health, RI Coastal Resources Management Council

There are a total of 28 members, 15-20 who attend the monthly meetings.

The development of an aquaculture plan is simplified greatly as the only current species cultured in the state's public trust submerged lands are shellfish. Shellfish culture is generally accepted as ecologically sustainable activity that can bring ecological benefits to the environment. The state's only finfish operations are on land culture of freshwater salmonid species by the state for a put and take fishery and the on land culture of marine ornamental species for the aquarium trade.

It will take all of the natural resource managers in the state working in close collaboration with all of the stakeholders to bring into effect the wide ranging suggestions arising out of the working groups meetings. This process is already well underway. One of the advantages of being the smallest state is that all of the stakeholders are either known or known of by all of the stakeholders.

With this background the working group has meet monthly. A number of significant goals have been achieved by the group. One is the report for the Biology Subgroup.

A second significant achievement of the working group has been to conduct, thanks to Mr. David Beutel, a charting project for all of the Rhode Island salt ponds. Mr. Beutel also conducted the charting project for Narragansett Bay during the first working group meetings. Additionally the working group has approved a standardized marking for aquaculture farms, and is working on suggested program changes for the CRMC and DEM regulations concerning aquaculture. As in the first series of working group meetings, the most important achievement has been increased communication between all of the industry groups.

Working Group Products

Biological Impacts of Aquaculture

In the early planning stages the working group agreed to address the issues in two sections; the biological and the social. On the biological issues there is a wealth of scientific research available on aquaculture's interactions with the environment. Thus a science-based review of the issues was conducted to provide credible information on what, if any, limits would be suggested for shellfish aquaculture in the state's salt ponds.

The working group was fortunate to have many well respected experts as participants. The following members volunteered to produce a very credible document that reviewed the issues and came up with science-based suggestions for the full working group to consider. The members of the biology subcommittee were, in alphabetical order:

David Bengtson Ph.D., Chair – Water quality

Professor and Chair, Department of Fisheries, Animal & Veterinary Science
University of Rhode Island

Barry Costa-Pierce Ph.D. – Ecosystem approach to aquaculture

Director and Professor, Rhode Island Sea Grant College Program

Marta Gomez-Chiarri Ph.D.– Disease

Associate Professor Graduate Program Director Department of Fisheries, Animal and Veterinary Science, University of Rhode Island

Dale Leavitt Ph.D. – Invasive and nuisance species

Assistant Professor & Aquaculture Extension Specialist
Roger Williams University

Brian Murphy MSc– Essential fish habitat

Principal Marine Fisheries Biologist, RI Department of Environmental Management,
Division of Fish and Wildlife

Perry Raso – Physical impacts of aquaculture

President Ocean State Aquaculture Association

Robert Rheault Ph.D. – Carrying capacity

President Spatco LTD.

Abby Jane Wood MSc– Essential fish habitat

Marine Education Specialist, Save The Bay

The group, chaired by Dr. David Bengtson, issued a draft report in the fall of 2007. The working group then had three months to review and make suggestions before the report was unanimously accepted by the full working group in January 2008. The full report can be accessed on the CRMC web site at: <http://www.crmc.ri.gov/projects/aquaculture.html>. Also on this page is an extensive list of peer reviewed scientific articles on the impacts of aquaculture and the environment, presentations and reports.

Executive Summary

A considerable amount of information exists from around the world on aquaculture operations and their relationship to the environment. Farming of fish in pens and shrimp in ponds can have significant detrimental environmental effects, usually restricted to the area right around the operation. Thus, any attempt to raise fish in Rhode Island's open waters will require extreme scrutiny. On the other hand, the shellfish aquaculture practiced in Rhode Island is most likely beneficial for the environment, for a number of reasons. Oysters filter phytoplankton from the water, thereby allowing light to penetrate deeper so that submerged aquatic vegetation (SAV) can grow from the bottom. In doing so, they also remove nutrients from the water and can help ease the eutrophication problems in Rhode Island's estuaries. Oyster operations also provide refuges for the juvenile stages of several species of popular fish. The physical presence of shellfish aquaculture in Rhode Island waters has an impact on the natural environment. The question is whether that impact is acceptable to ecosystem structure and function and, by extension, to a Rhode Island public that does not want to see our estuaries degraded. We have made our best attempt to answer that question, but the process of doing so has allowed us to identify areas for which more information is clearly needed. For example, does oyster aquaculture hinder or help the winter flounder populations? In the areas of disease and invasive species, we need to remain vigilant in our monitoring and to develop practices and technologies that will minimize damage to the existing shellfish industry from these factors. There has been no evidence that shellfish aquaculture (as practiced in Rhode Island) is having negative environmental impacts and little reason to believe that further modest growth will have negative impacts in the future. Even in states where shellfish aquaculture is far more widespread there is little evidence that the impacts have been anything other than positive.

From a biological and ecological perspective, the really critical question is: what is the maximum amount of shellfish aquaculture that can occur in a given water body without unacceptable ecological impact to that body of water? This amount is a calculable quantity called the ecological carrying capacity. Ultimately, we need to take an ecosystem approach and determine the real ecological carrying capacity for Narragansett Bay, the coastal ponds, and other Rhode Island waters. To fully define that capacity for each water body is a task that will require much more information and work than we are able to provide here. One of the recommendations is to seek funding to do that type of work. Meanwhile, we rely on work that was done in New Zealand to estimate carrying capacity for shellfish culture there. Adapting the New

Zealand work to Point Judith Pond as a representative coastal pond, we calculate that the carrying capacity of the pond for shellfish aquaculture is approximately 5% of the pond's area. We recommend that number as our scientifically defensible best estimate for the moment, with the realization that better estimates could be available in the future with better data and site-specific modeling efforts.

Recommendations

1. Limit shellfish aquaculture to no more than 5% of the area of any water body in the salt ponds until specific estimates for Rhode Island waters can be generated with site-specific data.
 2. Seek funding to investigate the ecological carrying capacity of estuaries in Rhode Island for aquaculture and to investigate the interaction of shellfish aquaculture with native species.
 3. Establish a single interdepartmental advisory board that would be in charge of providing recommendations for the regulation and management of infectious diseases in wild and cultured populations of aquatic organisms.
 4. Provide funding and mechanisms for assistance in the form of disease monitoring for aquaculture and wild harvest industries, extension personnel and develop a rapid-response plan for the outbreak of disease.
 5. Rhode Island should a) continue to participate in a region-wide Northeast Aquatic Nuisance Species (ANS) Panel, to ensure that regulations and management of ANS introductions are uniform throughout the region and that all states are in compliance with whatever strategies are in place, b) undertake an aggressive outreach and education program to teach the general public about the risks associated with the introductions of exotic species, and c) utilize the guidelines provided by the ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2004 if intentional introductions are proposed in the state.
 6. In considerations of aquaculture site selection, continue to provide special protection for eelgrass habitat and native species.
 7. Encourage growers, researchers and regulators to conduct studies to determine optimal stocking densities to maximize growth and minimize potential negative impacts; specifically, to monitor a) water column dissolved oxygen and phytoplankton abundance, and b) sediments for excessive organic enrichment and benthic oxygen demand.
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The Social Impacts of Aquaculture

The biological impacts of aquaculture are relatively well documented and were admirably covered by the biological subcommittee. But the biological impacts are only one side of the equation. The social impacts of another user of a limited resource have to be considered as well. It is easy to cite figures on the extremely small amount of the state's submerged lands aquaculture occupies, but much more difficult to quantify the impacts in a manner that is fair and balanced. The working group struggled with this side of the question in planning the methodology to be used for arriving at a report. Indeed the question is still not totally settled.

The first step in the process was to query user groups in an effort to determine perceived impacts. Towards this goal Mr. David Beutel of the University of Rhode Island Fisheries Center volunteered to work with various fishing groups to gain knowledge of these impacts. Mr. Beutel, along with other members of the working group Jody King, Bill Silkes, Tim Scott and Jeff Gardiner, went to commercial and recreational fishing association meetings including the RI Commercial Fishermen's Association, RI Saltwater Anglers Association, RI Shellfishermen's Association, and the Narragansett Striper Club and advertised public meetings at the Kettle Pond National Wildlife Refuge, and asked attendees for their opinions of the impacts. The list of aquaculture concerns is significant for a number of reasons. First it shows that there are valid concerns expressed about the future development of aquaculture in Rhode Island. These concerns are ones that the regulatory authorities need to address. The list is contradictory in a number of areas. These contradictions show an amount of confusion about aquaculture in Rhode Island. Another point of the list is that there are a number of concerns stated that are addressed by the regulations in place. These last two points, the contradictions and already addressed areas, show a real need for increased education of all the users of the states submerged lands.

Aquaculture Concerns

Mentioned 3 times

- Do not lease traditional wild harvest areas—commercial and recreational
- Lease duration and performance—limit lease terms based upon performance
- Limit total acreage for aquaculture in all ponds
- Limit percentage of pond use
- Limit total number of farms
- Continue to review new leases on case by case basis with other users
- Minimize impacts on wild harvest areas
- Minimize impediments to access wild harvest areas

Mentioned 2 times

- Clarify fishing/shellfishing access rights
- Keep buffer areas between leases
- Keep acreage in reserve for future farms
- Only allow expansion after proven performance (successful sale of crop)

Clarify rights of passage around/through leases

Mentioned once

Eliminate lease transferability—require a full reapplication process instead of a transfer

Control for disease effects on native products—what happens if aquaculture introduces disease to native products—who will pay for remediation?

Discourage finfish aquaculture in marine waters

What are the rights to wild products that settle on a lease?

Limit new permits to ponds only (leave Narragansett Bay alone)

Ban power washing of cages on coastal ponds

Put all leases together (zoned areas)

Increase lease fees to cover management costs

Include recreational fishing associations in public notices

Encourage aquaculture in Narragansett Bay (not the coastal ponds)

Farms should provide a net benefit for ecosystem—cleaner water, more habitat

Encourage low impact methods

After reviewing the list of aquaculture concerns the working group decided that public education was needed. After numerous edits the group put together a list of Frequently Asksed Questions that will be distributed to marinas, web sites, and other venues where users of the resource will be able to see it. Dr. Deale Leavitt of Roger Williams University has volunteered a summer student to put this effort in effect. The FAQ can also be found on the CRMC web site.

Aquaculture and You

FAQ's

Shellfish aquaculture is growing in Rhode Island. As it grows more people are seeing the farms and have questions about it. These Frequently Asksed Questions are intended to provide information to boaters, fishermen and the general public.

What is grown in RI? Currently all of the farms in the state's waters grow shellfish with the vast majority being oysters. There is a marine ornamental fish farm but it is on land in tanks, not in the state's waters. Additionally the state cultures fish for stocking freshwater fisheries and for restoring coastal habitats.

Who regulates aquaculture in Rhode Island? The RI Coastal Resources Management Council is the lead agency for all aquaculture in RI. The Council works with Department of Environmental Management, the Department of Health, fishing groups (both commercial and recreational) and towns when permitting an aquaculture lease.

How do these people occupy the submerged lands? The area occupied by an aquaculture farm is not given away. The water and land beneath it belongs to all of the citizens of the state and is managed under the “Public Trust Doctrine” for everyone. Aquaculture farms lease the submerged land from the state, they do not own it. If a farmer abuses the lease provisions, the state can revoke the lease.

Can just any area be leased? No. In consultation with fishing groups and other regulatory agencies, there are many restrictions on which areas can be leased. Areas that support a wild harvest of shellfish, areas of eelgrass, navigation areas, etc. are examples of areas not suitable for aquaculture farms.

How long do the leases last? The RI Legislature has set the lease maximum length at 15 years. Leases are renewable by the farmers upon submission of a new application upon expiration of their lease providing the farmer has continued to abide by the conditions in the lease.

What does the farmer have to do to maintain the lease? The lease must be actively farmed. The farmer has to post a bond to enable the state to remove the gear in case of default and the farmer has to sign a lease yearly and pay a yearly lease fee. Failure to comply with any of the conditions of the lease can result in the lease being revoked.

Are there limits on the amount of area that can be leased? Yes, the CRMC, in consultation with the fishing industry and other regulatory agencies, has developed guidelines that restrict aquaculture to a maximum 5% of any water body.

Can I use the farm area too? Yes, within limits. The public can pass through a farm, however it is illegal to disturb the farmer’s gear or harvest his stock. At all times mariners are expected to use caution and common sense when traversing farms. Most farms have at least 6’ of water over the farm gear. When in doubt, ask the farmer.

Does the farmer use wild stock? No, the farmer cannot collect wild shellfish to grow.

How is shellfish disease managed? The first thing to remember is that we are talking about diseases of shellfish only. None of the diseases that seed are tested for are capable of affecting humans. The state does not allow shellfish with diseases capable of affecting humans to be brought into the state. A report from a certified disease specialist certifying the seed as disease-free must be supplied to CRMC prior to any permission being granted to import shellfish seed into the state. CRMC also has an Aquaculture Biosecurity Board to ensure the rules are kept up to date.

Will the state allow marine finfish farms? Possibly, but it would be very difficult to permit a finfish farm in RI waters. One of the problems we already have is excess nutrients polluting the state’s waters. A marine finfish farm would add to this problem of excess nutrients from fish feeds and fish wastes. Finfish farms are already prohibited in the coastal ponds because of this pollution concern.

Then why allow shellfish? It is generally accepted that shellfish aquaculture is a net benefit for the

environment. Shellfish are filter feeders that consume algae from the water. The farmer does not feed them, thus there are no added nutrients. Additionally shellfish filter algae from the water, up to 50 gallons per day for a large oyster, and this helps clean the water.

How can I learn more about aquaculture? There are a number of ways. On the CRMC web page there are a number of articles, regulatory information, presentations and links to other sites. The web address is: <http://www.crmc.state.ri.us/projects/aquaculture.html>. Another way to learn more about aquaculture is to ask the farmer. Please use common sense in approaching farmers; they are working to make a living.

How can I recognize an aquaculture farm? The standard markers required include a 1 foot square safety orange square, or an orange diamond, with “Aquaculture” “CRMC” and the lease number on it. Leases are required to be marked on all four corners.



Information Buoy: Used to relay information.

Danger Buoy: Marks an obstruction where boats should not navigate or should use extreme caution.

Charting Project

The second step of this process was to work with Save the Bay, RI Shellfishermen’s Association, Ocean State Aquaculture Association, Salt Pond Coalition, local harbor masters, and interested public to determine the different uses for the salt ponds. Advertised meetings were held in South Kingstown, Charlestown and Westerly to provide ample opportunity for participants to share their knowledge. Charts of the salt ponds were used for each meeting to determine current and historic usage of the areas. The information was collated onto one chart for each salt pond and a report was provided to the working group. The charts are available for viewing through the CRMC Aquaculture Coordinator David Alves and will provide valuable credible information about potential conflicts and current usages of the South County salt ponds. This project followed the same format as the Narragansett Bay usage mapping of 2000. The CRMC hopes to have these charts posted on the web as the charts from the original charting project currently are.

Suggested Regulatory Changes

The working group had extensive discussions on regulatory changes that would address the concerns of the user groups. The discussions were wide ranging and productive as many misconceptions were clarified for the benefit of the group. Areas of concern were noted in lease

marking, fate of wild shellfish on existing leases, limits on new lease size, limits on existing lease expansion, protection of historically fished areas from aquaculture development, buffers between leases and recreational leases.

The working group's discussions resulted in the following suggested changes to the regulatory environment. All of the changes suggested here were accepted by the group with a majority vote. These suggestions will now have to undergo the regulatory process of changing existing regulations.

Lease Marking

Another point that came up is the need for legible, easily recognized, consistent marking for aquaculture leases in Rhode Island waters. The final result is mentioned in the FAQ. Currently the leases are required to be marked with standard lobster pot buoys with "CRMC" and the CRMC assent number marked on them in 4" letters. The issues arising from this standard were that the buoys soon became fouled, rendering the markings illegible and that some town requested larger or smaller markings due to local conditions. This resulted in users of the resource not being able to identify aquaculture leases. The final working group approved language for the marking of aquaculture leases includes the following:

Leases will be marked on each corner by a safety orange square or diamond 12 inches square. Within this area will be the words "Aquaculture" "CRMC" and the CRMC assent number of the lease. There will be a minimum 20 square inches of reflective material on the sign. The sign will be a minimum of one foot above the water and a maximum of five feet above the water at all stages of tide. The use of a diamond, the recognized sign for caution, or the square, a recognized informational marking, will be determined by the nature of the aquaculture culture method. There will also be allowed intermediate markers, if necessary, between the corner markers consisting of a standard lobster pot buoy painted orange and white with the marking "CRMC" and the lease assent number.

Fate of Wild Shellfish on Leases

One issue that elicited quite amount of discussion was the fate of wild shellfish on an aquaculture lease. Currently the wild shellfish remains the public's property. The problem arose when wild harvesters attempted to harvest shellfish under and around aquaculture leases and the gear on them. Another issue was the sequestering of harvestable shellfish on the small percentage of bottom occupied up by shellfish leases. After detailed discussion by all parties the following position was approved by the working group.

All wild stock on aquaculture leases either existing at the time of granting the lease or settled upon the area at any time after granting a lease, shall remain the property of the State of Rhode Island. An aquaculture lessee cannot harvest this resource without the specific permission of the Coastal Council. This resource is also not to be harvested by any person for commercial or recreational purposes. Any incidental catch within an aquaculture lease is to be released.

Limits on Growth of Aquaculture Leases

Much of the reason for the working groups renewed lease on life was due to a perception of unrestrained growth of aquaculture in Rhode Island. As noted previously the percentage of aquaculture in Rhode Island waters is miniscule at present and the available scientific evidence seems to bear out the point that there does not seem to be an ecological problem. But as previously noted there are societal effects to aquaculture development. In a display of collegiality the working group representatives from the fishing and aquaculture industry have worked together in side meetings to arrive at a series of compromises agreeable to both groups concerning the regulation of aquaculture growth.

There was not unanimous agreement on all points. The industry groups brought their comprise positions to the working group. The working group as a whole discussed them and voted on them. A position was accepted by the group if there was a majority vote for approval. If any member of the working group is in disagreement with the vote of the working group is free to offer a minority opinion.

Limits on New Lease Size

The working group approved, after long discussion, a limit on the size of new leases in the state's southern salt ponds. The purpose of this was to allow for a controlled growth of the industry. One of the fears of other user groups is the specter of uncontrolled leasing growth. In discussions between the industries it was decided that a maximum size of new lease was acceptable. This size is dependent on the type of aquaculture proposed. The sizes decided upon are sufficient to allow a new entrant into the industry to be successful. Later growth of the farms would be allowed (see next paragraph).

In the southern salt ponds new leases will be limited to three acres if the proposed method of culture is transient cage culture or any culture that utilizes a stacking method to culture shellfish. The limit on new lease size would be 6 acres if the culture method utilizes bottom planting; i.e. no gear used. This change in the regulation is suggested to be placed in the CRMC Aquaculture Section 300.11 Standards subpart.

Limits on Expansion of Existing Leases

An area of contention was expansion of existing leases. Some leases were thought to have expanded too quickly. The working group thought it prudent to allow expansion of existing leases utilizing public trust lands only after a need has been shown. The office of the CRMC aquaculture coordinator would document the need and report to the Coastal Council when an expansion was requested.

Thus lease holders may not apply for expansion of their lease unless they can demonstrate a need for the expansion. This change in the regulation is suggested to be placed in the CRMC Aquaculture Section 300.11 Regulations subpart.

Protection of Historically Fish Areas

An issue that has galvanized the fishing industry has been the perceived loss of fishing grounds. The existing CRMC procedures for protecting fishing grounds have been to involve as many stakeholders in the process as possible. Creditable information has always been given credence and there are multiple instances of proposals being moved or denied in the Preliminary Determination permitting phase. The fishing industry is concerned that species that they target are plentiful in one location sporadically and they might be barred from an area that has not been productive in recent memory if that area again becomes productive. The issue is a thorny one as there are many possible reasons for the change in productive areas, ranging from pollution, global warming, etc.

After long discussion of the issue the working group has approved suggested language to be added to the Guideline section of the CRMC regulations on aquaculture, 300.11. The suggested language will state that the CRMC will strive to protect historically productive fishing areas and that aquaculture leases will be encouraged in non-productive areas.

Buffers Between Aquaculture Leases

A discussion took place on the issue of suggesting buffers between aquaculture leases. The scientific consensus was there was not a need for the buffers. However there are instances where buffers between leases would be needed to allow for other reasons, ex. public access. It would be impossible to write a regulation that encompasses all of the possibilities that might arise. In some instances it might be better for a number of reasons to insist leases are abutting.

The group decided to suggest language that would give the CRMC aquaculture coordinator discretion in when, or if, to allow buffers. As always all new lease proposals would go through the regulatory process that requires review by a number of user groups. What ever decision was made regarding buffers would be reviewed in this process.

Recreational Leases

This issue brought up a number of interesting discussions. The range of concerns was enlightening. The group was concerned with the issues of professionalism and the possibility of public health being affected. Recreational lease holders would also be controlling the public trust lands for personal uses. On the other hand it was brought up that the public does own the public trust lands and has a right to use them.

The suggestions agreed upon by the group address the issue in a number of ways. One was to allow dock owners to have a culture float that could be hung off a dock or a mooring. Additionally the recreational permit holder would be required to attend an educational class to ensure compliance with public health regulations. It was also agreed that the existing definition of “actively farmed” in the CRMC regulations would have to be further defined.



CRMC Working Group on Aquaculture Regulations

Subcommittee on Biology Report on Biological Impacts of Aquaculture

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Preface

In its early deliberations, the CRMC Working Group on Aquaculture Regulations decided that a scientific review should be done to provide science-based information on the limits to aquaculture development in Rhode Island. Particular areas selected by the Working Group for consideration were: Water Quality, Diseases, Invasive Species, Physical Impacts of Aquaculture Gear, Essential Fish Habitat, and Carrying Capacity. We also wanted input on an Ecosystem Approach to Aquaculture. Members of the Working Group who volunteered to contribute to this effort took on the title “Subcommittee on Biology”. The intent of the Subcommittee has been to broadly summarize the state of knowledge in the above areas and to bring forward recommendations to the full Working Group. The first draft of the report was presented in September 2007 and comments were received from the Working Group at the October 2007 meeting. The final report was approved by the full Working Group at the January 2008 meeting.

Executive Summary

A considerable amount of information exists from around the world on aquaculture operations and their relationship to the environment. Farming of fish in pens and shrimp in ponds can have significant detrimental environmental effects, usually restricted to the area right around the operation. Thus, any attempt to raise fish in Rhode Island's open waters will require extreme scrutiny. On the other hand, the shellfish aquaculture practiced in Rhode Island is most likely beneficial for the environment, for a number of reasons. Oysters filter phytoplankton from the water, thereby allowing light to penetrate deeper so that submerged aquatic vegetation (SAV) can grow from the bottom. In doing so, they also remove nutrients from the water and can help ease the eutrophication problems in Rhode Island's estuaries. Oyster operations also provide refuges for the juvenile stages of several species of popular fish. The physical presence of shellfish aquaculture in Rhode Island waters has an impact on the natural environment. The question is whether that impact is acceptable to ecosystem structure and function and, by extension, to a Rhode Island public that does not want to see our estuaries degraded. We have made our best attempt to answer that question, but the process of doing so has allowed us to identify areas for which more information is clearly needed. For example, does oyster aquaculture hinder or help the winter flounder populations? In the areas of disease and invasive species, we need to remain vigilant in our monitoring and to develop practices and technologies that will minimize damage to the existing shellfish industry from these factors. There has been no evidence that shellfish aquaculture (as practiced in Rhode Island) is having negative environmental impacts and little reason to believe that further modest growth will have negative impacts in the future. Even in states where shellfish aquaculture is far more widespread there is little evidence that the impacts have been anything other than positive.

From a biological and ecological perspective, the really critical question is: what is the maximum amount of shellfish aquaculture that can occur in a given water body without unacceptable ecological impact to that body of water? This amount is a calculable quantity called the ecological carrying capacity. Ultimately, we need to take an ecosystem approach and determine the real ecological carrying capacity for Narragansett Bay, the coastal ponds, and other Rhode Island waters. To fully define that capacity for each water body is a task that will require much more information and work than we are able to provide here. One of the recommendations is to seek funding to do that type of work. Meanwhile, we rely on work that was done in New Zealand to estimate carrying capacity for shellfish culture there. Adapting the New Zealand work to Point Judith Pond as a representative coastal pond, we calculate that the carrying capacity of the pond for shellfish aquaculture is approximately 5% of the pond's area. We recommend that number as our scientifically defensible best estimate for the moment, with the realization that better estimates could be available in the future with better data and site-specific modeling efforts.

Recommendations

1. Limit shellfish aquaculture to no more than 5% of the area of any water body until specific estimates for Rhode Island waters can be generated with site-specific data.
2. Seek funding to investigate the ecological carrying capacity of estuaries in Rhode Island for aquaculture and to investigate the interaction of shellfish aquaculture with native species.
3. Establish a single interdepartmental advisory board that would be in charge of providing recommendations for the regulation and management of infectious diseases in wild and cultured populations of aquatic organisms.
4. Provide funding and mechanisms for assistance in the form of disease monitoring for aquaculture and wild harvest industries, extension personnel and develop a rapid-response plan for the outbreak of disease.
5. Rhode Island should a) continue to participate in a region-wide Northeast ANS Panel, to ensure that regulations and management of ANS introductions are uniform throughout the region and that all states are in compliance with whatever strategies are in place, b) undertake an aggressive outreach and education program to teach the general public about the risks associated with the introductions of exotic species, and c) utilize the guidelines provided by the ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2004 if intentional introductions are proposed in the state.
6. In considerations of aquaculture siting, continue to provide special protection for eelgrass habitat and native species.
7. Encourage growers, researchers and regulators to conduct studies to determine optimal stocking densities to maximize growth and minimize potential negative impacts; specifically, to monitor a) water column dissolved oxygen and phytoplankton abundance, and b) sediments for excessive organic enrichment and benthic oxygen demand.

Chapter 1

Water Quality

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Summary

Water quality is technically defined by a suite of physical and chemical characteristics. In Rhode Island, the RI Department of Environmental Management enforces federal water quality regulations. High-density aquaculture, including finfish, shrimp and molluscan aquaculture operations, has been shown to have detrimental impacts on water quality in certain areas of the world. Shellfish aquaculture, as practiced in Rhode Island, has not been shown to have detrimental impacts and in fact can be beneficial to water quality by removing excess nutrients.

Components of Water Quality – Although we may think of “water quality” as a single concept (is it good or bad?), water quality is made up of several components, defined below. In an ecological or aquacultural context, these components all contribute to the suitability of the water for habitation by species of plants and animals. Thus, water quality is, in turn, one component of essential fish habitat (cf. Murphy and Wood report in this document). While a single water quality component may be enough to make the water unsuitable for a given species, many of the components of water quality are interrelated (e.g., dissolved oxygen saturation levels decrease with increasing temperature), so suitability is often a question of multiple components considered simultaneously. The following definitions or explanations of water quality components are taken from Avault (1996):

1. **Temperature** – no definition needed, but Rhode Island coastal waters are characterized by large annual fluctuations in temperature; thus we may have very different biological communities in winter vs. summer and many fish move inshore and offshore depending on season.
2. **Salinity** – the total concentration of dissolved solids in seawater, ranging from 0 psu (practical salinity units) for fresh water to about 35 psu in full seawater. Many organisms that live in estuaries can exist in a wide range of salinities due to the salinity fluctuations with the tides.
3. **Dissolved oxygen** – as the term implies, the quantity of oxygen gas that can be dissolved in water, usually reported as milligrams per liter (mg/L) or parts per million (ppm), and referred to as DO. Temperature and salinity both affect the amount of DO that water is capable of holding at saturation. Demands on oxygen in the water and sediments include those for animal and plant respiration as well as chemical reactions. Plants of course produce oxygen via photosynthesis.
4. **Free carbon dioxide** – analogous to dissolved oxygen, the amount of carbon dioxide gas dissolved in water, usually reported as ppm. Plants take up carbon dioxide during photosynthesis and it is quite rare that CO₂ levels rise high enough to affect organisms in the natural environment or even in an aquaculture setting, particularly in marine aquaculture where seawater has a high buffering capacity due to the formation of carbonates from dissolved CO₂.
5. **Alkalinity** – the sum of exchangeable bases reacting to neutralize acid when acid is added to water. This is due primarily to bicarbonate, carbonate, and hydroxide ions and provides a buffering system to reduce fluctuations in pH. Because seawater has such high levels of these ions, alkalinity is much less of an issue in seawater than in freshwater.
6. **pH** – an index of hydrogen ion activity. A pH of 7 is neutral, lower than 7 is considered acidic,

and higher than 7 is considered basic or alkaline. The pH of seawater is about 8.

7. **Ammonia** – Un-ionized ammonia (NH_3) is toxic to organisms in high enough concentrations, whereas ammonium (NH_4^+) is generally unable to cross tissue barriers. Ammonia is excreted by aquatic organisms, is a product of decomposition of organic matter, and may be discharged into waters from terrestrial sources. Bacteria in the environment transform ammonia into nitrite and then into nitrate. All of these may be used as nutrients by plants in the environment.

8. **Suspended and settleable solids** – particles of various sizes that remain suspended in water (usually fine particles, often referred to as turbidity) or settle out quickly (larger particles). These can be produced by aquaculture facilities as a result of feeding or production of fecal matter, and are also produced by organisms living naturally in the environment, by inputs from land-based runoff, etc.

9. **Hydrogen sulfide** – produced by the anaerobic decomposition of organic matter and normally found only in sediment (the “rotten egg” smell that one gets from digging in mud). It can be toxic to organisms.

10. **Heavy metals** – these are normally present in the environment and in organisms in very small quantities and are necessary for life; however, inputs to the environment from industrial source can often elevate them to toxic levels.

11. **Organic pollutants** – substances like pesticides, chlorinated hydrocarbons (e.g., PCB's), etc. result from anthropogenic inputs and can be quite toxic. Due to federal regulations, both organic pollutants and heavy metals are currently being added to the environment in very low, non-toxic quantities

Regulation of water quality – As a result of the Clean Water Act, the U.S. Environmental Protection Agency (EPA) has regulated discharges that could reduce water quality in U.S. fresh and salt waters. EPA issues Water Quality Criteria (WQC) that are based on an analysis of all the scientific studies conducted on a given pollutant, primarily heavy metals and organic pollutants. These are typically used in writing permits for discharges by industries and municipalities. EPA has also produced a WQC for dissolved oxygen that is used in the calculation of Total Maximum Daily Load (TMDL) of discharges, based on the concept that the decomposition of organic material discharged into the environment will use up dissolved oxygen. EPA has a long history of regulating discharges that are considered “point source”, that is, coming from a single point, like the end of a discharge pipe. The regulation of non-point sources has been much more of a problem because the source is so diffuse and difficult to regulate (e.g., runoff of nutrients from farms). In Rhode Island, U.S. EPA has delegated regulation of water quality to RI DEM.

Background on water quality and marine aquaculture – The impacts of marine aquaculture on water quality have been well documented around the world and are generally local in nature, i.e., affecting the area quite close to the farm(s) (Gowen and Bradbury, 1987; Silvert, 2001). The culture of fish in net pens can have several adverse impacts. The fish crowded in pens take up oxygen at a rather high rate from water flowing through the pen (Silvert, 1992; Wildish et al., 1993). Because the organisms most affected by this are the fish themselves (i.e., they grow less when oxygen is sub-optimal), proper siting of pens in locations with good currents for adequate oxygen replacement becomes paramount (Lumb, 1989; Black and Truscott, 1994). Excess fish feed and fish feces that constitute settleable solids sink below the cage; if sufficient currents are not present, the material builds up below the cage and decomposition of this organic matter also consumes oxygen and results in ammonia production (Brown et al., 1987). In extreme cases, an anaerobic pile of decomposing

matter below the pens can produce outgassing (eruption of bubbles) of hydrogen sulfide and methane into the water (Black et al., 1996). Again, the organisms that suffer most are the fish in the pens through which the bubbles pass on their way to the surface. Another major impact on fish in pens is ammonia production (Aure and Stigebrandt, 1990; Silvert 2001). Fish excrete ammonia via their gills, which diffuses into the water. Even with minimal current flow, the amount of ammonia produced is rarely sufficient to have any toxic impacts on the fish or surrounding organisms, but does serve as a source of nutrients for algal blooms (Wildish et al. 1993). In recent decades, much suspicion has arisen regarding the contribution of fish farms to blooms of harmful (toxic) algae (Silvert, 2001). Finally, fish farmers use chemicals and/or antibiotics to treat diseases of fish in net pens (Grave et al., 1990; ICES, 1994). The use of antibiotics has declined substantially in recent years due to vaccination programs for fish, but chemicals are still used to treat sea lice in salmon, an external parasite (Black et al. 1997). Studies of this chemical usage have concluded that the concentrations involved are not likely to have an adverse impact on the surrounding environment (Davies et al., 1997, 1998; Burrige et al., 2000 a, b). Also, the nets used in the pens may contain heavy metals to ward off fouling organisms and these metals leach into the water when the nets are new; again, the concentrations of metal in the water are likely to not have an adverse impact on the environment (Balls, 1987).

Shrimp aquaculture mostly takes place in tropical coastal ponds and has also had several impacts on the environment (Clay, 2001). Because fresh water from wells is often used to control salinity in the ponds, release of water from the ponds can alter salinity in estuaries that receive the effluents. Those effluents typically also contain ammonia produced by the shrimp, suspended and settleable solids from the ponds, and any chemicals or antibiotics that may have been used in the ponds. The extent of damage done to the environment depends on the amount of effluent relative to the flushing rate of the estuary receiving the effluent. Over the last several decades, shrimp aquaculture progressed from a low-density operation with few organic inputs (like feed) to high-density culture with much added food, fertilization of the water and frequent water changes to counter the rapid build-up of ammonia (Browdy and Hopkins, 1995). Many efforts are currently underway to try to reduce the environmental impacts of shrimp culture (Hopkins et al., 1994, 1995; Clay, 2001).

Molluscan aquaculture is quite benign compared to fish and shrimp culture. Because no organic inputs like feed are added (the mollusks filter their feed directly from the water), the impacts on the environment are much reduced, in terms of decomposition, etc. Mollusks concentrated on a farm still consume oxygen, produce carbon dioxide, and produce ammonia as an excretory product, so there is clearly some impact, the extent of which depends on flushing of water around the farm. In the 1980's, several studies of extremely concentrated mussel farms (e.g., 120,000 MT annual production in the Ria de Arosa in Spain) showed that the deposition of feces and pseudofeces directly under the farms could overwhelm the ability of the environment to assimilate and transform those natural wastes coming from the mussels (Dahlbäck and Gunnarsson, 1981; LaPointe et al., 1981; Tenore et al., 1982; Kaspar et al., 1985; Kautsky and Evans, 1987). The result was an anaerobic environment similar to those under fish net pens. There has been no corresponding demonstration of negative results for oyster or clam culture. The only known instance of chemical contamination resulting from molluscan culture is the use of a pesticide (carbaryl) by oyster farmers in Washington on the tidal flats to kill burrowing shrimp that can harm the oyster cultures (Simenstad and Fresh, 1995).

Molluscan culture is usually considered the most beneficial form of aquaculture for the environment, because mollusks filter material from the water. Much of that material is phytoplankton, which has used nutrients in the water to grow. Thus, in eutrophied estuaries, i.e., those characterized by excessive nutrients, molluscan aquaculture can be quite beneficial because the mollusks transform the organic (plant) production resulting from those nutrients into animal tissue that can be removed and consumed by humans. Using published data on filtering rates of various molluscan species, several authors (Newell, 1988; Rice, 2001, etc.) have calculated the amount of water that is filtered by a large population of mollusks, either naturally occurring or in aquaculture farms, and have shown the role that these mollusks can play in removing nutrients, especially nitrogen (N) from estuarine waters. By filtering phytoplankton from the water, mollusks increase the amount of light that reaches the bottom, providing increased opportunities for submerged aquatic vegetation to grow (Newell, 2004).

One can argue that much of the nitrogen that the mollusks take up is released back to the environment either as excreted ammonia or in the pseudofeces that are deposited on the bottom. Pietros and Rice (2003) studied oyster impacts on water column nitrogen levels and sedimentation rates using mesocosms at the University of Rhode Island. They found that, although oysters clearly excrete ammonia, ammonia levels in oyster tanks were not significantly higher than those in control tanks without oysters, suggesting that the ammonia is quickly taken up by phytoplankton as a nutrient source. They also found that oysters significantly increased rates of sedimentation to the bottoms of the tanks and altered the phytoplankton composition in the tanks (presumably because of selective feeding on one particular phytoplankton species). Newell (2004), in an excellent review article, pointed out that oysters are one of the mollusk species particularly useful in clearing phytoplankton from the water column because they continue to feed even when food concentrations are high and they presumably have enough food. The excess, undigested phytoplankton (along with other less digestible particulate matter) is incorporated into pseudofeces that sink more quickly to the bottom than would the phytoplankton particles themselves. The fate of the nutrients, especially the organic nitrogen, in the sediment depends to some degree on the amount of sedimentation in relation to the absorptive capacity of the benthic microbial community to break down the organic material. Under normal conditions, aerobic bacteria will decompose that material into ammonia, which enters the process of nitrification to be converted to nitrite and nitrate, which in turn can be used as nutrients for benthic algae, submerged aquatic vegetation, or phytoplankton (if resuspended into the water column). In addition, deposition of organic nitrogen to the sediments may increase denitrification. Denitrification is the process by which nitrate or nitrite is converted to nitrous oxide or free nitrogen (N_2). The process can be completed by either aerobic or anaerobic bacteria and production of free nitrogen in particular represents a way by which nitrogen can be fixed by plants or returned to the atmosphere as nitrogen gas. Newell et al. (2002) studied nutrient regeneration in a laboratory experiment using bivalve biodeposits and found that 17-24% of the sediment nitrogen was released to the atmosphere as nitrogen gas (in the absence of light) or that most of the nitrogen was fixed by benthic algae (in the presence of light); in either case, substantial amounts of nitrogen were not released back to the water column as nutrients for phytoplankton. On the other hand, if conditions are not normal (e.g., excessive amounts of organic material deposited if aquaculture densities are too high), anaerobic processes come into play once the deposited material exhausts the oxygen available for aerobic decomposition. In this case, the water above the sediments can become anoxic and ammonia, hydrogen sulfide and methane can be released into the water column. Again, the critical aspect is the rate of deposition of organic material to the sediments compared to the rate

at which the bacteria there can process that material, in particular the nitrogen (cf. Rheault report on carrying capacity in this document).

Recommendation: A program should be developed to monitor DO, phytoplankton abundance and benthic oxygen demand to determine whether aquaculture farms are exceeding appropriate stocking densities.

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Chapter 2

Disease Considerations for the Rhode Island Aquaculture Plan

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Summary

Infectious diseases are a major threat to wild and cultured populations of marine organisms. Due to the potential catastrophic effect of diseases, and because disease does not distinguish between farmed and wild populations of marine organisms, several international, federal, and state agencies have established regulations geared to minimize the risk of the introduction of new pathogens to an area and the spread and impact of diseases in those areas where diseases are already present. In Rhode Island, regulations regarding the importation of shellfish are included in the Department of Environmental Management “Aquaculture of Marine Species in Rhode Island Waters” and the Coastal Resources Management Council (CRMC) aquaculture regulations. These regulations are routinely evaluated by the Rhode Island CRMC Biosecurity Board, an advisory group composed of representatives from state agencies, scientists and health specialists, extension agents, the aquaculture and fishing industries, and groups involved in restoration projects. The state uses available information on the distribution and prevalence of disease in bivalve populations, available through monitoring programs, to regulate the transfer of cultured shellfish within Rhode Island waters and to provide farmers with recommendations on how to best manage disease. Effective management should include monitoring programs, knowledge of the biology of the shellfish and their pathogens, awareness of the environmental conditions that trigger disease outbreaks, establishment of a plan outlining procedures on how to report and manage disease outbreaks, and access to the most recent tools available to manage disease, such as disease-resistant strains. Any plan regulating aquaculture in Rhode Island should include those elements.

Introduction – The impact of diseases on marine organisms

Infectious diseases are one of the major threats to wild and cultured populations of marine organisms. In examples relevant to the important role of oysters, hard clams, and lobsters in Rhode Island’s fishery and aquaculture industries, the diseases commonly known as dermo, multinucleated sphere unknown (MSX), Juvenile Oyster Disease (JOD), quahog parasite unknown (QPX), have caused hundreds of millions of dollars in losses to the oyster and clam fishing and culture industries in the Atlantic Coast of the United States, including the Northeast (Ford & Tripp 1996). Recently, populations of lobsters in Rhode Island have been severely impacted by shell disease (Castro & Angell 2000).

Marine organisms and their pathogens constitute a complex and evolving ecosystem heavily influenced by natural and anthropogenic factors (Harvell et al. 1999b, Harvell et al. 2002). The vast majority of cultured marine organisms (like salmon, cod, tuna, oysters, and clams, just to name some favorites of US consumers) are raised in “open systems” (*i.e.* cages and netpens) placed in the marine environment, exposed to a complex and changing milieu of microorganisms, interacting with wild populations of marine organisms, and in environmental conditions that cannot be controlled.

Disease outbreaks in cultured populations can spread to wild populations (Skall et al. 2005, Nowak 2007) and wild populations serve as reservoirs for aquaculture pathogens (Samuelsen et al. 2006). Furthermore, climate change now threatens to promote ecosystem instability and the emergence of new diseases that affect marine species (Harvell et al. 1999). Rising ocean temperatures are expected to expand the geographic range of familiar pathogens and cause more frequent outbreaks (Colwell 1996). Indeed, marine diseases already appear to be on the rise (Harvell et al. 1999).

Who is responsible for the management of diseases of aquatic organisms?

Due to the potential catastrophic effect of diseases, and because disease does not distinguish between farmed and wild populations of marine organisms, **several international, federal, and state agencies have established regulations geared to minimize the risk of the introduction of new pathogens to an area and the spread and impact of diseases in those areas where diseases are already present.** Most of these regulations target the aquaculture industries since wild populations are not under any effective control that would allow such activities.

Effective aquatic animal health management requires a cooperative effort between state and federal agencies, scientists and health specialists, extension agents, the aquaculture and fishing industries, and groups involved in restoration projects.

Effective aquatic animal health management requires a cooperative effort between all stakeholders (Atlantic States Marine Fisheries Commission 2002). **State, Federal (USDA), and International (World Organization for Animal Health and the International Council for the Exploration of the Sea) agencies** develop regulations and recommendations geared to minimize the introduction and impact of diseases on marine populations. In Rhode Island, the management of farmed fish (finfish and shellfish) populations is the responsibility of the Coastal Resources Management Council (CRMC). The management of wild and restored shellfish populations is overviewed by the Department of Environmental Management, Fish and Wildlife (RIDEM). The Rhode Island CRMC Biosecurity Board, lead by the Aquaculture Coordinator and composed of the state veterinarian, an aquatic animal health specialist, an aquaculture extension agent, and representatives of the fishing and aquaculture industries, as well as restoration groups, advises the CRMC on issues pertaining to disease and genetics as they concern the aquaculture industry. Decisions on how to manage farmed and wild fish populations are based on current scientific knowledge and information gathered by health specialists on disease distribution within the state. **Health specialists** are responsible for health certifications, disease diagnosis, and monitoring wild and cultured populations or marine organisms for disease. **Farmers, fishermen, and other groups** involved in the management of wild and restored populations of marine organisms (“user groups”) are responsible for avoiding as much as possible disease outbreaks by following the guidelines and recommendations of agencies and health specialists. User groups should report *as soon as possible* any unusual levels of mortality to local extension agents or health specialists, so appropriate measures to control the disease and minimize its impact can be taken.

Aquatic Animal Health Management: Regulations and Recommendations

Box 1. Potential routes for introduction of diseases in the marine environment:

1. Introduction of a new pathogen due to:
 - Importation of infected bivalves from infected areas.
 - Transport by vectors (animals or objects that carry the pathogen but do not suffer the disease). Examples of vectors include boats coming from infected areas, transported either in ballast water or in hitchhikers in fouled hulls, bait used for fishing, waste from shucking houses, and dirty shells from recently dead shellfish to be used as cultch.
 - Transport by currents.
2. Introduction of a susceptible host in an area where the pathogen exists in low levels.
3. Changes in environmental conditions, leading to increased susceptibility in the hosts (due to stress) or increased virulence of the pathogen.

Transfer of marine organisms for aquaculture: Health certification programs

The most effective regulations and recommendations are those geared to prevent the introduction of pathogens in an area. Pathogens affecting aquatic organisms can be **introduced** in a new area by several means (Box 1). A major route for the introduction of pathogens in clean areas is the importation of organisms from infected areas. To minimize the risk of introduction of diseases by this route, the transport of shellfish for aquaculture between states and countries is highly regulated. The Agreement on the Application of the Sanitary and Phytosanitary Measures ([SPS Agreement](#)) of the World Trade Organization (WTO) has stimulated the application of risk analysis to international trade policy for animals and animal products. *A key principle of the SPS agreement is that there should be no restrictions (sanitary measures) on trade in animal and animal products, unless it is likely that the trade will result in disease spread with unacceptable consequences.* The World Organization for Animal Health (OIE at www.oie.int) regulates the international transport of cultured aquatic organisms. Member countries agree to report to the OIE the presence of certain diseases considered a threat to aquaculture. OIE establishes a disease-free certification process that facilitates the transport of shellfish from certified areas to any other areas. The organization considers epidemiological information and risk analysis to regulate the transfer of shellfish between countries and areas in which the reportable diseases are already present. Examples of issues considered in this risk analysis are the presence of strains of a pathogen with different levels of virulence and patterns of distribution, or differences in the relative levels of disease in the two areas.

In the United States, each state has rules regarding the **importation from other states of marine organisms for aquaculture**. In Rhode Island, regulations regarding the importation of shellfish are included in the RI Department of Environmental Management “Aquaculture of Marine Species in

Box 2. Rhode Island regulations regarding importation of shellfish for aquaculture

- The aquaculturist must notify the Aquaculture Coordinator at CRMC in writing of every shipment of animals for culture entering this state, at least five working days prior to entry into the state.
- Each shipment of seed must be accompanied by a certificate of disease inspection from a recognized laboratory appropriate to the species received.
- The Director of DEM, in consultation with the Biosecurity Board, may waive the requirement

Rhode Island Waters” regulations (Box 2). These regulations should be routinely evaluated to make sure that they take into account the most recent information about diseases.

The state of Rhode Island uses available information on the distribution and prevalence of disease in bivalve populations to regulate the transfer of shellfish within Rhode Island waters (*intrastate transport of shellfish*). Since the risk of introducing disease agents increases with the amount of time that the organism to be transported has spent in coastal waters, the CRMC Biosecurity Board recommends that no adults are transported between the different bodies of water in Rhode Island (for example, between the coastal Ponds and Narragansett Bay). For example, the transport of seed oysters is considered on a case-by-case basis, using available information on disease prevalence and intensity. If no information about disease prevalence is available from the area of origin, and the seed shellfish is being moved to a different body of water, the Biosecurity Board may recommend that a sample of the shellfish to be moved be tested for relevant diseases.

The exiting regulations for transport of shellfish only apply to aquaculture leases. However, the pathogens could also be introduced through transfer of wild stocks and restoration projects, as well as frozen and live products imported from other countries or states. The risks from aquaculture activities should be evaluated relative to risks of transfer by other vectors, both natural and anthropogenic. Furthermore, it is **strongly recommended** that the same guidelines and regulations used to avoid the introduction of pathogens through the transport of aquaculture product should be followed in the case of transfer of bivalves for **restoration projects** and **fisheries management**. This will ensure the health of wild and restored populations of shellfish in Rhode Island waters.

Development of a plan for disease management in aquaculture

The Atlantic States Marine Fisheries Commission, in the Guidance Relative to Development of Responsible Aquaculture Activities in Atlantic Coast States, recommends that farmers, in order to minimize diseases in their farms, develop a comprehensive plan to manage diseases in their farms. These plans can be site and species specific, and should be developed with the help of state agencies, extension agents, and health specialists. Information about procedures and guidelines regarding key aspects in health management should be provided to farmers, including:

- Basic concepts of disease (impact, causes, transmission, effect of the environment, etc)
- A list of the pathogens that constitute major the major threats to wild and cultured populations of marine organisms
- Transfer and transport guidelines, and the role of health certification programs
- Guidelines for site and stock selection (avoid sites exposed to conditions that trigger disease outbreaks, and stocks susceptible to disease)
- Guidelines for routine, frequent disease monitoring, including information on how to recognize disease, procedures for the confidential reporting of potential disease outbreaks and obtaining a rapid disease diagnosis, recommendations for management of the outbreaks, and guidelines for the proper disposal of diseased organisms.
- Safe operational protocols and best management practices (how to minimize stress, maintain water quality, provide proper nutrition, sanitize equipment to minimize spread of diseases, employ quarantine protocols, etc)

In Rhode Island, health specialists and the aquaculture extension specialist with funding from the

Rhode Island Aquaculture Initiative are in the process of developing a brochure with guidelines for disease management in bivalve aquaculture farms. This brochure will be provided to all farmers. Furthermore, the USDA Natural Resources Conservation Services (NRCS) Environmental Quality Incentives Program (EQIP) is currently supporting an annual (2006 – 2009) disease monitoring program with participating farms for 3 years by the Aquatic Pathology Laboratory at URI, with the hope that farmers will see the benefits of disease monitoring and continue after the program is completed.

Monitoring of wild and cultured populations of key marine organisms and support of basic research on diseases of marine organisms.

To make wise management decisions and preserve valuable marine resources, the state must assemble accurate and timely data on the prevalence and intensity of disease in cultured and wild populations of key marine organisms. Health inspections and monitoring programs can minimize the potential for disease pathogens and parasites to be inadvertently introduced during production, transfer, or transport of animals and product. Data from monitoring programs should be available to all stakeholders nationwide, to foster communication between states and the development of fair and effective regulations and guidelines. Furthermore, the Atlantic States Marine Fisheries Commission recommends that disease research and local and regional collaboration in disease matters should be encouraged in all states (Atlantic States Marine Fisheries Commission 2002). Research is necessary to evaluate the geographic range and distribution of the pathogen, determine the environmental and host conditions that trigger disease outbreaks, develop accurate diagnostic tests and treatments, and determine the pathogenicity and virulence of the pathogen and the species of organisms at risk. This information is critical for risk analysis and the development of management plans.

Recommendations.

- **In Rhode Island, the regulation and management of infectious diseases of wild and cultured populations of finfish and shellfish is under the purview of several different agencies and sections within those agencies. For example, RIDEM manages wild populations of finfish and shellfish, while CRMC is in charge of managing cultured populations. The CRMC Biosecurity Board has no overview over wild or restored populations of marine organisms. We recommend the establishment of a single interdepartmental advisory board or expansion of the CRMC BioSecurity's Board purview that would be in charge of providing recommendations for the regulation and management of infectious diseases in wild and cultured populations of aquatic organisms. This advisory board should include representatives of all stakeholders, including state agencies, fishing and aquaculture industries, groups involved in restoration projects, scientists, health specialists, and a representative of the public at large.**
- **Consistent availability of funds for disease monitoring in wild and cultured populations of key species.**
- **Provide continuous assistance to farmers, through outreach programs, in the development and implementation of comprehensive plans for the management of disease.**

- **Establishment of a plan for reporting and rapid response (ensure privacy of people that report disease outbreaks, provision of emergency funds for rapid diagnosis, tools for rapid communication to stakeholders).**

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Chapter 3

Aquatic Nuisance Species and RI Aquaculture

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Summary

Aquatic nuisance species are a real risk to the shellfish aquaculture industry and wild harvest fisheries in Rhode Island. RI shellfish farmers are currently dealing with a wide variety of nonindigenous nuisance species that are increasing their workloads and decreasing their profits. While wild resources are under threat from a variety of introduced predators and competitors. Therefore, it is in the best interest of local shellfish farmers and harvesters to minimize the risk for new introductions. Furthermore, with the advent of stringent regulations controlling the transport of shellfish, the actual risk of introducing a nuisance aquatic species from the importation of shellfish for aquaculture that are contaminated with exotic species is extremely remote. On the other hand, the risk to farmers from introductions via other means is real and growing as the number of other users of the aquatic environment and the mobility of these users increases. Therefore, it is in the best interest of all users of the aquatic environment to expand the oversight of practices that can result in the introduction of exotics into Rhode Island waters. The following recommendations will provide a better base of operations to reduce the risk of introductions of new aquatic nuisance species:

- A standard protocol of evaluating and permitting the movement of shellfish and all other aquatic species into and within the state when being moved for fishery management purposes, such that both aquaculturists and fisheries managers are held to the same standard,
- Increase the oversight and authority of the Biosecurity Board to include all restoration and importation activities.
- Initiate a educational campaign to raise public awareness of ANS issues in Rhode Island, and
- Curtail intentional introductions by utilizing a strategy similar to that recommended by the International Council for the Exploration of the Seas.

As found on the CRMC ANS Plan

http://www.crmc.state.ri.us/projects/projectfiles/RIAIS_Plan_Draft.pdf aquatic nuisance species (ANS) are a group of organisms described as “nonindigenous species that threaten the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on such waters. ANS include nonindigenous species that may occur in inland, estuarine and marine waters and that presently or potentially threaten ecological processes and natural resources. In addition to adversely affecting activities dependant on waters of the United States, ANS adversely affect individuals, including health effects.” To refine the definition, “nonindigenous species (NIS) are any species or other viable biological material that enters an ecosystem beyond its historic range, including any such organism transferred from one country into another. Nonindigenous species include both exotics and transplants. Synonyms for NIS include *introduced, foreign, exotic, alien, non-native, immigrant* and *transplants.*”

Not all nonindigenous species are considered nuisance species although it is inevitable that any new species introduced into an ecosystem will have some level of impact on that system. In many instances, our level of knowledge regarding the minutiae of ecosystem operations precludes determining the impact an introduced species may play on native species. Whereas those introduced organisms identified as nuisance species have easily observed and measured ecological effects that may affect a variety of general classes of adverse consequences, including environmental, economic and public health issues (Table 1). It should be noted that, in some instances, the introduced species might contribute to a positive benefit to one or more of the general classes of consequences. For example, the introduction of the Japanese oyster (*Crassostrea gigas*) on the west coast of

Table 1 provides a list of the three classes of adverse impacts caused by aquatic nuisance species (From: <http://www.anstaskforce.gov/ans.php>):

Types of Aquatic-Nuisance-Species Impacts

Environmental Effects	Economic Impacts	Public Health
Predation	Industrial Water Users	Human Disease Risk
Parasitism	Municipal Water Supplies	e.g. cholera
Competition	Nuclear Power Plants	
Introduction of new pathogens	Commercial Fisheries	
Genetic	Recreational Fishing	
Habitat Alterations	Other Water Sports	

the US as well as in Europe in the late 1800's has resulted in significant economic benefit to the shellfish industries in those areas (Davies et al., 2007). For the sake of this document, we will confine our discussion to identifying, preventing and/or managing the potential deleterious effects of the introduction of an exotic species.

Exotic organisms can be accidentally introduced into a new environment via a variety of mechanisms. In surveying the current published materials about aquatic nuisance species, the predominant mechanisms by which new species are unintentionally introduced include transport during ship ballast water uptake and discharge, species attached to the hulls of ships as they traverse the oceans, unintentional introductions as species are contained in materials moved from site to site by commercial transport, aquaculture and the aquarium trade, and movement of materials as a component of tourism and recreational activities. In addition, there are numerous records of intentional introductions of exotic species for either economic or biological gain. For example, the U.S. Bureau of Commercial Fisheries (now NOAA Fisheries) intentionally introduced the European flat oyster (*Ostrea edulis*) into the waters of New England (Boothbay Harbor, ME) in 1949 in response to a lack of soft shell clams for harvest (Loosanoff 1955). It has since expanded its range from Nova Scotia through to Rhode Island.

Of late, the aquaculture industry has been severely criticized as a major player in the movement and introduction of aquatic nuisance species. For example, in 1993 the U.S. Office of Technology Assessment stated “unintentional introductions are currently one of the largest problems associated with aquaculture activities and warrant caution on the part of regulatory agencies and the fishing industries alike” (as cited in DeFur and Radar 1995). Naylor *et al.* (2001) focused an entire Policy Forum editorial in *Science* (a premier publication for research scientists), entitled *Aquaculture – a gateway for exotic species*, where the authors warned that the aquaculture industry was a “leading vector of aquatic invasive species worldwide”. Based on their evaluation of aquaculture as a significant contributor to the ANS problem and on their judgment that “local and state regulations are inadequate”, the authors argued that “a clear policy on exotic introductions is needed as aquaculture expands – one that includes scientific risk assessment for all nonnative introductions and single-agency oversight for the prevention, containment and monitoring of potentially harmful exotics.”

Before delving into the world of prediction, prevention and/or management of ANS as they relate to aquaculture activities in Rhode Island, I would like to explore more deeply the role that aquaculture, more specifically shellfish aquaculture, has historically played in the movement of ANS in the United States. For this information lends considerable light on the current risks of ANS introductions in Rhode Island and other regions where shellfish aquaculture is conducted. Jim Carlton published a manuscript in 1992 that provided an end of the 20th century perspective on mollusk introductions in North America (Carlton 1992). Within that document, Carlton summarizes our current state of knowledge regarding 36 different nonindigenous species of mollusks that have been successfully introduced in North American waters. Of those 36, 16 species are North American species that had been moved to new locales within the continent while 20 were introductions from Europe or the Far East. Regionally, 30 species were introduced to the Pacific Coast, 8 to the Atlantic Coast, and 1 to the Gulf Coast. An interesting observation about these introductions and one that is never mentioned when discussing the risk of ANS introductions from aquaculture activities is the timeline of these introductions. Table 2 provides a summary of the information included in Carlton’s work. Of the 46 species listed by Carlton, 23 were the direct result of fisheries and/or aquaculture activities while another 6 were intentionally introduced, presumably for fisheries and/or aquaculture reasons. The remaining introductions were the result of commercial and recreational transport processes. The obvious conclusion is that fisheries and aquaculture has contributed 50% to known exotic mollusk introductions in North America and therefore is currently a high risk for continued introductions.

However if one notes the timeline of introductions via fisheries and aquaculture, it is important to be aware that the bulk of the introductions occurred during a period of high intensity movement of oysters from both the Pacific rim and the Atlantic to the Pacific coast of North America, during an interval of the 1870’s to 1930’s. With the exception of an accidental introduction to the Pacific in 1981 (the Takinoshima shipworm that was actually introduced via wooden boxes that oysters were shipped in), the last documented introduction of an aquatic mollusk via fisheries and/or aquaculture activities was the European ovatella to the Pacific coast in 1965. This is compared to the more recent introductions, such as the zebra mussel in 1992 and the brown mussel in 1990, which were introduced via commercial ship traffic, either as fouling attached to the hull or in the ballast water. Why is this so?

Two oyster diseases have decimated eastern oyster populations throughout the Atlantic coast of

North America. Dermo, caused by the protistan *Perkinsus marinus*, and MSX, caused by the protistan *Haplosporidium nelsonii*, have taken a heavy toll on commercial oyster fisheries and aquaculture since first discovered, dermo in the 1940's in the Gulf of Mexico and MSX in the 1950's in Delaware Bay. Since their discovery, both diseases have been spread across the Atlantic range of North America, presumably by way of the practice of moving juvenile and adult oysters associated with fisheries and aquaculture management. As our level of understanding regarding shellfish disease processes began to coalesce through the 1970's and 1980's, it clearly became evident that the mass movement of juvenile and adult oyster stocks was a primary mechanism for spreading oyster diseases and one that could be curtailed through effective regulatory oversight. This new knowledge resulted in the implementation of increasingly stringent control of shellfish movements, due to disease considerations.

By carefully controlling the movement of juvenile and adult shellfish for disease purposes, to the point where most shellfish can only be moved from site to site, even within a single state, as post-set spat directly from the hatchery or as seed certified as having no known shellfish diseases, state regulations since the 1980's have indirectly but significantly reduced the hazard of moving unwanted ancillary organisms with the shellfish seed. Therefore, shellfish aquaculture presents an extremely small risk for the introduction of aquatic nuisance species in Rhode Island waters at the present time.

Local policy development for aquatic nuisance species falls under the auspices of the Northeast ANS Panel, a component of the Aquatic Nuisance Species Task Force. The ANS Task Force is an intergovernmental organization dedicated to preventing and controlling aquatic nuisance species, and implementing the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990. The various NANPCA mandates were expanded later with the passage of the National Invasive Species Act (NISA) in 1996. The Task Force consists of 10 Federal agency representatives and 12 Ex-officio members, and is co-chaired by the U.S. Fish and Wildlife Service and National

Table 2: A summary of the mollusk species introduced into North America (modified from Carlton 1992).

Species	Common name	Location of Introduction	Mechanism	Time of first reported observation
<i>Clanculus ater</i>	top snail	Pacific	Ballast	1964
<i>Cecina manchurica</i>	Manchurian cecina	Pacific	Fisheries/Aquaculture	early 1960's
<i>Littorina littorea</i>	common periwinkle	Atlantic	Ballast/Intentional	pre-1840's
		Pacific	Fisheries/Aquaculture	1968
<i>Tectarius muricatus</i>	beaded periwinkle	Atlantic/Gulf	unknown	1986
<i>Truncatella subcylindrica</i>	looping snail	Atlantic	Ballast	1880
<i>Barillaria attramentaria</i>	Japanese false cerith	Pacific	Fisheries/Aquaculture	1920's
<i>Sabia conica</i>	hoof snail	Pacific	Ballast	1940
<i>Crepidula convexa</i>	convex slipper snail	Pacific	Fisheries/Aquaculture	1898
<i>Crepidula fornicata</i>	Atlantic slipper snail	Pacific	Fisheries/Aquaculture	1898
<i>Crepidula plana</i>	white slipper snail	Pacific	Fisheries/Aquaculture	1901
<i>Cerastostoma inornatum</i>	Japanese oyster drill	Pacific	Fisheries/Aquaculture	1924
<i>Urosalpinx cinerea</i>	Atlantic oyster drill	Pacific	Fisheries/Aquaculture	1890
<i>Busycotypicus canaliculata</i>	channeled whelk	Pacific	Fisheries/Aquaculture	1938
<i>Ilyanassa obsoleta</i>	eastern mudsnail	Pacific	Fisheries/Aquaculture	1907
<i>Nassarius fraterculus</i>	Japanese nassa	Pacific	Fisheries/Aquaculture	1959
<i>Ovatella mysotis</i>	European ovatella	Atlantic	Ballast	1851
		Pacific	Fisheries/Aquaculture	1965
<i>Siphonaria pectinata</i>	striped false limpet	Atlantic	Ship fouling	pre-1800's
<i>Mytilus galloprovincialis</i>	European mussel	Pacific	Ship fouling	1880's
<i>Musculista senhousia</i>	Asian date mussel	Pacific	Fisheries/Aquaculture	1941
<i>Geukensia demissa</i>	ribbed mussel	Pacific	Fisheries/Aquaculture	1894
<i>Perna perna</i>	edible brown mussel	Gulf	Ballast	1990
<i>Mytella charruana</i>	charru mussel	Atlantic	Ballast	1986
<i>Patinopectin yessoensis</i>	Japanese sea scallop	Pacific	Intentional	1984
<i>Anomia chinensis</i>	Chinese jingle	Pacific	Fisheries/Aquaculture	1924
<i>Crassostrea gigas</i>	Pacific oyster	Pacific	Fisheries/Aquaculture	1914
<i>Crassostrea virginica</i>	eastern oyster	Pacific	Fisheries/Aquaculture	1917
<i>Ostrea edulis</i>	edible oyster	Atlantic	Intentional	1949
<i>Rangia cuneata</i>	Atlantic rangia	Atlantic	Ballast/Fish./Aquac.	1955
<i>Macoma balthica</i>	Baltic macoma	Pacific	Fisheries/Aquaculture	1800's
<i>Theora lubrica</i>	Asian semele	Pacific	Ballast	1968
<i>Dreissena polymorpha</i>	zebra mussel	Atlantic	Ballast	1992
<i>Mytilopsis leucophaeata</i>	dark false mussel	Atlantic	Ballast	1937
<i>Trapezium liratum</i>	Japanese trapezium	Pacific	Fisheries/Aquaculture	1947
<i>Corbicula fluminea</i>	Asian clam	Pac./Atl.	Intentional	1920's
<i>Venerupis philippinarum</i>	Japanese littleneck	Pacific	Intentional	1936
<i>Gemma gemma</i>	amethyst gem clam	Pacific	Fisheries/Aquaculture	1893
<i>Mercenaria mercenaria</i>	quahog	Pacific	Intentional	1967
<i>Petricola pholadiformis</i>	false angelwing	Pacific	Fisheries/Aquaculture	1927
<i>Mya arenaria</i>	soft shell clams	Pacific	Fisheries/Aquaculture	1911
<i>Pommocorbula amurensis</i>	Amur River corbula	Pacific	Ballast	1986
<i>Lyrodus pedicellatus</i>	blacktip shipworm	Pacific	Ship fouling	1871
<i>Lyrodus takanoshimensis</i>	Takanoshima shipworm	Pacific	Fisheries/Aquaculture	1981
<i>Teredo barrschii</i>	Barusch shipworm	Atlantic	Ship fouling	1971
<i>Teredo novalis</i>	naval shipworm	Pacific	Ship fouling	1913
<i>Teredo furcifera</i>	deep cleft shipworm	Atlantic	Ship fouling	1974
<i>Laturnula limicola</i>		Pacific	Ballast	1963

Oceanic and Atmospheric Administration. The Task force coordinates governmental efforts dealing with ANS in the U.S. with those of the private sector and other North American interests via regional panels and issue specific committees and work groups.

The ANS Task Force encourages state and interstate planning entities to develop management plans describing detection and monitoring efforts of aquatic nuisance species, prevention efforts to stop their introduction and spread, and control efforts to reduce their impacts. Management plan approval by the Aquatic Nuisance Species Task Force is required to obtain funding under Section 1204 of the Aquatic Nuisance Species Prevention and Control Act. Regardless of financial incentives, plans are a valuable and effective tool for identifying and addressing ANS problems and concerns in a climate of many jurisdictions and other interested entities. Rhode Island has recently developed a State ANS Management Plan, following guidelines published by the National Task Force (<http://www.anstaskforce.gov/stateplans.php>). In RI, The CRMC has taken the lead in the development of the RI plan and Kevin Cote (RI-CRMC) oversees the process. The RI Aquatic Invasive Species Management Plan was approved at the state level this fall and has been sent along for federal approval as of 28 September 2007 (http://www.anstaskforce.gov/State%20Plans/RI_SMP_Draft.pdf).

In the RI state management plan, there are currently guidelines or practices being implemented to protect state natural resources for ANS invasions. Protection of natural and important aquatic resources comes in the form of prevention, eradication and management. Eradication has only been successful in a very small subset of nuisance species introductions and cannot realistically be considered an option for dealing with ANS introductions in Rhode Island. Therefore, the effort that should be expended needs to focus on prevention followed by management in the event that prevention wasn't successful.

The current mechanism for the control of the movement of juvenile and adult shellfish is a state-managed effort at both the interstate and intrastate levels. In Rhode Island, there currently are two management agencies that oversee shellfish movement (with potential hitchhikers), depending on the fate of the seed. Shellfish and other species being moved for aquaculture purposes are overseen by the RI Coastal Resources Management Council's Aquaculture Coordinator, in consultation with the Biosecurity Advisory Board – an advisory board established to review proposed aquatic species movements into and out of Rhode Island. Farmed shellfish can only be moved into and around the state with permission of the CRMC. A process dictated through the state receiving the seed regulates shellfish seed being exported from RI.

With shellfish and other species being moved for fisheries management purposes, the process of control within RI is less well defined. To my knowledge, there is no formal process for requesting permission to move aquatic species within the RI Department of Environmental Management's Marine Fisheries Section. In surveying and searching the RI governmental websites, The Northeast ANS Panel only found well-presented regulations describing the process to move aquaculture shellfish in RI (see Appendix 1; <http://www.northeastans.org/docs/ri-laws.pdf>) but no equivalent descriptions for non-aquaculture marine aquatic species movements.

Recommendation: RIDEM should establish a formal process, including better use of the RI Biosecurity Board, for permitting the movement of aquatic species (for restoration or enhancement) within state waters as soon as possible.

Prevention of introductions, over and above the regulatory tools listed above, falls on all users of the aquatic environment. Anyone can introduce a nuisance species in local waters, from the shellfish farmer to the 8 year-old child tired of their saltwater aquarium! On the other hand, in those instances where an ANS is introduced at a location outside of state boundaries, the chances of actually preventing range expansion across the state line is unrealistic.

Recommendation: Rhode Island should continue participation in the region-wide Northeast ANS Panel, to ensure that regulations and management of ANS introductions are uniform throughout the region and that all states are in compliance with whatever strategies are in place.

See: http://www.crmc.state.ri.us/projects/projectfiles/RIAIS_Plan_Draft.pdf

Recommendation: Rhode Island should undertake an aggressive outreach and education program to teach the general public about the risks associated with the introductions of exotic species.

One strategy that has been adopted for preventing the spread of ANS and judged as relatively successful is the use of a HACCP-type of effort (Gunderson & Kinnunen, 2004). Hazard Analysis Critical Control Point (HACCP) management came from the food handling industry where food-processing methods were analyzed to determine the level of risk associated with each step in the handling process. At those stages where there is a real risk to introduce a human health hazard, methods are designed and implemented to monitor and control the critical control point such that the hazard is not manifested. This HACCP analysis and management strategy has been targeted to the baitfish industry in the mid-west to protect receiving waters from the inadvertent introduction of nuisance species from baitfish aquaculture operations. While not directly transferable from baitfish distribution to shellfish distribution, the strategy may have some useful components for application. In the event that an ANS control program may be needed in Rhode Island, this would be an interesting model to pursue. For more information, please visit <http://www.haccp-nrm.org/>.

Once an ANS has been established within RI waters, the management of the impact of the species on aquatic farmers currently lies within the responsibilities of the farmer. There currently are a number of ANS that have been introduced in the northeast that cause severe economic impacts on shellfish farmers, including those listed in Table 3. Traditional methods to control nuisance species include mechanical cleaning, air/sun drying, brine/freshwater treatment, biological control, and antifouling coatings. Research is currently being conducted on a number of these species to determine best methods to control and mitigate their impacts. As this information is forthcoming, it is dispersed to the local shellfish farmers through an active outreach program. The same process needs to be expanded to restoration and wild fisheries programs as well. In addition, Rhode Island growers are in constant communication with each other as well as other participants in the industry throughout the U.S. Significant information is transferred between growers as they share strategies and information to optimize their growing methods.

Table 3: a list of some common aquatic nuisance species that are impacting shellfish farmers in RI as either active predators or fouling organisms (not including pathogens).

<u>Species name</u>	<u>common name</u>
Coelenterate	
<i>Diadumene lineata</i>	orange-striped anemone
Bryozoa	
<i>Membranipora membranacea</i>	lacy crust bryozoan
Mollusks	
<i>Urosalpinx cinerea</i>	oyster drill
Crustaceans	
<i>Carcinus maenas</i>	Green crab
<i>Hemigrapsus sanguineus</i>	Asian shore crab
<i>??Eriocheir sinensis</i>	Chinese mitten crab??
Hemichordata	
<i>Styella clava</i>	club tunicate
<i>Botryllus schlosseri</i>	star tunicate
<i>Botrylloides violaceus</i>	orange sheath tunicate
<i>Didemnum</i> spp.	pancake batter tunicate
Algae	
<i>Codium tomentosoides</i>	oyster catcher
<i>Grateloupia turuturu</i>	red algae

In some instances, there have been proposals to intentionally introduce exotic aquatic animals into specific ecosystems for a variety of reasons, including economics, biological control of other exotic species, and etc. For example, there is a current proposal pending to introduce the Asian oyster (*Crassostrea ariakensis*) into Chesapeake Bay (Maryland and Virginia) to replace a native oyster (*Crassostrea virginica*) population that has been decimated by the diseases MSX and dermo and other stressors. Normally, these proposed introductions are subjected to an extensive review process to assess the associated benefits and risks of such an introduction before a decision is made. The most common process for evaluating intentional introductions, and one that is being used to evaluate the *C. ariakensis* introduction, has been developed by the International Council for the Exploration of the Seas (ICES), namely the ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2004. This document gives recommended procedures and practices to reduce the risks of detrimental effects from the intentional introduction and transfer of marine (including brackish water) organisms. The Code is aimed at a broad audience since it applies to both public (commercial and governmental) and private (including scientific) interests. In short, any persons engaged in activities that could lead to the intentional or accidental release of exotic species should be aware of the

procedures covered by the Code of Practice (<http://www.ices.dk/reports/general/2004/ICESCOP2004.pdf>). There currently is not a realistic expectation or need for local shellfish farmers to propose the introduction of an exotic species. While it is not necessary for RI shellfish farmers to propose the introduction of an exotic species, they have a vested interest in protecting the environment within which they conduct their business. Therefore, it is in the best interest of all coastal users to carefully evaluate any proposed introductions of exotic species.

Recommendation: Rhode Island should utilize the guidelines provided by the ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2004 if intentional introductions are proposed in the state.

In conclusion, aquatic nuisance species are a problem for all users of the coastal environment, in that they can be detrimental to native ecosystems. Aquatic farmers in Rhode Island are acutely aware of the impacts of nuisance species and have much to lose when new species get introduced into state waters. Therefore, an aggressive program to prevent the introduction of exotic species is a necessary component to the management of our marine resources.

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Appendix 1: Summary of Rhode Island ANS Laws

(retrieved from: <http://www.northeastans.org/docs/ri-laws.pdf>)

RI statutes: <http://www.rilin.state.ri.us/scripts/search/search.asp>

RI statutes: Introduction & Possession of Fish and Other Animals:

- 1) Stocking of streams and ponds: No one shall stock or liberate into any Rhode Island fresh water pond or stream any fish species without a DEM permit. R.I. Gen. Laws § 20-11-6 (2003).
- 2) Penalties: Any person who violates §§ 20-11-6 or 20-11-10 shall be guilty of a violation. The penalty for each violation is a \$100 fine. R.I. Gen. Laws § 20-11-20 (2003).

Control of Invasive Plants:

- 1) Injurious substances: With a DEM permit and under DEM regulations, a person may use certain chemicals to eradicate plants and to control fish populations. R.I. Gen. Laws § 20-11-10 (2003).

Fish Propagation and Aquaculture:

- 1) Procedures for Approval [to Conduct Aquaculture]: Upon submission of a permit to conduct aquaculture to the CRMC, the director of the Department of Environmental Management (DEM) shall determine, *inter alia*, if the proposed aquaculture activities are likely to adversely affect the vitality of Rhode Island's native fisheries. R.I. Gen. Laws §20-10-5 (2003).
- 2) Permits and Licenses for the Taking, Possession, Sale, Importation, and Transportation of Species Used in Aquaculture: The DEM director has the authority to grant permits and licenses regarding the possession, taking, importation, sale, and transportation of aquaculture plants and animals. The director may issue regulations regarding the same. R.I. Gen. Laws § 20-10-12(a) (2003).
- 3) Permits and Licenses for the Taking, Possession, Sale, Importation, and Transportation of Species Used in Aquaculture: Anyone who possesses, takes, imports, sells, or transports aquaculture plants or animals without a permit is guilty of a misdemeanor. The person may be imprisoned for a maximum of one year, or fined a maximum of \$500, or both. R.I. Gen. Laws § 20-10-12(b) (2003).
- 4) Introduction of non-indigenous species is prohibited unless protocols are in place to ensure that no accidental releases into the state's waters can occur. These protocols will be reviewed by the CRMC Bio-Security Board before any permit is issued. Any proposed modifications to the permitted operation will be reviewed by the Bio-Security Board before an assent modification can be issued. The issuance of a permit under these stipulations can be revoked if a release of non-indigenous species takes place during the term of the assent. (RI-CRMC Program Section 300.11 – Aquaculture regulations)

Appendix 2: the newest threat to shellfish farmers in Rhode Island.

http://www.crmc.ri.gov/news/2007_0601_mittencrabs.html



Mitten Crab WATCH

How to Identify a Mitten Crab

- Only crab in fresh waters of North America
- Claws equal in size and “hairy” (juveniles may not have “hairy” claws)
- Four lateral carapace spines (last one smaller); notch between eyes
- Carapace up to 4 inches (100mm) wide, light brown to olive green in color



**Adult Shown*

Illustration:
Randall D. Babb, for PWS
Project of U.S. Fish and Wildlife Service
and Bonneville Power Administration

The Mitten Crab

Mitten crabs may pose a serious threat to the freshwater, estuarine and marine ecosystems and economy of the West Coast. First discovered in San Francisco Bay in 1992, they spread to the Sacramento and San Joaquin rivers where massive migrations clog fish screens and hamper water delivery. One mitten crab was found in the Columbia River in 1997. Mitten crab burrows weaken levees and increase bank erosion. They can eat salmon, trout, and sturgeon eggs and may threaten successful spawning. Juvenile crabs also damage rice fields. These crabs can carry the oriental lung fluke, a threat to human health. Native to Asia, mitten crabs live in freshwater but migrate to saltwater to reproduce and are easy to identify because they have hairy claws (other identification traits on back of card). Often, recreational anglers or commercial fishermen are the first to discover the mitten crab because they commonly steal bait from anglers or are caught in commercial nets.

Your help is vital to report new sightings and to prevent their spread.

If you catch a mitten crab,

- Do not throw it back alive!
- Preserve it in rubbing alcohol or freeze it.
- Note the precise location where the crab was found.
- Contact your local natural resource management agency:
In Alaska, call the Fish and Wildlife Service (907- 262-9863);
in British Columbia, call Fisheries and Oceans (604-666-6529);
in Washington, call the WA Department of Fish and Wildlife (360-902-2200); in Oregon, call the OR Invasive Species Hotline (866-468-2337, toll free); in California, call the CA Mitten Crab Hotline (888-321-8913, toll free).

REMINDER: Know the rules!

Mitten crab specimens are needed to confirm sightings, but many jurisdictions have different possession and transport rules. Contact your local natural resources agency for instructions. Never transport live mitten crab.

2001 Pacific States Marine Fisheries Commission

Chapter 4

Physical Impacts of Aquaculture Gear

Perry Raso
Matunuck Oyster Farm

Summary

Properly managed aquaculture operations are a productive use of the coastal zone. Coastal planning is necessary to avoid undesirable ecological impacts resulting from all aspects of coastal development, including aquaculture operations. This section identifies ecological impacts of aquaculture gear and harvesting methods for consideration during the planning of commercial aquaculture operations in Rhode Island.

On-Bottom Structures:

Cages, trays and racks are commonly used grow-out gear for aquaculturists in Rhode Island. These structures, which vary in dimension, are placed directly on the seabed and usually hold sturdy plastic mesh bags containing oysters (see Pillay and Kutty 2005 for further detail regarding these grow-out methods). There are three potential impacts of these sorts of structures; 1) physical modification of water flow or local hydrography, 2) addition of vertical structure and substratum, 3) organic enrichment of local sediment. These impacts can be both positive and negative, usually depending on the intensity and scope of the project.

On-bottom cages, racks and bags used for shellfish grow-out increase species diversity in the vicinity of farms (Kaiser et al. 1998) as new sub-stratum is provided for epibiota to settle and grow. Introduction of structures used for shellfish grow-out also affect local hydrography as most water flows around submerged gear (Boyd and Heasman 1998). Reduced flow through gear can lead to the accumulation of silt and organic matter under and near gear that can result in anoxic patches of seabed.

Norling and Katusky (2007) found the abundance and biomass of associated flora and fauna were higher near mussel beds because mussel biodeposition and nutrient regeneration supplied limiting resources and increased carrying capacity. Species complexity and biodiversity increased and community metabolism in mussel patches depends on mussel biodeposition for 24 to 31% of its energy demand. Mallet et al (2006) found that there was no indication of organic enrichment in the sediment due to cultivation in oyster tables used in Eastern Canada. Macrofauna biomass, abundance and number of species, in areas where oyster tables were maintained, increased or had similar values compared to control sites. A study performed in Rhode Island comparing total organic carbon (TOC) within, near and away from aquaculture leases in Rhode Island showed that TOC levels were not significantly higher in the 16 shellfish grow-out leases sampled (Raso and Rice 2000). In fact TOC levels were higher in locations away from leased areas which is likely due to aquaculturist's selection of sites with a sandier, firmer substrate.

However others have documented negative impacts when deposition rates exceed the assimilation capacity of the local environment. Nugues et al. (1996) investigated environmental changes at an

oyster farm in England and found that the abundance of macrofauna decreased by nearly one half directly beneath grow-out gear, while water currents were significantly reduced through the farm. Sedimentation rates and the organic content of the sediment under the grow-out gear were increased. These changes were confined to the area immediately beneath the grow-out gear. Castel et al (1989) found that densely stocked oysters caused elevated organic carbon levels in local sediments from feces and pseudofeces of shellfish, combined with reduced flow under gear.

At lower stocking densities (which are optimal for increased growth rates) the effects of shellfish grow-out gear on benthic fauna are relatively benign and highly localized (Kaiser et al. 1998). However, these environmental effects are increased as the carrying capacity of the grow-out area is approached (Castel 1989).

Recommendation: Encourage growers and researchers to conduct studies to determine optimal stocking densities to maximize growth and minimize potential negative impacts.

Predator Netting:

Predator netting is used to protect juvenile northern quahogs (*Mercenaria mercenaria*) from gulls, crabs, gastropods and starfish after bottom planting (see Pillay and Kutty 2005 for further detail regarding the use of predator netting). The use of predator netting can lead to an increase in sedimentation and increased organic content of the sediment (Spencer et al. 1997). Sedimentation occurs as netting becomes fouled with algae and hydrographic conditions are altered. The fouling alga on the netting attracts grazers such as littorinid snails and other epifaunal species. Spencer et al. (1997) found that post-harvested sites seemed to be restored after 3 months, however; differences in the benthic community were apparent for 6 months post harvest. An alternative method to predator netting is the use of plastic grow-out bags placed directly on the sediment. This more labor-intensive alternative method of northern quahog grow-out has shown to have no detectable effects on the benthic invertebrate community (Mojica and Nelson 1993). Another method used for grow-out of clam species is adding gravel and shell material to decrease predation on juvenile clams. This method creates a new sediment structure and results in a longer lasting change to the local biota (this method has not been used on a commercial scale in Rhode Island).

Suspended Rope Culture:

Large numbers of blue mussel (*Mytilus edulis*) larvae set on rocks and other substrate in coastal bays and inlets. Frayed rope suspended in the water column is a common and effective method to obtain seed from this abundant source of natural mussel set (see Pillay and Kutty 2005 for further detail regarding rope culture methods).

The complex surface area provided by suspended mussels offer habitat for over 100 different species (Tenore and Gonzalez 1976). A large biomass of cultured mussels and fouling organisms suspended from lines attached to buoys or rafts has a major effect on phytoplanktonic, benthic and hydrographic conditions within the immediate area of cultivation (Kaiser et al. 1998). Suspended rope culture in high current waters does not promote accumulation of pseudofeces that allows for favorable increase in macrofaunal biomass (Rodhouse and Roden 1987) in the vicinity of the culture operation. However, areas with low diversity (usually due to pollution) and decreased flow rates demonstrate organic sedimentation under long lines to be up to two times of that found in adjacent uncultivated areas (Dahlbäck and Gunnarsson 1981).

Bottom Culture:

Broadcast seeding oysters on the seabed for grow-out is a method that is increasing in popularity among aquaculturists in Rhode Island. Field planting the oysters on the seabed reduces costs associated with grow-out of oysters, as increased gear costs and maintenance requirements (labor) are reduced as the oysters mature. Harvest of the bottom planted oysters is carried out via bull raking, the use of SCUBA and, most commonly, dredging.

Direct mortality of non-target species and destruction of habitat from mechanical harvesting techniques (dredging) is well documented. Studies on commercial scale dredging for wild harvested shellfish demonstrates the negative ecological impacts of dredging such as reduced species abundance and numbers as well as prolonged recovery of fauna. While the impacts of dredging for wild harvest shellfish are well documented, the impacts of dredging for seeded oysters on aquaculture leases is not. Wild harvested areas are likely to have an increased abundance of structure and habitat as compared to areas that are permitted for bottom culture in Rhode Island.

In order to assess the impacts of bottom planting and dredging of oysters, the natural productivity of the area prior to seeding must be considered. In Rhode Island, naturally productive areas are not permitted for aquaculture. By seeding these unproductive areas with oysters, structure and habitat is created for commercially important species as well as their prey. Howell et al. (1999) investigated nursery areas of winter flounder in shallow embayments in Connecticut to determine if there are areas that yield higher abundances, he found that winter flounder prefer a shell/mud matrix to any other habitat type. Visel (1988) reporting on the impacts of distributing shell stock on the seabed on populations of wild oysters in Connecticut found that increased shell stock promoted settlement of oysters. In more recent study by DeAlteris et al. (2004) found that higher abundances of winter flounder were found on shellfish gear than nearby eelgrass beds in a coastal pond in southern Rhode Island.

Aquaculturists that bottom seed aquaculture leases in Rhode Island stagger their crop through out the year, therefore only a portion of the leased area is being harvested (dredged) while the majority of the lease area is planted with small seed stock and is not disturbed for months at a time. This seasonal nature of harvesting/dredging for seeded shellfish within permitted aquaculture leases allows for juvenile oysters to mature and also allows for recovery of benthic communities. The amount of time that harvested areas require in order to fully recover depends on the amount of disturbance experienced and the time of year of the disturbance in relation to larval recruitment patterns of non-target species disrupted (Kaiser et al. 1998). There is no doubt that dredging causes some mortality of non-target species. What is not known is whether the habitat improvements created by acres of seed oysters planted on otherwise barren bottom compensates for the localized harvest activities.

The East Coast Shellfish Growers Association (ECSGA) has secured a grant from the United States Department of Commerce to investigate the environmental impacts of dredging seeded shellfish. The results of that study should be incorporated into this section when they are available.

Submerged Aquatic Vegetation (SAV):

Submerged aquatic vegetation (SAV) serves as an important habitat for fish and crabs as well as a food source for waterfowl (Wilkins 1982). Aquaculture gear placed on top of SAV can kill or

exclude growth of SAV, however; the presence of shellfish may promote SAV growth due to increased water quality and improved sediment nutrition (Hershener and Woods 1997). A recent study by Wisheart et al. (2006) investigated the interactions between oyster aquaculture and eelgrass recruitment. The results showed higher eel grass seedling densities in eel grass growing in dredged beds compared to eel grass under long lines or in eel grass beds suggesting that ground culture practices may positively affect eelgrass recruitment.

Recommendation: Maintain the prohibition on leasing areas within established eelgrass meadows.

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Chapter 5

Essential Fish Habitat (EFH) and Aquaculture

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Summary

The effects of aquaculture on EFH are varied and depend upon a number of interacting factors that include the type of species cultured, scale and intensity of operation, features of the physical environment, and culture and harvest methods employed. Careful consideration of these can effectively minimize impacts on EFH that might occur. In order to minimize impacts on EFH, protection of existing spawning and reproductive grounds is necessary. Aquaculture facilities should be limited or restricted in areas where they would be destructive to natural EFH.

Definition of Essential Fish Habitat

As defined by Congress in the Magnuson-Stevens Fishery Conservation and Management Act and reauthorized by the Sustainable Fisheries Act (1996), Essential Fish Habitat (EFH) consists of “those waters and substrate necessary for fish to spawn, breed, forage and grow to maturity” (USDOC, 1997). The term “fish” in this definition includes marine, estuarine, and anadromous finfish, mollusks, and crustaceans. EFH includes all the physical features of the environment to which fish have adapted and are necessary for the long-term survival of populations. Some of these features include temperature, nutrients, and salinity of the water column and substrate such as sand, rocky reefs, or vegetation.

The concept of EFH was adopted with the intention of protecting habitat for those species of fish that are managed through federal law in effort to ensure healthy and sustainable fisheries. The Sustainable Fisheries Act of 1996 requires the eight regional fisheries management councils to describe and identify EFH and activities that may adversely affect fish habitat. An adverse affect is any impact that reduces the quality or quantity of EFH and may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of or injury to benthic organisms, prey species and their habitat, and other ecosystem components. Adverse effects to EFH may result from actions occurring within or outside of EFH and may include site-specific or habitat-wide impacts.

This legislation has enabled federal agencies to assess whether there are any potential impacts on EFH associated with activities in the marine and estuarine environments. One such activity is the operation of aquaculture facilities. Within the United States there is a variety of aquaculture operations that differ depending on the species being raised, the geographical location such as shallow estuaries or coastal waters, types of gear used, and the harvesting practices employed to retrieve the product for market. A variety of effects associated with aquaculture on EFH have been described ranging from harmful to beneficial and are dependent upon the type of operation.

EFH and aquaculture in Rhode Island

In Rhode Island, aquaculture practices are carried out exclusively to raise shellfish with oysters comprising most of the product followed by quahogs (CRMC, 2006). Oysters are typically raised on leases within the shallow estuarine environments of Narragansett Bay and the salt ponds. Oysters are either raised in cages placed on the substratum or directly on bottom sediments within the boundaries of the lease. Once oysters reach market size they are removed from cages or collected by various means.

Farms are maintained within estuarine environments that are important habitat for many species of fish. Approximately 75% of the commercial fish and shellfish species of the United States depend on estuaries at some stage in their life cycles (Chambers, 1992). In Rhode Island, EFH has been identified within coastal estuaries for several species of commercially and recreationally important fish such as winter flounder, black sea bass, scup, bluefish, striped bass and menhaden that typically use these areas as nursery habitat. Features identified as EFH include a broad array of habitats such as sediments composed of sand, mud or covered with shell, hard bottom such as rocks, and submerged aquatic vegetation (SAV) such as eelgrass. With expansion of aquaculture in Rhode Island over recent years, the environmental impacts have become a concern. In particular, whether there are any effects associated with aquaculture on EFH.

The potential for negative effects on habitat associated with aquaculture undoubtedly exist however the intensity and magnitude differ between the types of aquaculture systems, organisms cultivated, and the characteristics of the local environment. The possible effects relevant to fish habitat can be grouped into the following sources; (1) addition of physical structure to the environment (2) addition of organisms and therefore biological activity (3) husbandry activities.

The obvious impact on the local environment is the alteration of habitat associated with the addition of gear that essentially converts a sediment type habitat into one with structure. Structural features are well known to harbor greater densities and diversity of fish compared with featureless substrate (Orth et al., 1984). With the addition of aquaculture gear species that prefer sandy or mud substrate would be replaced by species that prefer structure. Tallman and Forrester (2007) and Dealteris et al. (2004) both concluded that oyster grow-out cages serve as quality habitat for species of fish that typically associate with hard bottom habitat. Dealteris et al. (2004) demonstrated that oyster cages harbored significantly greater abundances and diversity of species than shallow non-vegetated seabed. Likewise, Tallman and Forrester (2007) showed that equal or greater densities of species such as scup and black sea bass were found near oyster grow-out cages than natural rock reefs. Whether the gear results in the production of additional fish biomass or the concentration of existing biomass depends on the factors that limit local fish abundance.

Conversely, species associated with substrate composed of sediments could be displaced by aquaculture gear or activities associated with the operation. It is well documented that winter flounder utilize sediments within shallow estuarine environments during all life stages including eggs which are found clung to algal mats or firm bottom (Howell et. al, 1999; Crawford, 1990). Specific sites that serve as persistent spawning habitat year after year have been identified within Point Judith Pond (Crawford and Carey, 1985). One such area consisted of a submerged gravel bar located in the north end of the pond. Placement of aquaculture farms in such locations could

conceivably reduce the availability of suitable habitat for egg production. Howell et al. (1999) found a correlation between abundance of young of the year winter flounder and sediment type with no consistent pattern with other environmental variables. Thus, it appears that juvenile winter flounder have strong associations with particular types of substratum and any alterations could affect habitat suitability.

Recommendation: Maintain the policy of not leasing of known spawning areas and protected essential fish habitats such as established eelgrass beds.

There is no documented evidence in the literature indicating that oyster grow out cages serve as suitable habitat for winter flounder. However, an association with oyster beds has been suggested (Castonguay and Visel, 1988). Based on anecdotal accounts from several individuals, Castonguay and Visel (1988) reported that high abundances of winter flounder have been observed to occur on natural and cultivated oyster beds. Farms where oysters are cultivated directly on substratum could potentially serve as suitable habitat, however methods used to retrieve the oysters such as dredging could counteract the benefits.

Of considerable concern regarding environmental impacts of aquaculture is the potential for hypoxic or anoxic conditions to develop as a result of decaying organic material such as feces, pseudofeces, and feed that accumulates around sites. Low oxygen conditions would compromise the water quality necessary for many species of fish to survive and effectively decrease the availability of suitable habitat. Concomitant with depletion of oxygen levels are changes in community structure to species tolerant of these conditions. Not all aquaculture operations have such an effect on the local environment and whether these conditions develop and the severity of the impact associated with the organic load introduced is dependent upon several factors including the type of species cultured, the scale of culture, physical conditions and culture method.

Most studies examining organic enrichment associated with aquaculture have concluded that the effects from finfish aquaculture are more pronounced than that caused by shellfish culture (Crawford et al., 2003). The key difference is the addition of an external food source for finfish which when unconsumed collects underneath pens, whereas food is readily available in the water column for shellfish. Studies measuring the effects of organic enrichment of sediments around shellfish aquaculture sites have produced varying results ranging from no evidence of increased organic content (Bastien-Daigle et al., 2007; Crawford et al., 2003; Mallet et al., 2006) to the production of extensive bacterial mats, oxygen depletion and shifts in the benthic community to opportunistic species tolerant of low oxygen (Barranguet et al., 1994; Mattsson and Linden, 1983; Dahlback and Gunnarson, 1981).

The scale or intensity of aquaculture operations appears to be a significant causal factor as to the extent of organic enrichment. In Sweden and South Africa severe impacts from organic enrichment associated with the culture of mussels were observed at farms with an annual production of 24 kg m⁻² and 175 kg m⁻², respectively (Dahlback and Gunnarson, 1981; Stenton-Dozey et al., 2001). In comparison, at sites with no observable impacts on benthic sediment chemistry produced annually 3 kg m⁻² of mussels in Prince Edward Island (Canada), 0.8 kg m⁻² of oysters in northern New Brunswick, and 8 kg m⁻² of oysters in St. Simon Bay, New Brunswick (Mallet et al., 2006). In Rhode Island the estimates range from 3-5 t/acre = 0.67-1.12 kg/m²

Accumulation of organic matter in the vicinity of aquaculture sites is regulated in part by the physical features of the area. Water flow directly affects the transport and erosion of biodeposits (Widdows et al., 1998). Areas that are shallow with slow currents are more likely to experience problems associated with eutrophication, as organic matter will accumulate under the equipment (Mattson and Linden, 1983). Conversely, strong currents and deep water will facilitate the dispersal of biodeposits to other areas. Chamberlain et al. (2001) attributed differences in the levels of organic enrichment to differences in current patterns between sites within an estuary located in Ireland. Other factors such as the frequency of storm generated wind and waves can act to re-suspend and redistribute organic material from the sediments, further mitigating the affects of organic enrichment.

Recommendation: Encourage growers, researchers and regulators to monitor sediments for excessive organic enrichment and possible impacts on water column oxygen concentrations.

The types of equipment used and the techniques employed in aquaculture also contribute to the amount of organic matter accumulating near farms. Finfish are typically raised in large pens that are anchored to the substratum but able to float and move with the tides. In the culture of shellfish there are a variety of techniques and equipment that can be classified as either suspended, off-bottom, or bottom culture (Bastien-Dagle et al., 2007). Suspended culture is conducted in the water column or at the surface where the structures which are typically bags, ropes, trays or cages suspended from longlines, are anchored but free to float or move with the tides. With off-bottom culture the equipment consisting of bags, tables, or trestles are fixed in place on the substrate and do not move with the tides, whereas bottom culture is conducted directly on or in the substrate. Structures provide a complex surface area on which epifauna and algal communities can develop. Accumulation of these organisms and algae on the substratum when they die can further increase levels of organic enrichment and elevate the demand for oxygen. The method and types of gear used therefore differ in the amount of structure available to other organisms and consequently the levels of organic matter introduced. For example, Murray et al. (2007) observed significantly greater macrofaunal densities associated with rope-grown mussels compared with mussels cultured on the substratum. The practices employed while harvesting the cultured product will also determine the amount of organic material introduced, i.e. whether nets and gear are cleaned of biofouling organisms on vessels or on land, and then transferred to landfills.

It has been suggested that water quality within estuarine systems could be improved by increasing the abundance of shellfish. This hypothesis is based on the supposition that shellfish could remove a significant fraction of particulate bound nutrients from the water column through filter feeding, thereby mitigating the effects of eutrophication. Using an empirical model, Haamer (1996) estimated that mussel farms covering 1% - 2.4% of a Swedish fjord could reduce dissolved inorganic nitrogen concentrations in the surface water by 20% and lower biological oxygen demand in the deep basin waters by 26%. An increase in oyster biomass in the Chesapeake Bay was projected to reduce chlorophyll, increase deep-water dissolved oxygen, increase biomass of submerged aquatic vegetation, and remove nitrogen (Cerco and Noel, 2007). Oyster restoration was not suggested as a solution to eutrophication but was recommended as one of many small steps that can help address the problem.

Submerged aquatic vegetation (SAV) such as eelgrass has been identified as EFH for numerous species of finfish and its importance as nursery habitat within shallow estuaries is well documented. In addition to its value as a refuge for juvenile fish, SAV is paramount in the cycling of nutrients, acts to reduce turbidity by trapping particles suspended in the water column, and acts to stabilize the substratum mitigating erosion (Caffrey and Kemp, 1990; Ward et al., 1984). Over several decades, eelgrass beds along the U.S. Atlantic Coast have been declining for many reasons such as disease, eutrophication, and removal associated with shoreline development, boat anchors, and moorings (Orth et al., 2006). Because of its importance in maintaining ecosystem integrity numerous restoration programs have been implemented with modest success. The value of transplanted eelgrass beds as adequate habitat is suspect and may not provide the same benefits as natural meadows. Therefore the protection of existing SAV is a high priority for environmental agencies.

Since many aquaculture operations (in other states) are sited in the same locations as SAV their impact has been investigated. For obvious reasons placement of gear directly on SAV results in damage to the vegetation through direct impact from the gear. Operations that are suspended above SAV have also been shown to have a negative impact on SAV. Rumrill and Poulton (2004) examined the spatial cover of eelgrass and shoot densities underneath suspended oyster lines and found a positive correlation with the spacing between lines. Other studies have suggested that introducing shellfish could benefit SAV. Through the removal of phytoplankton and suspended inorganic particles from the water column by means of filter feeding, bivalves maintain water clarity providing sufficient light for photosynthesis (Porter et. al, 2004). Declines in oyster abundance within Chesapeake Bay contributed in part to the decline in eelgrass because of the loss of this filtering process (Newell and Koch, 2004). Cerco and Noel (2007) incorporated an oyster module into a model used to examine eutrophication issues in Chesapeake Bay to demonstrate an increase in SAV abundance with an increase in oyster abundance. An example of this link between bivalves and SAV occurred in the tributaries of the Potomac River. Dramatic increases in the abundance of non-native Asiatic clams, *Corbicula fluminea*, during the early 1980's sufficiently reduced turbidity and increased light penetration allowing SAV to become reestablished (Cohen et al. 1984).

In summary, there are many possible effects of aquaculture on EFH, which depend upon a number of interacting physical factors which need careful consideration in order to minimize detrimental impacts on EFH. In regards to aquaculture in Rhode Island, there are currently no marine finfish aquaculture farms being operated, however due to the greater potential of environmental impact all of the issues should be carefully considered if the interest of such an operation ever arises in the future. The impacts on EFH due to the aquaculture of shellfish have been shown to be quite variable but if conducted properly can have little or no negative effect on the surrounding environment and could possibly be beneficial. **In order to minimize negative impacts on EFH recommendations include the protection of existing beds of eelgrass.** Aquaculture facilities should be limited or restricted in areas where they would be replacing or deterring natural eelgrass beds from growing. Sites should be selected in areas with adequate water flow to alleviate the effects of biodeposition. **Given the current status of local populations, demersal nature of their eggs and evidence for spawning site fidelity winter flounder spawning and nursery habitats should be protected.** And lastly, in the planning and development of aquaculture on a system wide level, consideration of the overall magnitude or scale of operations to is necessary to address large scale effects on EFH.

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Chapter 6 Carrying Capacity

Robert B. Rheault
Moonstone Oysters

The term “carrying capacity” has been used with varying definitions to describe the quantity of something that can be added to an ecosystem before some undesirable impact occurs. Small-scale shellfish aquaculture has been shown to have ecological benefits, but at some point too much of a good thing invariably has negative consequences. Where to draw that line can be a subjective question that depends on which specific consequences are of concern.

In the simplest of terms carrying capacity is determined by the amount of shellfish in a given body of water in relation to the flushing or exchange rate of the water in that basin. When the combined filtration capacity of a population of shellfish consumes an excessive proportion of the phytoplankton in that system before tidal flushing (and the natural reproduction of the phytoplankton in that system) can replenish that plankton, then the shellfish start to dominate the energy flow in that system (Dame and Prins 1998).

When a basin has large populations of filter feeding shellfish and small tidal flux (a long residence time), then the shellfish can dominate the energy flow of the system at the expense of zooplankton (and the fish that feed on the zooplankton). Deep basins with a small tidal flux will have a longer residence time and will not be able to support large shellfish populations. Conversely, shallow basins with relatively large tidal amplitude will be able to support much larger shellfish populations. Higher nutrient levels and moderate water temperatures will speed up the reproduction rate of the phytoplankton and such systems will support more secondary consumers (both shellfish and zooplankton) (Small and Prins 1993).

Dame (1996) compared eleven different water bodies around the world with differing circulation patterns and shellfish populations. For example Narragansett Bay was described as a “well balanced estuary” where 30% of the primary production was consumed by shellfish. Dame estimated that the population of clams in the Bay was capable of filtering the entire volume of the Bay in 25 days. The estimated residence time of the Bay was estimated at 27 days.

The question for resource managers becomes: What is the appropriate proportion of an ecosystem’s primary production that should go to shellfish as opposed to zooplankton? There is no simple objective answer to this question. When the biomass of shellfish are able to clear the volume of a basin faster than the water is replenished by tidal action there is the possibility that the shellfish will regulate the concentration and character of the primary production at the expense of the planktonic food web (Dame 1996).

A number of different carrying capacity definitions have evolved and it is important to define these terms before we can discuss the issue in depth.

Definitions: (from Inglis et al. (2000))

- i) **physical carrying capacity** — the total area of marine farms that can be accommodated in the available physical space.
- ii) **ecosystem carrying capacity** - maximum standing stock that can be supported by a given ecosystem for a given period of time (sometimes referred to as assimilative capacity) (Kuiper)
- iii) **production carrying capacity** — the stocking density of bivalves at which harvests are maximized. The “optimized” level of production of the target species. (review by Kaiser and Beadman (2002)) Well-developed models, many good examples.
- iv) **ecological carrying capacity** — the stocking or farm density above which unacceptable ecological impacts begin to manifest. From a practical standpoint this process begins with the definition of components of interest (e.g., species or habitats) and acceptable levels of change for each of these (McKindsey et al. 2006b). (no activity is without some level of impact) Also consider positive ecosystem impacts. Few well developed models or examples where this approach has been employed.
- v) **social carrying capacity** — the level of farm development that causes unacceptable social impacts.

Introduction:

There has been a great deal of speculation about potential environmental impacts of shellfish aquaculture. Intensive shellfish aquaculture has been implicated in altered nutrient dynamics, changes in phytoplankton populations and energy flows as well as enhanced sedimentation and benthic organic content (review by Cranford et al. 2003).

The feeding activity of bivalve filter feeders results in the packaging of fine suspended material into larger feces and pseudofeces that rapidly settle to the seabed. These activities divert primary production and energy flow from planktonic to benthic food webs (Cranford et al. 2003). Dense bivalve populations (either natural or cultured) may exert a strong influence on suspended particulate matter in some coastal systems through their combined capacity to clear particles from the surrounding water (Dame 1996). Bivalve aquaculture has the potential to alter energy flow at the coastal ecosystem scale, however these sorts of impacts are seldom observed except in extreme cases of intensive bivalve cultivation over large areas (Cranford et al. 2003).

The consumption and deposition of suspended particulate matter by bivalves, as well as the excretion of dissolved nutrients, can play a significant role in controlling the amounts and forms of nitrogen in coastal systems and the rate of nitrogen cycling (reviewed by Dame 1996). The transformation and translocation of nutrients and organic matter by bivalves can exert a controlling influence on nitrogen concentrations in some coastal regions (Dame et al. 1991) and may provide a means of retaining nutrients in coastal areas, where nutrients are recycled within detrital food chains, rather than being more rapidly exported (Jordan and Valiela 1982). Benthic nutrient mineralization can increase at culture sites as a result of the increased organic matter sedimentation, speeding up the rate of nitrogen cycling (Dahlback and Gunnarsson 1981; Kaspar et al. 1985; Grant et al. 1995). These processes can also increase the rate of denitrification (Newell et al. 2002) resulting in lowered nitrogen concentrations. The ammonia excreted from dense bivalve populations may have a significant effect on phytoplankton production (Dame 1996). Bivalve aquaculture may also result in significant nutrient export from coastal systems, as nutrients stored in the cultured biomass are

harvested and the nutrients are no longer available to the marine food web (Kaspar et al. 1985).

While all of these impacts on nutrient dynamics have been described as potential impacts, the actual impacts of intensive bivalve culture on coastal nutrient dynamics are poorly understood and difficult to predict. Increasingly, scientists have resorted to numerical modeling of carrying capacity in an attempt to quantify the relationship between different levels of shellfish farming and its environmental effects. Models vary greatly in complexity from simple ratios of flushing rates to filtration clearance rates to simplified 2-D box models and more complex 3-D finite element models with hydrodynamics driving the model, sometimes incorporating complex feedback loops.

Some of the factors that need consideration in the more complex models include

- hydrodynamics (tides, currents, stratification)
- sunlight
- internal sources and sinks (phytoplankton, detritus pool, sediments)
- Food supply and ingestion rates: phytoplankton, detritus, carbon
- Available nutrients (N, P, Si) atmospheric and anthropogenic inputs
- Feedback mechanisms – remineralization, accelerated nutrient cycling
- Competition between cultured stock and wild stock and/or zooplankton
- Population dynamics – growth rates, seasonal changes in rates
- Culture methods, species,

Review of ecological carrying capacity (excerpted from McKindsey et al. 2006)

Increasing evidence shows that the intensive culture of bivalves may have considerable influences on the benthic environment (Kaiser et al., 1998) as well as the concentration and composition of suspended particles and phytoplankton. To date, most research on the environmental effects of aquaculture has focused on benthic processes as they relate to increased deposition of organic matter (Carroll et al., 2003). This focus on benthic processes also ignores the influence of bivalve culture on water-column processes and the organisms that live in association with the bivalves growing in culture.

Most work to date has concentrated on near-field effects (benthic impacts), as opposed to far-field effects (impacts on nutrient cycling and plankton populations). Far-field effects are rarely discussed except to note “negative” effects, largely ignoring potentially “positive” ones (see, for example, Gibbs, 2004). A more holistic approach is needed to determine the influence of bivalve aquaculture on the environment and the ecological carrying capacity of the environment for bivalve culture.

There is a growing body of evidence showing that, similar to artificial reefs, the abundance of fish and macroinvertebrates associated with shellfish farming is substantially enhanced. (Costa-Pierce and Bridger, 2002; Olin, 2002; Davenport et al., 2003, DeAlteris et al. 2004, Tallman et al. 2007). Tenore and González (1976) found that the three-dimensional physical structure provided by mussel rafts provided habitat and food resources that enhance secondary productivity in this estuary while (Chesney and Iglesias, 1979) documented an increased abundance and productivity of macroinvertebrate and fish species. The production of epibiota (e.g., crabs, starfish) on structures in bivalve aquaculture should also be considered in the context of determining the total productivity associated with bivalve aquaculture. The biomass and diversity of such epibiota may be substantial (Tenore and González, 1976; Carlines, 1993; Kilpatrick, 2002) and contributes considerably to the

total productivity of the site.

At this time, two main classes of research are being advanced to determine the ecological carrying capacity of ecosystems for bivalve culture. The first of these uses the output from spatially explicit hydrodynamic-dependent particle tracking models to predict organic flux to the bottom. A quantitative relationship between organic flux and a benthic community descriptor is developed and then used to predict the influence of different levels of bivalve culture on benthic community structure (Henderson et al., 2001). Management decisions regarding stocking densities can then be made based on predicted environmental outcomes.

There are a number of problems with this approach, not all of which are unique in a bivalve culture context. First, it is rare to have accurate three-dimensional hydrographic models for every site and development of such models can be costly. Second, the resuspension component of deposition models has not yet been fully developed for bivalve aquaculture. Third, there is some controversy over the validity of the commonly used infaunal trophic index (Word, 1979a,b). Other indices may be more appropriate, although these also need to be validated. Fourth, the model has yet to be fully validated so under certain environmental regimes.

Furthermore, models developed for suspended culture systems are probably not appropriate for bottom culture sites and they do not consider other aspects of bivalve aquaculture, such as dredging for spat and harvesting. Finally, this approach considers only the benthic component and thus its utility in determining the ecological carrying capacity for the entire ecosystem within an area is not known.

The second approach to determining ecological carrying capacity uses mass-balance/food web models. Early conceptual mass balance models involved examining the influence of bivalve culture as a part of the ecosystem (Tenore et al., 1982). More recent work has used ECOPATH (Christensen and Pauly, 1992) to determine the trophic functioning of areas that include bivalve culture in sites around the world (Wolff, 1994, Lin et al., 1999, Stenton-Dozey and Shannon, 2000, Wolff et al., 2000, and Brando et al., 2004). These models differ considerably in complexity and the number of trophic groups considered. Predictably, the presence of bivalve culture promotes short energy pathways with high trophic efficiency and may considerably accelerate nutrient and energy cycling.

As with the benthic deposition model, the mass balance approach also has limitations. First, the models are typically steady-state, ignoring seasonal and temporal variation. Second, the mass balance model (ECOPATH) is not spatially explicit and therefore the model may not be used to differentiate between near-field and far-field effects. Third, many biological variables (life history values, interactions, etc.) are poorly understood. Fourth, most applications of ECOPATH (with ECOSIM) do not adequately address uncertainty in data inputs and model structure (Plaganyi and Butterworth, 2004). And finally, this method, typically only considers the growout phase of shellfish culture; ignoring the potential impacts of activities such as seeding and harvest.

In sum, most of the potential measures of ecological carrying capacity consider only a single or a restrained number of ecosystem components (Broekhuizen et al., 2002). As we learn more about the functioning of marine ecosystems it is likely that our understanding of the factors affecting ecological carrying capacity will evolve, and we need to develop a flexible approach to allow for

these changes.

Knowledge gaps and research needs for ecological carrying capacity studies:

- Studies must be done to better understand the environmental interactions (positive and negative) of various types of bivalve culture including all farming activities from seed collection to on-growing, harvesting and processing.
 - Existing models must be made spatially explicit.
 - Temporal and seasonal variation must be built into existing models.
 - Models must be validated in a number of locations.
- Appropriate management tools, such as Fuzzy Expert Systems, must be developed to aid in decision-making.

Where do we stand in Rhode Island? - Estimates of Filtration Capacity

Since numerical modeling is expensive, time consuming and relies on extensive knowledge about the interdependence of all of the major elements of a given ecosystem, it is tempting to make some crude “back of the envelope calculations” to see whether “significant” impacts are “likely” to occur at a given level of production.

For instance we can calculate the combined filtration capacity of a given biomass of bivalves. This number can then be compared with the tidal flux of a given body of water and a subjective judgment can be made to assess whether such filtration impacts are acceptable.

Such an exercise was done for the largest oyster farm in the state (Spatco, Ltd.). It was estimated that the combined filtration capacity of the oysters on the site cleared approximately 10 to 40 million gallons each day.

Estimates of oyster filtration rates vary widely from 50 to 240 liters per day per gram tissue dry weight (typical weight for a market size oyster ~2gdw) (Haven and Morales Alamo 1970). Using these estimates and estimates of the numbers and sizes of oysters held on Spatco’s leases in Point Judith Pond it has been estimated that these animals filter between 0.36 to 1.8% of the total pond volume each day. (see attached spreadsheet) This translates to clearance times of 55 to 275 days.

These filtration rate estimates are probably high because they do not account for refiltration of water that has already been filtered by upstream animals held in dense concentrations. Whether this represents a “significant percentage” is an entirely different question. To answer this we need to evaluate food webs and energy flows to various trophic levels and we should take into account the fact that, like many coastal estuaries, Point Judith Pond suffers from excessive phytoplankton concentrations caused by excessive nitrogen inputs, to the point that eelgrass is not receiving adequate sunlight (Newell and Koch 2004).

Unfortunately we do not have good estimates for the biomass of wild filter-feeding shellfish in the pond, so we cannot make an accurate estimate of the combined clearance capacity (wild and cultured shellfish). Judging from the extremely high chlorophyll concentrations observed in the pond during the summer months (often as high as 10 $\mu\text{gChl/L}$ (Rheault 1995) it is probably safe to assume that the combined clearance time (Dame 1996) is nowhere near the residence time in this pond.

Where do we stand in Rhode Island? - Extrapolation to Other Models of Ecological Carrying Capacity

Another crude approach to estimating carrying capacity is to extrapolate from other numerical models and see if they can be adapted to our situation. This is how the much-discussed “5 percent” number was developed.

Jiang and Gibbs (2005) recently attempted to determine the carrying capacity of a large bay in New Zealand for mussel culture using a mass-balance approach and the ECOPATH model. The question that the model attempted to answer was: What level of green mussel aquaculture could be supported in their system before impacts to the energy flow and trophic dynamics would become apparent? Their model predicts that the production carrying capacity of the bay was 310 tons per km² per year, and the ecological carrying capacity of the area was 65 tons per km² per year. Below this lower level their model predicts no significant changes in energy fluxes within the system's food web.

If we assume that all of the elements of their model are directly applicable to our system (a big assumption for reasons I will go into below) and extrapolate the 65 ton/km² number to Point Judith Pond and use stocking densities typical of Rhode Island farms, we come up with an estimate of 5% of the total area of the pond that could be used for shellfish culture without seeing significant changes in the energy fluxes in our system. (see attached table for the calculation).

To apply this particular model to Point Judith Pond in Rhode Island requires that we ignore several obvious differences. First, the bay in New Zealand that they were modeling is about the size of the entire state of Rhode Island (4500km²). There are no doubt significant differences between the two ecosystems, the food web dynamics and the energy flows. The New Zealand bay supports a finfish fishery with annual landings

Filtration Capacity of Spatco's Peak Annual Oyster Biomass

size	number	filtration rate	Low rate est.	cubic meter/d
	count	liters/day	liters/day	
4-6 inch	150,000	100	15,000,000	15,000
2-4 inch	1,000,000	25	25,000,000	25,000
1-2 inch	3,200,000	2	<u>6,400,000</u>	<u>6,400</u>
		total filtered	46,400,000	46,400

size	number	filtration rate	high rate est.	cubic meter/d
	count	liters/day	liters/day	
4-6 inch	150,000	480	72,000,000	72,000
2-4 inch	1,000,000	120	120,000,000	120,000
1-2 inch	3,200,000	12	<u>38,400,000</u>	<u>38,400</u>

		total filtered	230,400,000	230,400	
Area of Point Judith Pond					
1,574	acres =	6,369,978	square meters	at low rate est. percent filtered	at high rate est percent filtered
total volume - assume avg. depth 2m					
12,739,956	cu meter total volume			0.36%	1.81%
tidal prism - assume avg. 1m tide					
6,369,978	cu meter per tide			0.73%	3.62%
Clearance time				275 days	55 days

Predicted Ecological Carrying Capacity - The 5% Solution

(that biomass of cultured shellfish that could be added w/o significant impact)
from Jiang and Gibbs (2005) Aquaculture v244:171-185

Using a linear food web model based on a 4500km² bay in New Zealand
Authors predict that 65 tons per year could be harvested annually from each
km²
without "significantly changing the major energy fluxes or structure of the food web"

Area of Point Judith Pond = 1574 acres = 6.37 km²
65 tons/km² x 6.37 km² = 414 tons per year is theoretical max biomass for the pond
at an average production biomass of 5 tons per acre = 82.8 acres needed to produce 414 tons
82.8 / 1574 = 5.3%

of 6000 tons, an aquaculturally enhanced scallop fishery that lands an average of 42 tons per year and an additional 500 tons of other wild shellfish species.

Lastly, and perhaps most significantly, the standing stock of phytoplankton in Point Judith Pond is much higher (Chl-a concentrations of 10 g/l are not uncommon) (Rheault 1995) than that of the open water conditions of the New Zealand model. And since nutrient levels are likely to be much higher in shallow eutrophic waters we can predict that phytoplankton doubling times should be faster as well. Both of these suggest that Point Judith Pond should be able to support greater stocks of both bivalves and planktonic filter feeders (Dame and Prins 1993).

Recommendation: Attempt to secure funding to develop models that will allow us to accurately predict the ecological carrying capacity of typical aquaculture sites in Rhode Island.

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Chapter 7

An ecosystem approach to marine aquaculture

Summary of the FAO Working Group on an Ecosystem Approach to Aquaculture

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At an FAO Workshop on an ecosystem approach to aquaculture (EAA) in Mallorca, Spain in 2007, an EAA was defined as:

“a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems”.

Principles, Key Issues and Scales

Soto (2007) developed the following three principles and key issues of an EAA at the different scales defined below:

PRINCIPLE 1: *Aquaculture should be developed in the context of ecosystem functions and services (including biodiversity) with no degradation of these beyond their resilience capacity.*

The key issue is to define or estimate resilience capacity or the limits to “acceptable environmental change”. States Soto (2007), “In the case of biodiversity, local declines may be acceptable (e.g. below fish cages) as long as such losses can be compensated and restored, at least at the water body scale, in order to preserve ecosystem function and services. For example, after a cage farm operation is halted it is expected that the relevant biodiversity recovers. Many environmental impact assessments touch on these issues and yet the tools to address them are either not well developed or used; a promising one is that offered by risk assessment. Relevant questions remain: How much biodiversity are we willing to lose?; at what scale levels?; at what costs?; and how are costs balanced with the benefits from aquaculture? On the other hand, aquaculture impacts need to be seen in context by comparing them with those from other food producing sectors such as agriculture and livestock farming. Most terrestrial food producing systems, especially intensive ones, have been achieved after drastically transforming the landscape (e.g. clearing native forests and grasslands for agriculture with permanent impacts on the original biodiversity); but we historically grew used to those impacts, while intensive aquaculture is a rather new development worldwide. Efforts need to be made in order to permanently monitor aquaculture effects on biodiversity to make sure that such effects do not result in serious/significant losses of ecosystem functions and services. In this respect real values of ecosystem goods and services should be integrated into micro- and macro-environmental accounting.”

PRINCIPLE 2: *Aquaculture should improve human-well being and equity for all stakeholders.*

Key Issues

This principle ensures that aquaculture provides equal opportunities for development; and that the benefits from aquaculture are properly shared, while the activity does not result in any detriment for any society, especially for the poor. It ensures both food security and safety as key components of societal well-being.

PRINCIPLE 3: *Aquaculture should be developed in the context of other sectors, policies and goals.*

Key Issues

This principle recognizes the important interactions between aquaculture and the larger ecosystem, in particular, the influence of the surrounding natural and social environments on aquaculture. Aquaculture does not take place in isolation, and, in most cases is not the only human activity impacting on water bodies, which worldwide are more heavily impacted by agriculture, industrial activities, trash and sewage wastes. This principle also acknowledges the opportunity of coupling aquaculture activities with other producing sectors in order to promote materials and energy recycling.

Spatial Scales

There are three physical scales of interest in this review regarding the planning for and assessment progress towards an ecosystem approach to aquaculture: farm, water body/watershed/aquaculture zone/regional, and global. This breakdown is artificial, since issues at each scale are overlapping, and there are many important similarities among different scales.

Farm Scale: Planning and Assessment

Planning for the farm scale is easily defined physically and could, for example, be few meters beyond the boundaries of farming structures. However the increasing size and intensity of some farms (e.g. large scale shrimp farming or salmon farming) could affect a whole water body or watershed. Most planning for an EAA has been conducted at this scale.

Assessment of an EAA at the farm scale entails an evaluation of planning and implementation of economic, ecological, and social programs that account for the wider ecosystem and social impacts of farm-level aquaculture developments, including impact assessments, use of better management practices, and use of restoration, remediation, and mitigation methods. Proper site selection, production intensity levels, use of species (exotic vs. native), use of appropriate farming systems and technologies, and the social-economic impacts at the farm level are considered.

Regional Scale: Coastal Water Body/Aquaculture Zone: Planning and Assessment

Planning and assessment of progress towards an EAA for the water body scale will address circumscribed coastal/marine areas as well as impacts on aquaculture zones/regions and watersheds. Coastal/marine aquaculture can also have impacts on inland watersheds.

Planning for an EAA at aquaculture zone/regional level is more relevant to social/economic and political issues, but there may be some common and very relevant ecosystem issues; for example, diseases, seed and feeds trade, climatic and landscape conditions, etc. In practical terms many management issues are similar at the watershed and aquaculture zone/region.

Assessment of an EAA at this scale will address technical issues of farm interactions and densities, etc., as well, assessment of aquaculture's inclusion as a part of governance frameworks, e.g. as a part of, or separate from, an overall framework of other natural resource systems such as fisheries and forestry, integrated coastal zone management or integrated land-water resource management planning and implementation. Assessment would consider regional issues such as escapees, disease transmission, contamination to/from aquaculture, and user competition/conflicts for land and water use. Social considerations at the regional scale would be, for example: aquaculture's role in rural development, comprehensive planning for the beneficial multiplier effects of aquaculture on jobs and the regional economy, and considerations of aquaculture's impacts on indigenous communities.

A regional ecosystem approach to aquaculture also needs to consider the governance of aquaculture developments, including existing scenarios and alternatives for human development. While an EAA should be the responsibility of a lead aquaculture agency, its full implementation will require government to consider alternative methods of governance and use innovative approaches so that agencies responsible for managing activities impacting aquatic ecosystems (e.g. capture fisheries, coastal zone development, watershed management organizations, agriculture, forestry, industrial developments) can regularly communicate, cooperate, and collaborate. The design of aquaculture management zones could be a relevant tool, particularly when the benefits of integrated aquaculture, polyculture, or integrated aquaculture–fisheries initiatives are being considered.

Global: Planning and Assessment

Planning for an EAA at a global scale considers impacts of the global aquaculture industry for some commodity products (e.g. salmon and shrimp), and industrial progress on ecosystem (natural and social ecosystem) issues of global relevance.

Assessment of progress towards an EAA entails evaluation of issues such as availability of agriculture and fisheries feedstocks for aquaculture feeds, and the broader ecosystem, economic and social impacts of aquaculture on fisheries and agriculture resources, and society's infrastructure. Applications of tools such as lifecycle assessments of aquaculture commodities are useful at this level. Other relevant issues include markets and marketing, social sustainability (social capital, goods and social opportunities, and the application of innovative social enterprise management guidelines and tools in the aquaculture industry.

Needs for a Tighter Coupling of Aquaculture Science, Policy and Management for a Widespread Adoption of an EAA

An EAA will require a much tighter coupling of science, policy, and management. Aquaculture has intimate connections not only with capture fisheries, but also with agriculture, markets, and marine policy and regulatory environments. Accelerated production of aquatic proteins cannot be evaluated in a vacuum separate from other types of land-based animal agriculture or ocean-based capture fisheries since these food systems use similar (and sometimes competing) inputs and outputs, face similar policy and regulatory environments and markets, and have to deal with common consumers and decision-makers. More holistic planning perspectives are needed to ensure the survival and plan the future of traditional coastal fishing and aquaculture communities, and to link aquaculture

science, industry, and society in order to design effective policies, practices and technologies to address the many challenges ahead.

Aquaculture is not a uniform "industry" or a standard set of practices easy to classify—or label—and regulate. There is a wide diversity of systems and species that can be classified in many different ways. For example, the integration of aquaculture, agriculture and animal husbandry on small farms in Asia creates definable aquaculture ecosystem types that closely resemble natural ecosystems having their own structure, closely-coupled nutrient recycling pathways, and ecological management strategies.

Aquaculture should be pro-active, promote and develop itself as the world's most ecologically integrated industry, and adopting this new strategy—that of a community-based, sustainable, ecological aquaculture industry that produces ecologically and socially certified produce—adopting input management strategies and codes of better practices. In this regards, the recent international guidelines developed for shrimp farming are a major advance (FAO/NACA/UNEP/WB/WWF, 2006).

In the 21st century, aquaculture developers will need to spend as much time on the technological advances coming to the field as they do in designing ecological approaches to aquaculture development that clearly exhibits stewardship of the environment. For aquaculture development to proceed to the point where it will be recognized worldwide as the most efficient contributor to new protein production—clear, unambiguous linkages between aquaculture and the environment must be created, fostered, and communicated—and the complementary roles of aquaculture in contributing to environmental sustainability, rehabilitation and enhancement must be developed and clearly articulated to a highly concerned, increasingly educated and involved public.

An ecological approach to aquaculture brings modern sustainability, ecological methods and systems thinking to aquaculture, incorporating social, economic, and planning for its wider social and environmental contexts in fisheries and coastal zone management. Ecological aquaculture will create new opportunities for a more diverse group of professionals and entrepreneurs to get involved in aquaculture since new advances will be needed not only in treatment technologies, production management and feed technologies; but also in energy technologies, information management, public information and outreach, community facilitation and networking.

Literature Cited

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- Soto, D. 2007. *Principles of an Ecosystem Approach to Aquaculture*. FAO, Rome, Italy. In Prep.

Section 300.11.

Aquaculture

A. Definition

1. For the purpose of the Coastal Resources Management Council, marine aquaculture is defined as the culture of ~~salt tolerant~~ aquatic species under natural or artificial conditions in ~~tidal waters and coastal ponds~~ the state's waters including but not limited to: fish farming utilizing pens, tanks, or impoundments; the culture of shellfish on the sea floor in permitted and leased areas, in cages, or suspended from structures in the water; and the culturing of aquatic plants. **NOTE:** land-based ~~marine~~ aquaculture operations (i.e., above mean high water) are also regulated under Section 300.3 of the RICRMP.

2. For the purpose of the Coastal Resources Management Council freshwater aquaculture is defined as the culture of aquatic species under natural or artificial conditions in freshwater ponds, tanks, raceways or other freshwater impoundments located within the coastal zone or in inland locations throughout the state.

3. Transient or mobile aquaculture gear is defined as cages containing cultured species which are periodically moved about within a specified area so as to reduce user conflicts. This gear is typically in the form of wire cages which are either individually marked with a surface buoy or strung together in trawls with end buoys to identify the location of gear.

B. Policies

1. The CRMC recognizes that commercial aquaculture is a viable means for supplementing the yields of marine fish and shellfish food products, and shall support commercial aquaculture in those locations where it can be accommodated among other uses of Rhode Island waters. The CRMC recognizes that responsible shellfish aquaculture has a net positive effect on the environment. As any human activity can have adverse environmental affects, the Council recognizes the possibility of setting scientifically defensible limits on aquaculture leasing in any particular water body. The CRMC also recognizes that in the framework of adaptive management protocols, research into the ecology of coastal waters and our understanding of carrying capacities is constantly evolving and improving.

2. The Council may grant aquaculture activities by permit only. The CRMC may grant aquaculture applicants exclusive use of the submerged lands and water column, including the surface of the water, when the Council finds such exclusive use is necessary to the effective conduct of the permitted aquaculture activities. Except to the extent necessary to permit the effective development of the species of animal or plant life being cultivated by the permittee, the public shall be provided with means of reasonable ingress and egress to and from the area subject to an aquaculture lease for traditional water activities such as boating, swimming, and fishing. All plant and animal species listed for culture in an aquaculture lease are the personal property of the permittee.

3. At the discretion of the Council, leaseholders may be required to temporarily remove their aquaculture facilities when they are not being used to conduct research, culture or to harvest an aquatic species of plant or animal for a substantial period of time. The Council may permit inactive facilities to remain if it determines that the temporary removal of these facilities would place an undue burden on the leaseholder.

4. The Council may require the removal of any aquaculture facility that is in an obvious state of disrepair or has become a navigation or safety hazard.

5. Upon application to renew an existing aquaculture Assent, the Executive Director may administratively

renew said Assent for a period not to exceed that period set forth in Title 20 Chapter 10 of the General Laws for each renewable period, provided the applicant is in conformance with the terms and conditions of the Assent, the aquaculture lease, and with the Coastal Resources Management Program (RICRMP) in effect at the time of renewal provided, further, that there are no amendments to the Assent or lease. Report of such action by the Executive Director shall be made in writing to the full Council at the next regularly scheduled meeting of the Council.

6. In the event that a CRMC approved aquaculture operation is determined by the Council to not be actively “farmed” for a period of one year, the assent and lease shall be deemed null and void and the site shall be returned to the State’s public use. Actively farmed may be defined by the yearly monetary investment in the farm, ex: the purchase of seed and supplies and/or proof of sales.

7. The Council may grant an aquaculture Assent for a period not to exceed that period set forth in Title 20 Chapter 10 of the General Laws.

8. It is the Council’s policy to prohibit private molluscan shellfish aquaculture for human consumption activities in not-approved areas as defined by the National Shellfish Sanitation Program that contain significant shellfish stocks potentially available for relay into approved areas for free and common fishery.

(a) This prohibition shall not apply to activities like spat collection, or to the cultivation of scallops, or to private aquaculture operations conducted within the confines of a marina perimeter limit (as set forth in 300.4), or to projects which are designed, with Council approval, to enhance and restore the public resource.

(b) Aquaculture projects other than shellfish aquaculture proposed for not-approved areas may be granted by the Council provided the applicant provides sufficient evidence that no harm to public health or safety will result. In the case of shellfish aquaculture, such activities shall be prohibited unless the applicant provides written statements from the directors of the departments of environmental management and health certifying that the proposed activity is consistent with the requirements of the National Shellfish Sanitation Program.

(c) Where a private shellfish aquaculture applicant expressly releases ownership of any and all shellfish stock existing in a permitted area, the Council may grant a lease in addition to a permit.

C. Prerequisites

1. Prior to issuing a permit for marine aquaculture within tidal waters, the Council shall obtain and give appropriate consideration to written recommendations from the Director or his or her designee of the Department of Environmental Management and the chairman of the Marine Fisheries Council, as required by Chapter 20.10 of the state's General Laws. The director or his or her designee of the Department of Environmental Management shall review the application to determine that the proposed aquaculture activity will not adversely affect (a) marine life adjacent to the proposed area and the waters of the state, and (b) the continued vitality of indigenous fisheries. The chairman of the Marine Fisheries Council shall review the application to determine that it is consistent with competing uses involved with the exploitation of marine fisheries.

2. An Aquaculture License for the possession, importation, and transportation of marine shellfish species used in any aquaculture operation shall be obtained from the director or his or her designee of the Department of Environmental Management. The DEM Aquaculture License may be processed concurrently, but must be obtained prior to the issuance of a CRMC Assent.

3. Prior to submitting a formal Category B application for aquaculture activities within tidal waters, applicants

must first submit a Preliminary Determination application for the proposed project in accordance with existing CRMC procedures. A formal application may be submitted only after the receipt of the completed Preliminary Determination report.

4. Applicants for aquaculture operations within tidal waters must submit with their application(s) all required information as specified in the most recent version of the CRMC aquaculture checklist.

5. In those cases where alterations to freshwater wetlands may occur, applicants for freshwater and land-based aquaculture operations must first obtain a permit from the DEM Division of Agriculture or DEM Freshwater Wetlands prior to applying with the Council.

6. Applicants for freshwater and land-based aquaculture structures and/or improvements must obtain local building official approval and zoning approval, where necessary, prior to submitting an application to the CRMC.

7. Applicants for land-based aquaculture operations which result in discharges to waters of the state shall be required to obtain a Rhode Island Pollution Discharge Elimination System (RIPDES) permit.

8. Applicants for aquaculture operations conducted at marinas using technologies such as an upweller unit may be reviewed as a Category A activity provided that the operation is conducted within a Council-approved marina perimeter, and that RIDEM has issued a Special Permit for Aquaculture for such an activity. Further, at the time of application, the applicant must provide proof that such seed product - prior to exceeding the size of the RIDEM seed definition - will be transferred to: (1) a permitted aquaculture facility operating in approved waters; (2) a scientific or educational institution; or(3) a government agency.

9. Upweller units at CRMC permitted residential docks, piers and floats may be reviewed as a Category A activity provided that: (1) only current council-approved aquaculture lease holders may propose to utilize upweller units at residential docks; (2) the inclusion of an upweller is incidental to the permitted use of the dock, pier, or float, and the original use of the structure not be inhibited by the inclusion of an upweller; (3) all shellfish from the addition of an upweller belong to a licensed CRMC aquaculture leaseholder and that the production from the upweller will go to the owners lease site; (4) all applicable Rhode Island Department of Environmental Management and Rhode Island Department of Health Regulations are followed; (5) all local and national codes regarding addition of electrical power to docks and associated structures will be adhered to; and, (6) adequate depth of water at the upweller addition is maintained. A CRMC assent will be issued for a period of up to five (5) years but in no case longer than the length of time remaining on the approved aquaculture leaseholder's permit. Addition of upwellers in existing residential docks, piers, or floats in type 1 waters is prohibited.

10. Applicants who propose to introduce non-indigenous species into an aquaculture setting are required to design a protocol that will be reviewed by the Bio-Security Board prior to issuance of an assent. This review can occur concurrently with the aquaculture application process.

D. Additional Category B Requirements

1. Applicants proposing to undertake any aquaculture endeavor shall: (a) describe the location and size of the area proposed; (b) identify the species to be managed or cultivated within the permitted area and over which the applicant shall have exclusive right; (c) describe the method or manner of management or cultivation to be utilized, including whether the activities proposed are experimental, commercial, or for personal use; and (d) provide such other information as may be necessary for the Council to determine: (1) the compatibility of the proposal with other existing and potential uses of the area and areas contiguous to it, including navigation, recreation, and fisheries; (2) the degree of exclusivity required for aquacultural activities on the proposed site;

(3) the safety and security of equipment, including appropriate marking of the equipment and/or lease area; (4) the projected per unit area yield of harvestable product; (5) the cumulative impact of a particular aquaculture proposal in an area, in addition to other aquaculture operations already in place; (6) the capability of the applicant to carry out the proposed activities; and (7) the impact of the proposed activities on the scenic qualities of the area.

E. Prohibitions

1. Fish pen aquaculture operations are prohibited in all coastal ponds.
2. Private aquaculture leases for molluscan shellfish are prohibited in uncertified waters (i.e., restricted areas as defined by the National Shellfish Sanitation Program) which contain significant shellfish stocks available for relay into certified public waters for the free and common fishery.
3. Upwellers at existing residential docks, piers, or floats in Type 1 waters are prohibited.
4. Introduction of non-indigenous species is prohibited unless protocols are in place to ensure that no accidental releases into the state's waters can occur. These protocols will be reviewed by the CRMC Bio-Security Board before any permit is issued. Any proposed modifications to the permitted operation will be reviewed by the Bio-Security Board before an assent modification can be issued. The issuance of a permit under these stipulations can be revoked if a release of non-indigenous species takes place during the term of the assent.
5. The harvest of wild shellfish naturally occurring in a CRMC permitted lease shall be prohibited. All wild shellfish within a lease area will remain the property of the State of Rhode Island and remain in place for the benefit of the state. This resource is not to be harvested by any person for commercial or recreational purposes. Any incidental catch by the lease holder within an aquaculture lease shall be released.
6. In the coastal salt ponds a 5% upper limit on area occupied by aquaculture is established based upon the present knowledge of ecological carrying capacity models. The 5% upper limit is determined upon the total open water surface area below MLW. See: [Salt Pond SAMP §100.B.1 and Figure 1-1](#)

F. Standards

1. Marine Aquaculture within Tidal Waters
 - (a) In the event of revocation, termination or expiration of any lease or Assent, the lessee or Assent holder is responsible for restoring the area to pre-existing conditions within ninety (90) days from the date of permit revocation, termination, or expiration. This shall include the removal of all structures, rafts, floats, markers, buoys, anchors, and other equipment brought to the site. Failure to comply with the Council's order to restore the site may result in the forfeiture of the permit bond posted by the lessee.
 - (b) Any person who maliciously and willfully destroys, vandalizes, or otherwise disrupts aquaculture activities permitted by the Council shall be in violation of an order of the Council and liable to all fines and penalties under law.
 - (c) All permittees shall mark off the areas under permit by appropriate buoys or stakes, as determined by the CRMC, so as not to interfere unnecessarily with navigation and other traditional uses of the water surface. The requirement for the agreed upon marking will be found in the lease requirements detailed in the assent. All authorized limitations upon the use by the public of areas subject to the permit shall be posted by the permittee.
 - (d) The Council may require the leaseholder for an aquaculture facility to post a performance bond in order to

ensure the cleanup and removal of said facility upon either the termination or expiration of the lease.

(e) The Executive Director may approve the transfer of a lease from the lessee to another party provided the aquaculture operation remains the same, including size, species, gear, and methods of culturing. The full Council must approve any transfers that involve a deviation from the existing assented aquaculture operation.

(f) Experimental permits. (1) The Executive Director may issue an experimental aquaculture permit for operations which are expressly for the purpose of developing and testing new gear or techniques for aquaculture production. Applicants may be approved for three separate sites, with up to an area of one-thousand (1,000) square feet for each site. Experimental sites shall not be within 500 feet of one another. Areas in excess of this may be approved by the full Council. Experimental aquaculture Assents shall be valid for a period not to exceed three (3) years. A lease may be required and the sale of any aquaculture product is not allowed. Report of such action by the Executive Director shall be made in writing to the full Council at the next regularly scheduled meeting of the Council. (2) Experimental aquaculture operations wholly contained within the confines of a council-approved marina perimeter area excluded from the 500 foot separation standard, as contained above, any may maintain a total of 3,000 square feet in any configuration for such operations.

(g) Commercial viability permit. (1) The Executive Director may issue a commercial viability aquaculture permit for operations which are expressly for the purpose of determining if a particular site is suitable for commercial aquaculture. The applicant may have one site, limited to a thousand (1000) square feet. Commercial viability permits shall be valid for a period not to exceed three (3) years. Permits for a commercial viability shall be subject to a two step process: (1) Issuance of a one-time administrative permit for the period of eighteen (18) months; followed by a one-time council-approved permit for an additional eighteen (18) months. A lease may be required. Report of such action by the Executive Director shall be made in writing to the full Council at the next regularly scheduled meeting of the Council. (2) Any continuation of the operation by the applicant beyond this permit length shall require a separate application which will be considered and reviewed by the Council as a Category B application and is subject to all applicable aquaculture policies and regulations. (3) The permittee may, on a one time basis, sell those products approved within the permit. Upon termination of the operation, or at the end of the three (3) year permit period, whichever comes first, the permittee must terminate the operation. (4) The permittee must show that, in case of successful trial, there is potential area to expand to a commercial aquaculture lease in the same area that the commercial viability permit was granted. The Executive Director may require the permittee to post a performance bond in order to ensure the cleanup and removal of said facility. Detailed economic reports shall be required for all commercial viability permittees.

(h) Education/research permit. The Executive Director may issue a education/research aquaculture permit for operations which expressly for the purpose of using aquaculture for education or research. A lease may be required. Applicants may be approved for three separate sites, with up to an area of one-thousand (1,000) square feet for each site. Education/research sites shall not be within 500 feet of one another. Areas in excess of this may only be approved by the full Council. Educational/research aquaculture assents shall be valid for a period not to exceed three (3) years. A lease may be required and sale of any aquacultured product is not allowed, report of such action by the Executive Director shall be made in writing to the full Council at the next regularly scheduled meeting of the Council. The Executive Director may grant extensions to these permits. Each extension shall not exceed three (3) years. Educational/research aquaculture operations wholly contained within the confines of a council-approved marina perimeter are excluded from the 500-foot separation standard, as contained above, and may maintain a total of 3,000 square feet in any configuration for such operations.

(i) All transient aquaculture gear shall be operated within defined areas as established by the tidal water aquaculture management plan. Transient gear lease fees shall be based on the minimum area necessary to

operate the proposed number of cages.

(j) Aquaculture operations shall be located at sites and operated in such a manner as to not obstruct public access to and from tidal waters.

(k) Any new lease in a coastal salt pond shall be limited in size as follows:

(1) maximum three (3) acres for traditional rack and bag or cage methods; or

(2) maximum six (6) acres for bottom planting

(l) leaseholder may not apply for any lease expansion until such time leaseholder can demonstrate to the CRMC a need for additional area.

(k) In the salt ponds all new leases:

(1) will be initially limited in size.

(a) If the applicant proposes to utilize the traditional rack and bag or cage methods the initial lease size will be limited to three (3) acres.

(b) If the applicant proposes to utilizing bottom planting the lease size will be limited to six (6) acres.

(2) leaseholders may not apply for expansion of leases until they can demonstrate a need for the expansion to the CRMC for the additional area.

(l) Recreational Permits. The Executive Director may grant permits for recreational culture of shellfish by littoral landowners.

(1) Recreational permits shall be limited to one culture enclosure limited to a volume of 48 cubic feet; and

(2) This cage shall be hung from an existing CRMC approved dock in a manner that it will not interfere with traditional navigation; and

(3) Recreational permit holders will follow all existing seed importation regulations; and

(4) Recreational permit holders will be required to complete a CRMC approved educational program.

(5) recreational permits will be exempt from prohibition #6.

(6) All gear used under an education permit will be legibly marked with the letters "CRMC" and the CRMC permit number.

(m) In the coastal salt ponds a 5% upper limit on area occupied by aquaculture is established based upon the present knowledge of ecological carrying capacity models. The 5% upper limit is determined upon the total open water surface area below MLW.

2. Freshwater Aquaculture

(a) The Council shall require a permit for all freshwater and land-based aquaculture operations located within the coastal zone or in inland locations throughout the state.

(b) Permits for land-based aquaculture operations shall be granted by the CRMC for a term not to exceed 50 years.

(c) When required, all species utilized for culture within land-based aquaculture operations must be approved by the DEM director or his or her designee. The aforementioned approval must be obtained prior to the Council issuing its assent, however, it may be concurrently processed with the Council's review.

G. Guidelines for Marine Aquaculture within Tidal Waters

In addition to the policies, prerequisites, additional requirements for Category B assents, prohibitions and standards above, the Council also suggests that applicants take the following items into consideration for any proposed aquaculture application.

1. Marine aquaculture lease size in Narragansett Bay.

(a) For the area known as upper Narragansett Bay, defined as the area north of a line across the bay at the latitude of 41 degrees 35 minutes, proposed aquaculture farms should be limited to three acres.

(b) Three (3)-acre leases will be granted by giving an initial two (2)-acre lease. Subsequently the third acre will be granted when the permittee shows that the initial 2-acre lease is being utilized.

(c) These guidelines may be adjusted for variations in water depth, species cultured, etc.

2. Guidelines for Marine Aquaculture in the Salt Ponds.

(a) Aquaculture leases will be discouraged in historically fished areas and encouraged in areas that have not been historically utilized in the wild harvest fishery.

(b) Buffer zones between aquaculture leases may be required when considering new leases.

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