Technical Report

EXOTIC SPECIES WORKSHOP: ISSUES RELATING TO AQUACULTURE AND BIODIVERSITY

Judith Pederson

MITSG 96-15

MIT Sea Grant College Program

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EXOTIC SPECIES WORKSHOP:
ISSUES RELATING TO AQUACULTURE AND BIODIVERSITY

February 8, 1996
Hill Conference Room
Draper Laboratory
Cambridge, MA 02139

Agenda

8:30 am	Registration
9:00 am	Introduction and Welcome Judith Pederson, MIT Sea Grant College Program
9:15 am	Overview of Issues Related to Biodiversity and Exotic Species Introductions James Carlton, Director, Williams College/Mystic Seaport Program
10:00 am	New Species in the Gulf of Maine - Have Human Activities Created a Positive Vacuum for Invaders? Larry Harris, University of New Hampshire
10:20 am	Break
10:40 am	The Role of Ballast Water in Transporting Nonindigenous Species to U.S. Waters David Smith, Nahant Marine Center, Northeastern University
11:00 am	Atlantic Cod: Reintroduction of an Exotic Species in the Gulf of Maine Richard Langton, Maine Department of Marine Resources
11:20 am	Management issues: Perspectives from Northeastern States Representatives Nancy Balcom, Connecticut; Ken Honey, Maine; James Fair, Massachusetts; Bruce Smith, New Hampshire; Commander Tom Walker, US Coast Guard
12:00 noon	Lunch

1:00 pm	Impacts of Shellfish Introductions on Local Communities Bruce Barber, University of Maine
1:20 pm	Introductions and Transfers - Perspectives of the Aquaculture Industry Robert Rheault, Moonstone Oysters
1:40 pm	Diseases of Bivalves Roxanna Smolowitz, Marine Biological Laboratory
2:00 pm	Seaweed Mariculture and the Use of Introduced and Genetically Modified Species Don Cheney, Northeastern University
2:20 pm	Break
2:40 pm	Indigenous Finfish Populations and Exotic Species Introductions Les Kaufman, Boston University Marine Program
3:00 pm	Genetically Modified Finfish and Shellfish Eric Hallerman, Virginia Polytechnic Institute and State University
3:20 pm	Farming Exotic Species in Closed Systems: AquaFuture's Experience in Massachusetts and with the ICES Work Group on Introductions Scott Lindell and Tracy Hellerman *, AquaFuture, Inc.
3:40 pm	Panel discussion: What is the role of government in promoting aquaculture and managing exotic species introductions? Susan Snow Cotter, Massachusetts Coastal Zone Management; Bruce Barber, University of Maine; Les Kaufman, Boston University Marine Program; Robert Rheault, Moonstone Oysters
4:40 pm	Epilogue James Carlton, Mystic Seaport/Williams College

*Presenter

Proceedings from

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Presenters (in order of presentations):
James Carlton, Ph.D., Director, Williams College/Mystic Seaport Program
Larry Harris, Ph.D., Professor of Zoology, University of New Hampshire
L. David Smith, Ph.D., Assistant Professor of Marine Biology, Nahant Marine Center, Northeastern University
Richard Langton, Ph.D., Maine Department of Marine Resources
Nancy Balcom, Extension Leader, Connecticutt
Ken Honey, Retired State Representative, Maine
James Fair, State Representative, Massachusetts
Bruce Smith, State Representative, New Hampshire
Commander Tom Walker, US Coast Guard
Bruce Barber, Ph.D., Associate Professor, Department of Animal, Veterinary, and Aquatic Science, University of Maine
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Susan Snow Cotter, Ocean Policy Coordinator, Massachusetts Coastal Zone Management

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INTRODUCTION

There is serious concern both for maintaining the biological integrity of marine systems and for supporting exploitation of the oceans for aquaculture and mariculture. Although we have introduced species into marine environments for the past 100 years and longer, we have only recently begun to document these invasions and assess impacts. The desire to increase seafood availability through aquaculture and mariculture has added to an awareness of the potential for intentional or accidental introductions that may result in unwanted consequences. It is not surprising that the introduction, transfer, or release of marine organisms has created considerable debate about real and perceived risks.

This workshop is intended to provide an overview, in a regional context, of the issues relating to protection of native resources and biodiversity and the development of aquaculture and mariculture in the Northeast region. The speakers will examine issues related to conservation biology, impacts of exotic species on indigenous populations, measures of control or management, mechanisms of transport, and review of our level of understanding of ecosystems. Both the views of scientists and those involve in aquaculture and mariculture will be expressed and discussion encouraged among presenters and participants. It is anticipated that the information will assist those who are responsible for developing legislation and regulations to manage exotic species introductions. From deeper understanding of the scientific issues, potential risk to coastal ecosystems from introductions, transfers and releases should emerge and areas where risk is negligible should be identified with resulting benefit to maintaining biological diversity and supporting aquaculture and mariculture.

ISSUES RELATED TO EXOITC SPECIES INTRODUCTIONS AND BIODIVERSITY

James T. Carlton
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Concern about and interest in introduced (nonindigneous, exotic, alien) species in aquatic ecosystems encompass a number of issues within several major arenas: (1) the prevention of accidental introductions by any of a broad menu of human activities, including ballast water and aquaculture, (2) the use and management of nonindigenous species in novel geographic locations for mariculture, (3) the open release of genetically-altered organisms, (4) the direct human-related social-economic impacts (including recreational, health, and industrial) that introductions have, both positive and negative, (5) the broad suite of ecological (including biodiversity) impacts that introductions have, and (6) the control of the geographic spread and of the abundance of exotic species. The first three appeal to the "ghost of Christmas future" in terms of anticipating and predicting the risks of future invasions; the fourth and fifth address on-going issues of impacts that have resulted or could result from successful invasions, as related in part to the alteration of aboriginal resources, and the last concerns both classical methods of control and management as well as the emerging field of marine biocontrol. In 1995 the National Research Council's major study on biodiversity, "Understanding Marine Biodiversity: A Research Agenda for the Nation," identified invasions of exotic species as one of the five most critical environmental issues facing the ocean's marine life. This type of focus, combined with the efforts of numerous international and national agencies, is essential to beginning to close the invasion flood gates that appear to have swung open since the 1970s.

ISSUES RELATED TO EXOTIC SPECIES INTRODUCTIONS AND BIODIVERSITY

by

James T. Carlton
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National Research Council (1995):

Marine Biodiversity: A Research Agenda for the Nation

Changes to Marine Biodiversity due to Anthropogenic Effects

* Fisheries Operations
* Chemical Pollution and Eutrophication
* Alterations in Physical Habitat
* Invasions of Exotic Species
* Global Climate Change

ISSUES CONCERNING NONINDIGENOUS AND GENETICALLY MODIFIED SPECIES

Prevention of Accidental Introductions

Utilization of Intentional Introductions

Utilization of Genetically Modified Organisms

Socio-Economic Impacts of Invasions

Ecological Impacts of Invasions

Controlling the Abundance and Spread of Invasions

Temporal and Spatial Patterns of Invasions

PREVENTION OF ACCIDENTAL INTRODUCTIONS

What Do We Have in Mind?

Dispersal Mechanisms (Vectors)

Ships:

ballast water, sea chests, anchors, hull fouling

Fisheries:

aquaculture non-target species; bait industry

Research/Educational Institutions:

releases

The Multiple Vector Challenge:
The Case of the Green Crab in San Francisco Bay

Ballast Water
Other Shipping Vectors
Fisheries products dunnage (seaweed)
Intentional Release
Research/Educational Institutions

Compelling (motivational) Species

Zebra Mussels

Vector Interception: When and How to Do It

Area of Origin -- In Transit -- Target (Recipient) Region

How to Intercept?

Who Do We Have in Mind?

(Predictive abilities: direct effects and cascading effects)

All Species

Target Species

of economic-social concern
of human health concern
of fisheries diseases concern

Education

Quarantine Science: Reduction, Rarely Elimination
Industrial Cooperation
Public Cooperation
Political Motivation

UTILIZATION OF INTENTIONAL INTRODUCTIONS

Promotion of Aquaculture/Mariculture: "Food from the Sea"
- Use of Nonindigenous Species
- Use of Indigenous Species

Level of Interest
- Private
- Regional (county, state)
- Federal

The Concerns
- Actual or Potential Impact (Predictive Capabilities)

Perceptions: Some Case Histories
- Pacific Oyster *Crassostrea gigas*
  - Pacific Northwest/Europe: Atlantic America
- Japanese Kelp *Undaria pinnatifida*
  - France: Australia
- Japanese Clam *Venerupis philippinarum* (= *Tapes japonica*)
  - BC+Washington/France: Oregon

ICES:
The International Council for the Exploration of the Sea

WGITMO:
Working Group on Introductions and Transfers of Marine Organisms (1979)

Reviews proposals for introductions in the North Atlantic Ocean

The Undaria Decision : Atlantic France

The Porphyra Decision: Maine/Canada

UTILIZATION OF GENETICALLY MODIFIED ORGANISMS

Viewing GMOs as Introductions

Releases in Open Systems:
Level of Control and Retrieval

Predictive Abilities

SOCIO-ECONOMIC IMPACTS

"What It's Going to Do ?"
"Is it Bad?" "Is it Good"
"Can we Use it for Something?"
"How Much Will It Cost Us?"
"Can We Get Rid of It?"

"Environmental Impacts"
= Human Values (First-Order Impacts)

The Issues?:

	Fisheries	Industry	Recreation	Aesthetics	Science
Positive	X	X	X	X	X
Negative	X	X	X	X	X

Reduction (Abatement) of Negative Impacts
How Much Will it Cost?

Expansion (Facilitation) of Positive Impacts
Economic Benefits

ECOLOGICAL IMPACTS

"Ecological Impacts" =
* consumers, competitors, disturbers, diseases
* extirpation/extinction of native species

Predictive abilities (cascading effects):

Post-Invasion Changes in Invasive Species
Bottleneck, Founder Effect, Genetic Drift
Altered phenological expression
Alter diets
Alter species interactions
(etc.)

"Most species appear to have little impact on the environment"

(the ecological interactions/impacts of most invasions have *not* been studied, perhaps because many species when inserted into communities attract little attention if there are no "macroscopic shifts" in community structure)

Reducing The Impacts (Abatement)

CONTROLLING ABUNDANCE AND SPREAD

Abundance: " How to Kill Living Things 101"
- Mechanical
- Chemical
- Biological (Autocidal; Biocontrol)
- Ecological (Habitat Modification)

Spread: Barriers, Prevention, Education
- * Pre-invasion: Defensive, rarely Offensive
- * Post-Invasion: Intranationally, rarely Internationally

Biocontrol
- * Freshwater: Aquatic Biocontrol
- * The Ocean: Marine Biocontrol

Education Campaigns

TEMPORAL AND SPATIAL PATTERNS

Why Invasions Still Occur

"Everything that could have been introduced would be here by now"

A Kaleidoscopic World:

Donor + Recipient Region Changes; Vector Changes; Inoculation Scale Changes; Invasion Windows

When Invasions Occur

When will a new species invade? (see "Why", above)
Are there more invasions or are we paying more attention?

Where are/will they be from?

Hot spot concept
Molecular genetics: tracing origins
: link to transport mechanism

Where Invasions Occur:

Resistance and Susceptibility

Example:

Disturbed, younger, and/or high seasonal variance ecosystems = ecosystems of lower diversity, for whatever historical reasons (glaciated rocky shores to weedy lots), thus more susceptible to invasions (but not always)

- **Link between:**
  ["scale" of dispersal mechanism]
  + [probability of introduction]
- **Successes and Failures**
  = these 2 concepts bridge why, when, and where questions

How Many

Determining Which Species are Native and Introduced
And therefore...Cryptogenic Species
Saturation levels

Who Will Invade?: Predicting Future Invasions

One's Philosophy of The Natural Order of Things

"Just Speeding Up Nature"
(It Would Happen Anyway)

"Humans are Part of Nature, thus Introduced Species are Only Part of the Natural World"
("Man and Nature" and "Man versus Nature" Debate)

NEW SPECIES IN THE GULF OF MAINE - HAVE HUMAN ACTIVITIES CREATED A POSITIVE VACUUM FOR INVADERS?

Larry G. Harris
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In recent years, several new species of marine invertebrates have appeared and become established in marine benthic communities of the south-western portion of the Gulf of Maine. The colonial tunicates *Botrylloides* and *Diplosoma* and the bryozoan *Membranipora* are becoming established in a variety of coastal habitats and they are joining the green crab, *Carcinus*, and another tunicate, *Styela*, which are more common in estuarine habitats. These species all have in common the facts that (1) they are still increasing their range in the Gulf of Maine, and (2) their impact in most habitats is still poorly understood. The most recently established species, the tunicate *Diplosoma* sp. which appeared at the Isles of Shoals in 1992, has recently demonstrated a capacity for growth and reproduction beyond anything previously observed in the Gulf of Maine. At one site at the Isles of Shoals, a population of *Diplosoma* increased from a few scattered colonies (less than .01% cover) to more than 60% cover of all surfaces over a depth range of 2 to 15m and an area of many 1000 square meters. This increase occurred in the Fall of 1995 in six weeks! A major problem for scientists and managers who would like to understand the potential impact of new species within the Gulf of Maine, is the rapidity with which benthic communities are changing due to the exploitation of commercial species. The typical climax community of shallow rocky habitats was replaced in the late 1970s and early 1980s by sea urchin barren systems. Recent heavy fishing of sea urchins has resulted in the return of algal dominated communities in some areas, but in many locations the composition is quite different from the previous kelp bed systems. The reduction in native species may have played a critical role in facilitating the success of some of the introduced species and the long term implications of these introductions and changes in community state are unknown. It will be critical that future management decisions be based on the best scientific information available if we are to avoid some of the mistakes of the past.

THE ROLE OF BALLAST WATER IN TRANSPORTING NONINDIGENOUS SPECIES TO U.S. WATERS

David L. Smith
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Marine Science Center
Nahant, MA

The introduction of nonindigenous aquatic species into coastal waters worldwide is having profound ecological and economic impact upon recipient communities and has generated concern regionally, nationally, and internationally. In recent years, a principal mechanism for transport of exotic species is their movement in ballast water of ocean-going ships. Used to maintain stability during a voyage, ballast water is actively pumped or gravitated into dedicated tanks and cargo holds at one port and released at other ports when receiving or delivering cargo. The volumes of water being released into U.S. waters are immense (> 57 million metric tons in 1991). Most ships carry a diverse assemblage of organisms in their ballast water, and a number of devastating invasions are now linked to ballast transport (e.g., zebra mussel in the Great Lakes; comb jelly in the Black Sea).

The potential for exotic organisms to invade depends on a host of factors, including species-specific characteristics, inoculum density and frequency, and physico-chemical similarity between source and recipient waters. I will summarize results of a recent study characterizing the amounts and sources of ballast water and the composition of plankton arriving to Chesapeake Bay. As the major gateway to New England, Boston and the Gulf of Maine are potentially at significant risk to ballast-mediated invasions not only from foreign ports, but also from domestic ports with established populations of exotic species.

ATLANTIC COD - REINTRODUCTION OF AN EXOTIC SPECIES IN THE GULF OF MAINE

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Fisheries resources in the northwest Atlantic have been described as being in crisis. The most recent landings data for many species of traditional commercial importance have shown consistent declines over the last decade. Similarly the spawning stock biomass of many of these species has declined, often reaching record low levels. Such declines have given rise to a heightened public awareness of the fishery resource problem and has ultimately led to changes in the management approach for these resources.

In contrast to the crisis for commercially important species the ecosystem itself might best be described as in a state of change. Although the commercially important stocks have experienced major declines in abundance, the total biomass of finfish has not. There is a well documented replacement of the commercial species by commercially lower value species like dogfish and skates. There has also been a recovery in the biomass of pelagic species like mackerel and herring. So, *in toto*, what has occurred is not a crisis in a biological sense but a shift to a new species equilibrium.

The crisis in the fisheries is, perhaps, more intellectual than biological. There are ongoing debates regarding the appropriate management steps to take so that the system can recover. The most recent analysis suggests that simply stopping fishing will allow the stocks to recover to their prior equilibrium. The unanswered questions in this argument are how long will it take, and, is there something that we can do to hasten the recovery?

A variety of management concepts have been proposed that address the issue of stock levels and resource harvesting. One of the concepts that is gaining momemtum, particularly for the Gulf of Maine, is marine stock enhancement. Although groundfish enhancement has a long and controversial history, there is currently little evidence that augmenting groundfish populations with hatchery-raised fish is beneficial. On the other hand, there is no direct evidence to disprove the concepts. In the context of the concern over the introduction of exotic species it is interesting to speculate on why the re-establishment of indigenous species would be so difficult.

The most recent attempts at groundfish stock enhancement began in Maine in 1993. Currently two private hatcheries are rearing Atlantic cod for potential release. At the same time the Maine Department of Marine Resources is developing a program of research to evaluate the efficacy of groundfish stock enhancement as well as a strategy for release of hatchery-raised fish. This program is experimental in nature but holds the promise of reestablishing a vibrant coastal fishery if only Alantic cod act like an exotic species.

MANAGEMENT ISSUES: PERSPECTIVES FROM NORTHEASTERN STATES - THE NEW HAMPSHIRE VIEW

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The keystone to protection from undersirable exotic species in New Hampshire is state law which covers Importing or Releasing Wildlife - (RSA 207:14). Rules that stem from this law are found in NH Code of Administrative Rules (Fis 800) "The Importation, Possession and Use of all Wildlife." Though defined specifically, "Exotic species" as a term plays little role in the language that protects against their importation, possession or release. Instead this protection is ensured by a requirement in 803.05 that deals with controlled species.

What then is a controlled species? They are all except listed noncontrolled (acceptable, nonthreatening exotics) or prohibited (totally unacceptable exotics) species. In effect then controlled species are exotic species that pose a potential threat. This rule clearly calls for a permit, issued by New Hampshire Fish & Game for the importation of a controlled (= exotic) species. In order to get such a permit one must apply to the Department and provide enough information such that a determination can be made consistent with the wording in the parent law which says the permit shall be denied if it is determined to "....." pose significant disease, genetic, ecological, environmental, health, safety or welfare risks to persons, marine species or wildlife." As additional safeguards, rules similar to those for importation cover possession and release of imported controlled (= exotic) species.

Also, newly promulgated (1995) aquaculture rules contain specific ties to importation and release of wildlife species rules and moreover they provide a permitting process control that pays particular attention to not only the introduction of non-indigenous species but also to distinct sources of any indigenous species. This of course recognizes the risk of importation of diseased stock where native stock is currently disease-free. Additionally, it provides some safeguard against introduction of cryptic exotic epifauna. The permitting process also provides discretionary safeguards as for example the requirement for aged dry-land stored cultch shell if the shell source is outside the area.

In summary, New Hampshire currently has laws and rules designed to protect our native marine resources from the unwelcome intrusion of exotic species. However, the protection offered by existing rules is not completed as can be seen by examples presented earlier of introduced exotic species in New Hampshire. While currently there is no pending law or rule changes that would tighten up on this, I can see this as a need. Unfortunately, things like this seem only to be accomplished after some very adverse episode brings such a need into the public spotlight.

IMPACTS OF SHELLFISH INTRODUCTIONS ON LOCAL COMMUNITIES

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The introduction of exotic or non-native bivalve species to coastal communities is appealing from an economic standpoint if it results in a new fishery resource or diversification of an existing aquaculture industry. Negative impacts from introductions, however, can result from three main sources: outbreaks of disease; inadvertent introductions of "piggyback" species; and competition with native species.

There are many examples of disease outbreaks associated with introductions. The introduction of *Crassostrea virginica* from New England to Prince Edward Island (P.E.I.), Canada, resulted in the outbreak of Malpeque Bay Disease in 1915. The sudden occurrence of *Haplosporidium nelsoni* (MSX) in Delaware Bay (1957) and later in Chesapeake Bay was likely the result of introductions on *C. gigas* from the west coast to the east coast. Outbreaks of *Bonamia ostreae* (Bonamiasis) can be traced to the introduction of *Ostrea edulis* from California to France, Washington, and Maine.

Species composition of many coastal ecosystems have been permanently altered by the inadvertent introduction of "piggyback" species. Examples include: the introduction of *Urosalpinx cinera* (a predatory gastropod) and *Crepidula fornicata* (a fouling gastropd) to Great Britain with the movements of *C. virginica* from the eastern U.S.; introductions of *Mytilocola orientalis* (a parasitic copepod) and *Sargassum* sp. (competitor of *Chrondrus crispus*) along with *Crassostrea gigas* introductions from Japan to France; and, introductions of *Ocenebra japonica* (a predatory gastropod), *Pseudostylochus* sp. (a predatory flatworm), and *Tapes philippinarum* (an edible clam) along with *C. gigas* introduced from Japan to the east coast of the U.S. beginning in the late 1800s.

Additional impact on local communities come from direct compeititon between the introduced species and one or more native species. For example, in France, *C. gigas* has completed replaced *C. angulata* and reduced the size and distribution of native *O. edulis* populations. *C. gigas* was introduced to Tasmania beginning in 1947, but spread to New South Wales, Australia where it now competes with the native *Saccostrea commercialis* and has consequently been declared a "noxious fish." On the west coast of the U.S., *C. gigas* has taken over most intertidal areas and has replaced the native *O. lurida*. In these instances, *C. gigas* has a competitive advantage over the native oyster species because it grows faster, is more fecund, and occupies a similar ecological niche.

Introductions of shellfish having a less serious impact on local communites have also occurred. *C. virginica* introduced to Great Britain from the U.S. was unable to reproduce because of prevailing cold temperatures. In the U.S., *C. virginica* and *Mercenaria*

mercenaria did not reproduce successfully when moved from the east coast to the west coast, but *Mya arenaria* is now distributed from Alaska to San Diego, California. In addidtion, *T. philippinarum* (introduced from Japan to the Pacific Northwest) has filled the warm, intertidal niche not occupied by a native species. In Maine, *O. edulis* introductions beginning in 1949 have resulted in a small, naturally reproducing population along the southern coast; however, this species appears to be limited by lack of substrate, cold winters, and disease. In these cases, direct competition between exotic and native species was precluded by the reproductive failure of the exotic species or the lack of niche overlap with native species.

Successful introductions will depend on the degree to which the negative impacts mentioned above can be avoided. In many cases, disease outbreaks can be avoided by spawning broodstock in quarantine and introducing only F_1 animals. This strategy is not effective for vertically transmitted pathogens, however. A prime example of this occurred in P.E.I., Canada, where *Perkinsus karlssoni* persisted for 10 generations in quarantined populations of *Argopecten irradians*. Most, if not all, "piggyback" organisms can be eliminated by spawning broodstock in quarantine and introducing only F_1 animals. Direct competition can be lessened by choosing species that would not occupy a niche similar to that of any native species or would be not capable of reproducing in the new environment. This approach is inexact at best, however, as the adaptive capability of the exotic species in the new environment cannot be entirely predicted. Controlled research can provide some answers.

When trying to determine likely competition between introduced and native species, there are several aspects that need to be considered. First, survival ability of the introduced species will depend on its resistance to local diseases, predators, and, ultimately, its environmental limits. Second, ability of the introduced species to grow will depend on environmental conditions such as temperature, salinity, and food availability. Third, ability of the introduced species to reproduce will depend on environmental conditions which control gametogenesis, spawning, larval development, and recruitment. The potential for interbreeding between native and introduced species should not be overlooked.

For several years, the state of Virginia has been contemplating the introduction of *C. gigas* to Chesapeake Bay to augment native populations of *C. virginica* which have been severely depleted by two diseases, *H. nelsoni* (MSX) and *P. marinus* (Dermo). Proponents of the introduction feel that *C. gigas* would provide economic stability to the area <u>and</u> provide a much needed filter feeder to the bay ecosystem. Opponents of the introduction feel that *C. gigas* would "take over" the bay. Unfortunately, the debate is going nowhere because of a lack of scientific information on which to base a decision. The only way to determine the ability of *C. gigas* to survive, grow, and reproduce in Chesapeake Bay is to conduct experiments directly comparing the performance of *C. gigas* with that of *C. virginica* in the local environment, given the limitations of working in quarantine.

Since 1989, research at the Virginia Institute of Marine Science and Rutgers University, using locally produced F_1 and F_2 *C. gigas* in both recirculating tanks and once-through flumes with on-land disposal, have established that compared to *C. virginica*, *C. gigas* is highly resistant to both *P. marinus* and *H. nelsoni* but has a higher overall mortality (related to salinity < 20 ppt); grows faster; undergoes a complete gametogenic cycle; and has a higher fecundity. In addition, it has been established that *C. virginica* and *C. gigas* cannot hybridize. What is not known, however, is what the survival and dispersal of larvae will be, what predation rates will be, and what the adaptive capability of *C. gigas* will be over several generations in Chesapeake Bay. All of these factors would determine its ultimate distribution along the east coast of the U.S.

In summary, the impacts of shellfish introductions on local communities can only partially be predicted with existing knowledge or determined through scientific endeavor. Although unwanted disease outbreaks and "piggyback" introductions can be largely avoided, impacts on communities from inter-species competition are more difficult to predict. In the past, the greatest impact on communities has occurred where native and introduced species occupy the same niche and/or where the introduced species grows faster and is more fecund than the native species. Ultimately, the ability of a species to adapt to a new environment will determine its ultimate success and distribution. Decision makers will have to weigh the potential economic gains of an introduction against possible effects on communities.

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AN AQUACULTURE INDUSTRY PERSPECTIVE ON EXOTICS, INTRODUCTIONS AND TRANSFERS

Robert B. Rheault
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Ocean State Aquaculture Association
NRAC

Everyone has heard horrific tales describing the unforseen consequences of introductions of various exotic species, whether intentional or accidental. In response to these tales, it is easy for our resource managers to clamp down on aquaculturists and simply prohibit the culture of any non-indigenous species. However, this approach ignores the potential of certain well-managed introductions to do tremendous good for society with minimal risk to the environment. The subject has led to a polarized debate where rational educated discussion is warranted. The subject is neither black nor white, but rather a vast area of gray that needs to be examined in detail so that sound recommendations can be made based on the best scientific evidence available. I hope to examine some of these gray areas and raise some new questions for discussion.

DISEASES OF BIVALVES

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The occurrence of disease depends on the interaction of three factors: virulence of the agent, susceptibility of the host population, and characteristics of the environment. The economic viability of molluscan aquaculture may often depend on the morbidity and mortality resulting from disease in the cultured animals. Several diseases have been identified in cultured bivalves. This paper identifies four of the most important diseases in three commonly cultured bivalves.

Crassostrea virginica

Traditionally, one of the most important cultured bivalves on the east coast of the United States is *Crassostrea virginica*, the eastern oyster. Two important diseases occur in adult *C. virginica*.

A. Multinucleated Sphere with unknown affinity (MSX) (Ewart and Ford, 1993; Ford and Haskin, 1982; Sparks, 1985)

MSX is caused by *Haplosporidian nelsoni*. This protozoan parasite was first seen in 1957 and 1958 in the Delaware Bay. Mortality reached 95% of all oysters in the bay during that epidemic. Since then, the parasite has become endemic in the bay and the parasite has been identified in oysters from Maine to Florida. It was first seen in oysters from Wellfleet, Cape Cod in 1967.

The infectious stage of the parasite enters via the gills, develops plasmodia that proliferate and spread throughout the animals' tissues and eventually causes the death of the oyster. Most animals die during the late summer and early fall. It takes about two summer seasons for the parasite to kill the oyster. In order for the parasite to grow, oysters must be in > 15 ppt salinity seawater. The parasite is adversely affected by lower salinity water. An intermediate host for the parasite is believed to exist based on epidemiologic factors, but has never been identified. Warmer temperatures promote proliferation in the tissues. If winters are warmer than usual, an increase in severity and prevalence of the disease is noted in the following summer.

Management methods

1. Do not move juvenile oysters to higher salinities (> 15 ppt) until after end of July.

2. Monitoring of affected populations should be ongoing in order to determine morbidity and mortality.

3. Do not transfer infected animals to uninfected areas.

4. Lines of resistant oysters are being developed.

B. "Dermo" (Ewarts and Ford, 1993; Sparks, 1985)

Dermo is caused by *Perkinsus marinus.* This protozoan parasite was first identifed in 1950 in oysters from the Gulf of Mexico. Originally, the parasite caused disease in oysters from the Gulf of Mexico to the Chesapeake Bay. Since 1990, the parasite has been identified in oysters from both mid and north Atlantic coastal locations. Dermo has recently been identified in cultured oysters from Massachusetts coastal waters.

The digestive system, gills and mantles are the primary tissues infected by the parasite. The infective aplanospore undergoes endosporulation resulting in a sporangia containing up to 64 new aplanospores which are liberated by lysis of the mother cell wall to repeat the cycle again. The organism eventually fills up the tissues and causes the death of the animal over approximately two summer seasons.

The parasite grows best in clam tissues at > 12 ppt salinities but it does exist in the tissues at low salinities. Warmer temperaturs promote the growth of the organism in the tissues. Unlike MSX mortality appears to increasingly escalate in successive years at infected locations. Although, cold winters decrease morbidity and mortality considerably in the northeast coastal areas. Most animals die during the late summer and fall.

Dermo is a directly infective organism. No intermediate host is required although physical transport of infective stages between oysters is helped along by the parastic snail, *Boonea impressa.*

Management methods

1. Plant seed oysters late in the summer to delay infection but still allow some time for growth before winter begins.

2. Do not transport infected seed or brood stock to uninfected sites.

3. Removing all oysters from the flat and letting the flat "lie fallow" for a season decreases the concentration of the parasite in the flat.

4. Develop resistant animals.

5. Monitoring of affected populations should be ongoing in order to determine morbidity and mortality.

Ostrea edulis

An oyster that many culturists have considered as an alternative to *C. virginica* on the east coast is *Ostrea edulis*. The flat oyster has been introduced and does exist as commercially viable population in some locations in Maine. Unfortunately, this bivalve catches diseases that are just as horrible as the eastern oyster's disease.

A. Bonamiasis (Microcell) (Elston et al., 1986; Friedman and Perkins, 1994; Montes et al., 1994; Sparks, 1985)

Bonamia ostrea is the cause of Bonamiasis, also called Microcell disease. The protozoan parasite was first seen in California in 1969, but was not identified until 1979 in France. Bonamiasis is a severe problem in flat oyster culture in Europe and has spread up and down the European coast. *Bonamia ostrea* is thought to have been imported from Callifornia to France along with the oysters between 1969 and 1979. More recently (1991 and 1992), it was identified in flat oysters in Maine. These oysters were also originally imported from Calfironia. The parasite causes disease resulting in up to 80% mortality within six months of infection in a previous unexposed population of flat oysters.

The infective form is a small 2.5 micron cell which is ingested by hemocytes (an oyster blood cell). *Bonamia* proliferates within the homcyte eventally destroying it. The new Microcells then invade other hemocytes and repeat the cycle. *Bonamia* has also been identified in gill epithelium in infected animals. The organism is directly infective. At the present time, it does not appear that temperature and salinity affect the transmission of the parasite or proliferation of the parasite in the oyster tissues.

Management methods

1. Do not transport infected seed or brood stock into uninfected sites.

2. Develop resistant oysters lines.

3. Do not import new species of bivalves to new locations.

Mercenaria mercenaria

In the last decade, hard clams have become the cultured bivalve of choice on the east coast. This change is primarily due to the disease problems encountered in the oyster culture and the apparent lack of disease in hard clam culture. However, even hard clams have significant disease!

A. Quahog parasite X (QPX) (Sparks, 1985; Whyte et al., 1994)

Recently, QPX-like disease was diagnosed in two populations of cultured hard clams on the coast of Massachusetts. The disease has been increasing in prevalence and severity with succeeding years in the Provincetown, Cape Cod clam flats. QPX-like disease has been noted to cause an 80% cumulative mortality in an original planting of seed clams in one flat from Provincetown. In 1989, QPX disease was identified as the cause of severe morbidity and mortality in hard clams less than 30 mm in shell height in a hatchery on Prince Edward Island, Canada, and was responsible for mortality up to 100% in some stocks of clams in that hatchery.

This disease is caused by an endosporulating protozoan parasite, tentatively classified as a thraustochytrid. The organisms appear to directly infect first the tissues of the mantle and gill and then spread throughout the clam's body. Secondary bacterial infections appear to be common during the summertime. Morbidity is highest during the summer but is noted in all seasons.

Work is currently underway to determine characteristics of the disease and methods of management.

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SEAWEED MARICULTURE AND THE USE OF INTRODUCED AND GENETICALLY MODIFIED SPECIES

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Over the past twenty years, seaweed cultivation has expanded greatly. Currently, most of the world's seaweed raw material consumed either directly as food or used in food and pharmaceutical industries is produced on seaweed farms in western Pacific and Asian countries such as China, Japan, Indonesia and the Philippines. Seaweed cultivation is economically important to numerous western Pacific countries, especially some lesser developed countries where it provides a valuable alternative source of income to coastal inhabitants where traditional fisheries have declined. In the Philippines, for example, *Eucheuma* cultivation currently provides a livelihood for over 80,000 seaweed farmers and more than another 200,000 people indirectly. In addition to its obvious economic benefits *Eucheuma* farming has also contributed greatly to the social and political stability of previously more unstable regions. *Laminaria* cultivation has been similarly important to the economy of undeveloped coastal regions of China, while *Porphyra* (or nori) cultivation is one of the world's largest mariculture industries, worth over 2.5 billion US dollars in Japan and China alone.

As in land plant cultivation, much of the success of today's seaweed cultivation is due to the development of new and improved strains, as well as to the introduction of such strains into new locations. In Zanzibar, for example, fast-growing strains of *Eucheuma spinosum* were deliberately introduced from the Philippines which resulted in a viable new seaweed cultivation industry in just four years, today it provides income to over 16,000 farmers, with no apparent harmful environmental effects. In our own region, efforts are underway to cultivate nori in Eastport, Maine, using a nonindigenous, Japanese strain of *Porphyra*, *P. yezoensis*. The company involved, Coastal Plantations International, obtained permits to grow this species from local, regional and international (e.g. ICES) authorities, based upon the species's inability to sexually reproduce in the cold waters where it would be grown. Not surprisingly, *P. yezoensis* does not grow as optimally in Maine waters as it does in Japan; therefore, efforts are underway in my laboratory to develop new, genetically improved strains of *P. yezoensis* utilizing modern genetic manipulation (protoplast fusion) techniques. I believe that the introduction of such genetically modified (not genetically engineered) strains may ultimately determine the economic viability of such cultivation efforts in developed countries like the US, and that it can be done in an environmentally safe manner. While regulations governing the introduction of genetically modified organisms (GMOs) are no doubt necessary, it should be recognized that not all introductions necessarily pose a real environment threat and that introductions of nonindigenous organisms (including GMOs) need to be considered on a case by case basis.

BIODIVERSITY IMPACTS OF CONVENTIONAL VS. INNOVATIVE MARICULTURE : THE RIGHT WAY FOR NEW ENGLAND

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Mariculture is frequently touted as a tool for conserving marine biological diversity and enhancing the sustainability of coastal fisheries. While such advantages are theoretically attainable, mariculture as currently practiced is unsustainable. Its expansion in New England severely threatens marine biodiversity as well as the long-term viability of marine resource-based industries in the region. Impacts include coastal habitat degradation, accidental or deliberate introduction of exotic species and pathogens, contamination of wild stocks, and the ecological impacts of feedstock fisheries. The need for aquaculture feed generates many of the same problems as traditional fisheries, just on trophic level removed: e.g., bycatch, entanglement, habitat destruction, competition with marine mammals and birds, and energy costs. Naturalization of exotic aquaculture target species is highly probable due to the intrinsic vulnerability to invasion of marine systems, the invasive attributes of taxa that prosper in aquaculture systems, and political pressure to introduce species perceived as more valuable than indigenous taxa. New England has already demonstrated its susceptibility to the above mentioned risk factors, and proposals to expand mariculture in current form should be rejected. However, such features as polyculture, waste recycling, closed-systems, and use of indigenous taxa are of proven efficacy, and represent the vanguard of a new generation of aquaculture technologies. The concentration of academic, technological, and industrial resources in this region constitutes a premier opportunity to implement, advance, and market more sustainable forms of mariculture. The old approach to mariculture lowers investment risk by maximizing risk of failure on long-term returns. Innovative mariculture reduces long-term risk but requires up-front investment in resesarch and development, things that the New England region is very good at. Thus a focus on sustainable mariculture development, as opposed to conventional mariculture on a massive scale, is biologically, environmentally, and economically the most advisable course for New England. The actual choice lies effectively with lawmakers and permitting agencies.

GENETICALLY MODIFIED FINFISH AND SHELLFISH

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Biotechnology can be defined as the application of technology to the genetic material of living organisms for practical purposes. Biotechnology includes methods for genetic modification of aquatic organisms, such as gene transfer, chromosome set manipulation, and interspecific hybridization. Research and development activities target application of biotechnology to problems in fisheries management and aquaculture. Although realized or potential benefits are clear, potential hazards posed by certain biotechnologies might limit their application.

What are the potential benefits of biotechnology in aquaculture?

Biotechnology can improve the productivity and profitability of aquaculture in two ways. First, it can increase the efficiency of production, for example, by contribuing to the development of faster-growing lines. This might be approached by transfer of a gene for a growth factor, such as growth hormone. Devlin et al. (1994) reported dramatic results for transgenic coho salmon, *Oncorhynchus kisutch*, with growth rate among transgenic families on average 11 times greater than controls. Since we really are interested in quantifying growth rate enhancement in true-breeding lines stably inheriting the transgene, we should wait and ask the question anew for the F_2 generation. The critical unanswered question ultimately to be faced is whether the dramatic acceleration of growth observed for certain transgenic stocks at the experimental scale also will be observed upon scale-up to commercial systems.

Triploidy induction can be applied as an effective means of achieving reproductive sterility, supporting culture of exotic species while minimizing risks of establishing self-sustaining populations. The most notable example of this application is in commercial production and sale of triploid grass carp, *Ctenopharyngodon idella*. For species marketed after sexual maturity, triploidy can increase production by affecting the allocation of energy from reproduction to somatic tissue growth, as in triploid Pacific oyster, *Crassostrea gigas*. However, the growth performance among triploids has proven highly variable among species, with some species exhibiting increases and others not.

Interspecific hybridizaton long has been used as a means of combining the favorable production characteristics of the parental species. Perhaps the best example is commercial culture of hybrid strped bass, which exploits the rapid growth and market acceptance of striped bass, *Morone saxatilis*, and the hardiness of white bass, *M. chrysops*.

A second way that biotechnology can improve the efficiency and profitability of aquaculture is to minimize losses, such as those to disease, through development of disease-resistant strains, vaccines, or diagnostic tools. Gene transfer has been posed as a means of improving disease resistance in aquatic organisms. Before we can purposefully use gene transfer, we must answer basic questions regarding the molecular genetic basis for disease resistance in fishes and invertebrates. Certain experiments have suggested that interspecific hybridization and ploidy manipulation might improve disease resistance in cultured stocks. Key questions are whether these results prove repeatable and whether these interspecific hybrids and triploid hybrids prove attractive aquaculture candidates.

There are significant questions concerning the impacts of released or escaped cultured fish on wild stocks (Hindar et al. 1991). A number of biotechnologies, notably triploidy induction, have been applid to reproductive control. When we culture interspecific hybrids such as hybrid striped bass, reproductive confinement can minimize or eliminate any risks of backcrossing with either parental species. When we culture exotic species, such as grass carp, reproductive confinement can minimize or eliminate the risk of the species becoming established, and perhaps becoming an aquatic nuisance species.

What are the potential risks of application of biotechnology in aquaculture?

We can anticipate ecological risks to a range of species with which the genetically modified organisms (GMO) interacts in the accessible ecosystem, and genetic risks to conspecific natural populations. Ecological risks include the possibility of heightened predation or competition, colonization by or persistence of modified organisms in ecoystems outside the native range of the species, and possibly, alteration of population or community dynamics due to activities of the aquatic GMO (Kapuscinski and Hallerman 1990, Hallerman and Kapuscinski 1991). Should GMOs be fertile, they could interbreed with natural populations. Any impacts would depend on the fitness of novel genotypes in the wild. We have to consider cases where fitness relative to wild type is high, and also the opposite case where genetic load might be introduced into native populations. Reproduction of GMOs would also prolong any ecological effects beyond the one generation at issue for sterile GMOs.

Use of sterile GMOs reduces but does not eliminate risk. Even sterile organisms compete with conspecifics. For small natural populations, this could limit the number of potential spawners, causing a population bottleneck. Male triploids of at least some species undergo steroidogenesis, produce functional spermatozoa, and may attempt to spawn, leading to losses of the resulting aneuploid broods. Key unanswered questions concern the reproductive behavior of triploids in the field and the potential impact of such behavior on population dynamics.

An additional question that should be considered is whether triploidy is necessarily permanent. The question is raised by the surprising results of a study by Stan Allen. Stan and Roger Mann hypothesized that Pacific oysters might be resistant to the diseases MSX and dermo, which devastated the native east coast oyster. They set out trays of triploid Pacific oysters in Delaware Bay and in the York River in Virginia. They periodically removed a few for disease inspection and triploid verification. After a diploid was found, a followup found mosaic individuals with both triploid and diploid cells. The last 85 oysters were removed from the York River, and 20% of them were mosaics apparently in the process of reverting to diploidy. This is the first known incidence of progressive reversion. The questions it raises are, "How common or rare is this phenomenon?" and "What are the implications regarding triploidy as a means of reproductive control?"

Interspecific hybrids of many aquatic species are fertile. Release of such hybrids into an ecosystem containing either or both parental species introduces the genetic risks of backcrossing and introgressive hybridization. One example of interspecific hybrids posing risk to parental species arises from the stocking of hybrid striped bass to establish sport fisheries in reservoirs. Evidence of introgressive hybridization has been documented in *Morone* stocks in the Chesapeake Bay, Savannah River, and Lake Palestine, Texas.

How can we quantify any potential risks? No single experimental approach is likely to lead to the full range of needed data. We'll need to pursue a combination of laboratory, field, and simulation modelling approaches. The first experiments approaching risk assessment are yielding results.

William Muir, Richard Howard, and Chris Bidwell of Purdue University had a U.S. Department of Agriculture (USDA) Biotechnology Risk Assessment Program grant to use transgenic medaka, *Oryzias latipes*, as a laboratory model system. The project is addressed adaptability and genetic stability of transgenic fish in artificial environments, with implications to native habitats. It was found that individuals expressing an introduced growth hormone gene grew larger, and that large males secured more matings. However, transgenic young were less viable, threatening the demographic viability of the population.

Rex Dunham of Auburn University had a USDA grant to assess risk posed by research with transgenic channel catfish, *Ictalurus punctatus*, expressing an introduced growth hormone gene. The study addressed potential mechanisms and likelihoods of ecological and genetic impacts. The central issue was the fitness of transgenic stocks relative to non-transgenics. The quantification of relative fitness focussed on three aspects of channel catfish ecology - predator abundance, foraging ability, and reproductive ability - and involved experiments following whether the frequencies of transgenic genotypes increased, decreased or remained the same as those of control genotypes. Among transgenic catfish, the growth hormone gene had no effect on survival, age at maturity, or disease resistance. It was tentatively concluded that the frequency of the transgene is likely to track initial frequency, unless the transgene is linked in a given family to wild genes for predator avoidance. In a related experiment, among transgenic common carp, *Cyprinus carpio*, expected inheritance rates for the transgene were not observed, suggesting differential mortality or unstable integration. However, from 30 grams on, transgenic carp exhibited as good or better survival rates than control carp. Under a dissolved oxygen challenge, transgenic individuals lived longer before they died, suggesting greater fitness in this regard.

How should we approach biotechnology R&D?

Given our desire to pursue research with incomplete information, how should we approach biotechnology (R&D)? Although risk presently cannot be characterized quantitatively, it can be anticipated qualitatively. This suggests the possibility of using a risk assssment and risk management framework to identify possible hazards and to carry out research with appropriate confinement. The researcher is not without tools in this regard. The U.S. Department of Agriculture (USDA) Agricultural Biotechnology Research Advisory Committee (1995) adopted Performance Standards for Safely Conducting Research with Genetically Modified Finfish and Shellfish. By helping researchers cost-effectively manage risk, if any is identified, it is hoped that the Performance Standards will stimulate reseach with aquatic GMOs. A computerized expert system has been developed to support use of the Performance Standards, intended to facilitate implementation of the standards by researchers and fisheries managmeent authorities. Copies of the expert system can be obtained by writing Information Systems for Biotechnology (Department of Biochemistry, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061), or, eventually, by downloading them from the Internet at http://www.nbiap.vt.edu.

We can anticipate one field test of particular interest to fisheries managers in the Northeast. A/F Protein, of Boston, is developing transgenic Atlantic salmon, *Salmo salar*, for production in cage culture operations. These fish express a salmon growth hormone gene under the control of an antifreeze polypeptide promoter. Expression of the transgene is expected to occur only in winter. In culture situations, fish would be fed, supporting continued growth through winter when feeding generally stops. Should these fish escape, so the argument does, lack of food in the wild would limit growth and, therefore, any possible ecological impacts. Is this a sufficient safeguard? Though it seems plausible, we cannot definitvely say without field data. Elliot Entis, CEO of A/F Protein, says that only sterile fish ultimately will be licensed to growers, to minimize risk and also to protect investment in R&D.

Commercial applications

Let's move from R&D, and look farther along the product development pathway to commercialization. Certain biotechnologies have already led to commercial application. Examples include: monosex rainbow trout, *Oncorhynchus mykiss*, triploid grass carp, and triploid Pacific oysters. Triploid Atlantic salmon seem on the verge of commercialization. These particular applications pose little or no risk; indeed, application of triploidy minimizes genetic risk.

However, certain other biotechnologies, such as certain gene transfers, may pose considerable risk. Development of some of these GMOs is going forward rapidly. As these GMOs become more widely produced, the likelihood of undesired outcomes increases. It's appropriate to ask whether scale-up will affect risk. We have not adequately addressed certain key issues posed by scale-up. In the interim, and maybe over the long term, for transgenic stocks posing risk, on-shore tank culture may be the appropriate mode of production.

What is the appropriate role for biotechnology in fisheries management and aquaculture?

In some applications, for example, culture of triploids, biotechnology minimizes potential ecological or genetic impacts of aquaculture. In other applications, such as certain transgenics, biotechnology may pose risk. Early results indicate that neither safety nor risk are absolute. Assessing the appropriateness of biotechnology for a given purpose will involve case-by-case analysis requiring application of all current knowledge and the best judgement of fisheries scientists, managers, and aquaculturists. As our base of knowledge increases, our judgement of the appropriate role of biotechnology in fisheries management and aquaculture will evolve. I anticipate that biotechnology will play an increasingly important role. The charge to us as fisheries scientists and managers is to generate useful knowledge and to render the best judgements we can.

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FARMING EXOTIC SPECIES IN CLOSED SYSTEMS: AQUAFUTURE'S EXPERIENCES IN MASSACHUSETTS AND WITH THE ICES WORK GROUP ON INTRODUCTIONS

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AquaFuture Inc. has grown "exotic" fish in proprietary recirculating systems for over seven years in Massachusetts. We have worked extensively with state and federal authorities to ensure no fish escape and to safeguard our watershed from introduction of exotic diseases. Details of preventative measures are given. Also described is AquaFuture's response to the Code of Practice guidelines developed by the International Council for Exploration of the Seas (ICES) Workgroup on Introductions and Transfers of Marine Organisms to import hybrid striped bass for fish culture in Ireland.

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Sea Grant College Program

January 31, 1996

Dear Exotic Species Workshop Participant:

The enclosed white papers highlight issues relating to biodiversity in marine ecosystems and provide background information relevant to the upcoming Workshop on Exotic Species. The *Introduction of Exotic Species in Marine Environments*, prepared by Jessica Morton who was an Intern at the Massachusetts Institute of Technology Sea Grant College Program with Judith Pederson, provides a broad overview of issues relating to species introductions into marine environments. The paper discusses how organisms can be transported and reviews the likelihood for exotic species becoming established, as well as, emphasizing potential impacts on the ecosystem. The specific issues relating to mariculture (or aquaculture) are discussed in the context of potential risk and how negative impacts might be minimized. These are issues of major economic and social importance as pressure to feed our increasing human population mounts. Regulations are also briefly discussed and overall approaches to managing introductions are reviewed.

The *Summary of State and Federal Programs Regulating the Introduction of Exotic Marine Species* was prepared by Tay Evans who was an intern with Susan Snow-Cotter at the Massachusetts Coastal Zone Management Office. This paper reviews the status of federal and state regulations, legislation and policies based on available information. Only New York State has met the requirement of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (also known as the Zebra Mussel Act).

Both papers are based on the available information and references we could identify in the time available. We encourage the participants to review and provide comments and suggestions. Because of the difficulty in getting information about federal and state programs, we recognize there may be errors of omission, commission or interpretation in the reviews presented.

We look forward to your participation in the workshop on February 8, 1996 at the Draper Laboratory.

Sincerely yours,

Judy Pederson

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ISSUE PAPER

INTRODUCTION OF EXOTIC SPECIES IN MARINE ENVIRONMENTS

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INTRODUCTION

The introduction of exotic species is described by E.O. Wilson in the *Diversity of Life* (1992) as the second leading cause of environmental degradation today. Exotics, also known as nonnative, alien, nonindigenous, invasive, foreign, immigrant and introduced species, are generally considered to be organisms that have moved beyond their natural geographical range, exceeding normal expansion of their habitat. This rarely happens without human intervention. The increasing mobility of people has led to an increasing number of organisms being transported with them, both accidentally and deliberately. Although many organisms do not survive the transition to a new environment, a few thrive and spread unimpeded. The Mediterranean fruit fly (medfly), the European gypsy moth, and the zebra mussel alone are accountable for ecological disasters in widespread areas of the United States and millions of dollars in damage and control costs every year. These and others have negatively impacted terrestrial and aquatic ecosystems and are, in part, familiar to us because so many people have been affected. Less familiar, although not necessarily of less importance, is the invasion and subsequent loss of native ecosystems and species in the marine environment. The intent of this report is to review issues involved with exotic marine species introductions in the hope that this important issue will receive necessary attention.

The lack of attention and research on exotic species in marine environments is attributable to a number of causes. Humans live mainly in the terrestrial world, and most of the marine world is not visible to the human eye. Boundaries within the ocean waters are not quite so easily defined as on land, and water pays little attention to political borders. Humans are generally not affected as directly by a change in marine ecosystems, and as of yet, no marine exotic organism has caused damage equal to that of the zebra mussel or medfly. In fact, until recently, when such issues as depletion of world fisheries and the loss of coral reefs focused attention on the oceans, it was not even conceivable humans could significantly impact marine ecosystems. There also have not been marine extinctions anywhere near the scale now occurring in some terrestrial environments, although whether this trend will continue is debatable. Global trends such as a growing international commerce and the depletion and loss of wild fish stocks will only increase exotic species in state and federal ocean waters as organisms are transported via ballast water to U.S. ports and the use of commercial species in mariculture and to replenish overfished wild stocks becomes more common. The National Academy of Science sponsored a Workshop on Biological Diversity in Marine Systems, May 24-26, 1994 in recognition of the need to better understand the ecology of marine organisms to prevent irreversible damage to living resources. *Understanding Marine Biodiversity* (Carlton and Butman 1995) summarizes the outcome of the scientists gathered to identify scientific issues and recommend an initiate that is socially responsible.

Policies and regulations concerning exotic species are often inadequate in dealing with the problems presented by introductions of exotics into the marine environment. They are not easily or effectively enforced, are not specifically directed towards or tailored to meet the conditions of a marine environment, and they vary from state to state. States with strict controls that share a coastline with states with less strict controls may nevertheless be affected by the accidental or intentional release of an organism, since, once an organism is established, it is virtually impossible to eradicate by any reasonable method. Even if regulations in some states impose tight controls on intentional introduction of a species for mariculture, most do not address the issue of accidental release via ballast water. Two Sea Grant publications from recent workshops review issues relating to introductions of nuisance species and regulations intended to minimize risk without prohibiting rational sustainable use of the ecosystem (DeVoe 1992 and Balcom 1995).

If the cost of exotic species introductions is measured not in dollars but in habitat alteration, loss and displacement of indigenous species and, ultimately, a reduction in marine biodiversity, it will be costly. However, human population and its dependence on the sea for food and other products is increasing, and there are viable social and economic benefits in introducing exotics. With responsible methods to control or minimize impacts, perhaps a compromise between the two can be reached.

BACKGROUND

It is difficult if not impossible to account for the number of species transported by humans from one marine environment to another. Not until fairly recently have inventories of species been taken, but the movement by humans across the oceans and subsequent transportation of other species has occurred for thousands of years. However, most introductions were not recorded, and there is nothing with which to compare present inventories. This makes the identification of an introduced species very difficult and it is often only by patching together a global picture of species' geographical locations and genetics that an original environment can be determined (Carlton 1985).

Methods of introduction.

In the past species have traveled across oceans through various mechanisms. They may be introduced intentionally -- in the last century it was United States policy to "transplant all potentially useful species everywhere else" (Hedgpeth 1980). They can attach themselves to the hulls of ships or accompany other introduced organisms. They also can migrate into new bodies of waters through the construction of canals.

In 1908 ballast water was first suggested as a mechanism for introduction, but it wasn't until 1985 that a comprehensive study of ballast water was published (Carlton 1985). Ships use ballast waters to provide stability when they are not carrying cargo, but expel it when they reach their destination and take on a load. Larger ships can take in over 150,000 tons of water, including living organisms in the water column and from sediments located near ballast water intakes.

As ships become larger and faster, and shipping traffic more frequent, ballast water becomes a more effective way to transport these organisms from port to port. Recent studies have recorded the release of hundreds of taxa in foreign environments. Williams *et al.* (1987) recorded two fish species, 22 zooplankton and 45 other taxa in the ballast water of bulk cargo ships sailing from Japan to Australia. Hallegraeff and Bolch (1991) attributed the spread of toxic dinoflagellate cysts, including those responsible for paralytic shellfish poisoning in humans, to ballast water movement as well as the movement of shellfish stocks. Carlton and Geller (1993) counted 367 taxa released into Oregon waters from Japanese ballasts. Because of this high number of introduced species, bays, estuaries and inland water are described as "one of the most threatened ecosystems on the planet" (Calton and Geller 1993). Ballast water transport is now estimated to be the principle means of accidental introductions of exotic species in the marine environment.

Another method of accidental dispersal of exotic species is directly related to the intentional introduction of commercial mariculture to a region. Microorganisms that 'hitchhike' on commercial species, can be transported through the water column causing detrimental effects to native ecosystems. As long as they have access to the water column, microorganisms can be a problem even in cases where the hosts are contained in restricted areas or in pens. Various invertebrates were detected hitchhiking on the eastern oyster *Crassostrea virginica* when it was introduced into San Francisco Bay in the 1870s (Hedgpeth 1980). This was also the case when the introductions of salmonids into North American waters led not only to competition with and predation of native fishes, but to the spread of diseases and parasites among them (Krueger and May 1991). Fear of the introduction of the bacteria *Vibrio* along with the Pacific oyster has also led to controversy involving its release into Chesapeake Bay (Baker 1992).

Adaptation and Survival

The survival of an introduced species depends on a number of factors, and for this reason it is difficult to predict. In general, the environment that the organism is released in must allow for survival. The condition of the environment also plays a role, as environments already stressed by pollution, shipping traffic, dredging and human development, and previous invasions are more susceptible to new invasions (Carlton and Geller 1993). Organisms that can survive transportation may also be more likely to survive in a stressed environment. The time spent in a ballast tank during transportation is also an important factor. Shorter voyages would suggest a higher rate of survival, as the water will be fresher and there will be less time for the food chain to break down in (Carlton 1985).

While it may seem too late to do much regarding the accidental release of exotics through ballast water exchange, since it has occurred since the beginning of this century, the idea that 'everything that could be there is already there' is not true. Invasion of new exotics is happening even now and it will continue to occur. This is probably due to a number of causes. The environmental conditions in the receiving ports may change, *i.e.* they may become more polluted or stressed making introduction easier. The donor port may also change as trading between ports of different nations changes. Technological advances in transportation will also continue to affect the health and number of organisms released, as faster ships are able to dump fresher ballast water in port.

Once dispersed into a new environment the organism is more likely to die than survive and reproduce. Its adaptability, including tolerance to temperature and salinity changes and its reproduction rates, will affect its survival, although other factors such as available food sources and predation play a role. Once established in a new environment the nonnative species may not do very well or may become hybridized with a native species, making detection difficult. For this reason studies on the survival and adaptability of exotics are difficult. Unless a species becomes a 'nuisance,' *i.e.* it succeeds in its new environment to the extent that it out competes native species, threatens them, and also affects humans, it can go unnoticed. Within scientific communities there is often a lack of communication about introduced species, and even while some studies may inadvertently identify an exotic, that is rarely the goal. The results of introductions are also understudied, including the effects on coastal ecosystems, on estuaries, and even on mariculture.

AFTER "MARICULTURE"

The introduction of nonindigenous species into the marine environment can be beneficial, cause little harm, or even have mixed consequences. When a species introduced to a seriously degraded ecosystem helps rebuild it by providing a missing link in a food chain, it can be beneficial to that ecosystem. An introduced game fish can provide people with food and recreation, but may cause damage to the ecosystems into which it is introduced and into which it spreads. This chapter is concerned mostly with the negative effects, as these more often than not outweigh any positive ones.

Loss of biodiversity

The most important consequence an introduced species can have on an ecosystem is to bring about the extinction of a native species, thus affect the biological diversity of that ecosystem, and ultimately of the world. Biological diversity, or biodiversity, is the variability of living organisms in a given area, whether that be a local ecosystem or the entire planet. It includes variability at the genetic level within a species, between species and even between ecosystems. At the 1992 United Nations Conference on Environment and Development at Rio de Janeiro the issue of biodiversity was considered so critical that a separate convention was held specifically to address it. The conservation of biodiversity was recognized as crucial for its "genetic, ecological, social, economic, scientific, educational, cultural, recreational and aesthetic values" as well as for its importance for "evolution and maintaining life sustaining systems" (U.N. document 13.15, Convention on Biological Diversity 1992). Biodiversity provides a safety net for world ecosystems. Without a variety of organisms both within and between species, an ecosystem may not be able to adapt to changes imposed by disease, pollution or natural disasters. Homogeneity leaves an ecosystem unable to adapt to these changes, making it vulnerable to breakdown with the loss of even a single vital species in the food web.

Biodiversity of an ecosystem can be affected by the introduction of an exotic species in a number of ways. An introduced species may compete with and out compete native organisms for food and space, and an especially aggressive species can replace a native one in their ecological niche. The introduced species may also be predatory and feed on native species, who more likely than not would not have evolved with any defense against the sudden introduction of a new predator. The introduced species may also be able to interbreed with native ones, causing hybridization and 'genetic pollution.' This affects local gene pools of native species and can result in loss of genetic variability. Breeding between two closely related species may also produce offspring with reduced rates of growth and survival (Krueger and May 1991; Hindar *et al.* 1991). An exotic species can also carry diseases, parasites, bacteria, and viruses that affect native species. As these effects occur throughout marine environments certain non-native species spread and other local species are adversely affected; the marine world becomes more homogenous and its biodiversity is threatened.

The marine world

Although more diverse by far at the phylum level, the marine world has not seen the kind of attention given the terrestrial world as regards the loss of biodiversity. The changes going on are much more subtle than the mass destruction of terrestrial ecosystems. It is still not apparent whether any species have gone extinct, as it was not until very recent that many marine organisms could be monitored, and there is still much that is not known about their habits. However, it is not necessarily a question of which ecosystems have more species diversity, but rather what roles those ecosystems play globally. The question of value of a species is inherently judgmental, and cannot be made without a more complete knowledge of marine ecosystems than is now available. In comparison to terrestrial ecosystems, little is understood about the interaction between biological and physical processes, in the ocean or how they affect other global processes such as atmospheric cycles.

INTENTIONAL INTRODUCTIONS - MARICULTURE

With the increase in consumption of sea products and decrease in wild fish, marine organism stocks, and algae, mariculture will most likely become more prevalent. Somewhat equivalent to agriculture, this 'farming of the seas' predominately uses a limited number of organisms which have proved to be marketable, productive and profitable. As with pigs or chickens, a few marine organisms do well in many parts of the world and are familiar to most people. As a result, they, rather than a local or native species, are more likely to be cultured. These species are introduced world wide, in countries with marine environments that are ecologically, geographically and politically hospitable, and bring with them both economical benefits and ecological costs. The enhancement of fisheries through the introduction of new commercial species, or even the replenishing of native stocks with farm raised or genetically bred species can bring economic benefits through increased job opportunities, investment opportunities, recreation and tourism (Robinette *et al.* 1991). However, negative effects on marine ecosystems are usually the result of a successful introduction and can also affect other commercial mariculture industries (Ray 1988).

Most introductions are now done with sufficient means of evaluation to weigh these negative effects, and are more often than not deemed harmful (Allendorf 1991; Baltz 1991).

The introduction of a species for culture usually occurs in one of two ways: the free release of the organism into a region's waters or the containment of it in closed or open circulation pens, with varying methods to control reproduction, food, growth and spread. Although there are not enough data to fully assess the effects of both, as surveys of local ecosystems are not often taken prior to culturing, it is more likely that direct release will have the greatest impact. Without any control on population size or habits, a successful exotic can threaten indigenous species by competition, predation, hybridization or spread of disease (Allendorf 1991).

Controlled mariculture can affect local ecosystems as well, even when it is entirely enclosed and with tight controls kept on inputs and outputs. It can monopolize space or food sources, and it can change the conditions of the environment it inhabits through the use of nutrients and fertilizers, through fecal and urinary wastes, or even through the escape of cultured organisms (Beveridge 1994). Mariculture can also increase human traffic in an area, creating environmental stress which can make an ecosystem more susceptible to invasion. These effects may be in addition to ones already mentioned in the previous chapter, including predation, competition, disease introduction and interbreeding. Most of these implications hold not only for cultured species but for transgenics and genetically manipulated and engineered species (Kapuscinski and Hallerman 1991). While quarantines and other methods of reducing these risks are becoming more effective, past lessons have shown us that it is not easy to determine effects of an introduced species short of actually releasing it, and so it is with extreme caution that many governments approach this issue (Robinette *et al.* 1991).

REGULATIONS

Existing regulations controlling introductions of exotic species affecting the Gulf of Maine Region occur on several levels, and for the most part treat accidental and intentional introductions under the same laws. Since 1933 on the international level, there has been a move to preserve indigenous biota and an increased recognition of exotics as 'pollution'. In the United States, federal policy, starting almost a century ago, has attempted to control introductions domestically. There are also varying regulations from state to state, ranging from allowing all importations and releases to prohibiting all species, except those on a designated 'clean' list.

International regulations.

In the European African colonies in 1933 the Convention Relative to the Preservation of Fauna and Flora in their Natural State first prohibited introductions into certain nature reserves. This was renewed in 1968 and similar agreements were made in the South Pacific and Europe. In 1964 the Antarctic Treaty Consultative Parties also set up a strict regime that attempted to prohibit all introductions. The 1979 Bonn Convention on the Conservation of Migratory Species of Wild Animals called for signatories to protect migratory species from harm from exotic species. In 1992 the U.N. Convention on Biological Diversity recognized the control of exotics as crucial to preserving biodiversity.

In 1958 at the Convention on the Continental Shelf, as well as the 1973 International Convention for the Prevention of Pollution from Ships (MARPOL), steps were first made to identify marine exotics. Pollution was defined as a harmful 'agent' or 'substance' without any specific indication as to whether or not that included living organisms. But it was the 1972 Law of the Sea Convention that specifically identified exotic species as harmful, and that they therefore must be controlled. Article 196 declares "States shall take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control, or the intentional or accidental introduction of species, alien or new, to any particular part of the marine environment, which may cause significant or harmful changes thereto." This would become the basis for a number of regional agreements to reduce introductions (Bederman 1991; Kurdila 1988).

United States policies.

The United States reacted to some disastrous exotic introductions with the Lacey Act in 1900. It prohibited the introduction of foreign species without federal permit into the U.S., even identifying particular species and 'blacklisting' them. This act was directed primarily towards game animals, and in 1926 the Black Bass Act prohibited certain fish as well. In 1977 federal agencies were ordered to restrict exotic introductions into lands under their jurisdiction by President Jimmy Carter in Executive Order 11, 1987. In 1981 further restrictions were added to the Lacey Act to control trade in wildlife. Most of these regulations, however, concentrated on blacklisting species already known to be harmful and did little to prevent unknown species from being introduced.

It was not until the 1990 Nonindigenous Aquatic Nuisance Prevention and Control Act that a preventative legislation was adopted. This was in reaction to the economic and ecological disaster resulting from the zebra mussel invasion of the Great Lakes. This Act set up a task force which identified vectors of introduction and developed methods for limiting them. It also set up provisions for identifying and reducing risks of intentional introductions.

Ballast water was determined to be the main method of transportation for accidental introductions into coastal waters (Carlton 1985) . Controls to prevent introduction through ballast water have been suggested and include, mid-ocean ballast water exchange, which is most effective for cargo ships containing freshwater ballast and heading for a freshwater port such as the Great Lakes (Locke *et al.* 1993). However, it is not as effective in marine ports for a number of reasons. The exchange of sea water for sea water and incomplete flushings or failure to remove all sediments from the ballast tanks does not rid the tanks of exotic organisms (Locke *et al.* 1991). There is also some concern over the safety of deballasting and refilling the tanks while at sea, especially during rough weather. This method is also difficult for states to enforce, as they do not have the Constitutional right to regulate foreign trade in their own port, which is left up to federal agencies, which may not enforce state regulations. The most recent attempt to address the ballast water issue is the 1994 Ballast Water Management Act (U.S. Dept. of Transportation), which set up studies on methods to prevent ballast water introductions. Other suggested methods include irradiating or heating the ballast water, or providing facilities in ports into which the water can be discharged and treated as toxic waste.

CONCLUSION

Control of exotic species needs to focus on two aspects: accidental and intentional introductions. Most regulations on accidental introductions focus on preventing ballast water release by methods discussed earlier, and are in some cases already in various stages of research and implementation (see also *The Introduction of Nonindigenous Species to the Chesapeake Bay via Ballast Water*, 1995). In order to be effective these regulations need to be enforced.

Methods for controlling and monitoring intentional introductions in a responsible manner are reviewed and summarized as follows:

1. Introductions will occur and should not be totally prohibited. This is true especially if the introductions are part of a restoration or endangered species program. Considerations to take into account:

    - minimization of potential gene flow to native populations
    - minimal escape of penned organisms
    - locations should be chosen where there is minimal impact on local ecosystems (Hindar *et al.* 1991).

    With introductions an effective procedure to review the environmental risk should be undertaken, including:

    - environmental impact statement
    - publicity
    - independent review
    - implementation

    If extreme caution is being used, the independent review should be followed by experimental research and another round of publicity and independent review before the final step of implementation (Townsend and Winterbourn 1992).

2. The protection of native gene pools is essential to maintain biodiversity, therefore:

    - No release of a species that can interbreed with native populations should be allowed.

    - The intercontinental transfer of organisms should be discouraged in favor of the use of local populations whenever possible.

    - Technology should be developed and utilized to minimize escape of cultured organisms.

- Transgenic and genetically manipulated or engineered organisms should not be released (Krueger and May 1991) or extra care should be taken, as they represent a greater unknown (Allendorf 1991).

3. Future actions regarding this introduction of exotic species should take into consideration the following actions:

   - education of the public and management agencies
   - cooperation of participating agencies, states and countries
   - regulation and policies assuring minimum standard safety procedures
   - research to anticipate effects, including a survey of local ecosystems that could potentially be impacted (Allendorf 1991).

Whatever approaches are taken, they will need to balance the precautionary principle with the recognition that, if we are to feed the increasing human population, we will need to better use the ocean as a resource.

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FINAL DRAFT

SUMMARY OF STATE AND FEDERAL PROGRAMS REGULATING THE INTRODUCTION OF EXOTIC MARINE SPECIES

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Findings

The issue of exotic marine species introductions has not been fully confronted in many northeastern coastal states. New York State has taken the lead state on this issue in the region and is the only state to have completed an approved comprehensive management plan on aquatic nuisance control. Other East Coast states such as, Rhode Island, Connecticut and Massachusetts are lacking consistent regulations and management measures that are necessary to control aquatic species introductions. A summary of existing federal and state legislation, regulation, and management measures has been put together for your reference. While this listing may not be complete it contains the only relevant information that was identifed at the time of this draft.

Federal

Legislation/Regulation

Title 1- Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (Public Law 101-646) (also known as the Zebra Mussel Act)

Goals:

1. Prevention of accidental introductions through ballast water management and other requirements. Requirements on ships entering ports include alternative ballast water release methods such as ocean ballast water exchange, exchange in nonvulnerable areas, or use of environmentally sound ballast water alternatives.
2. Coordinate Federally authorized research, prevention, control and other activities.
3. Develop and carry out environmentally sound control methods.
4. Understand and minimize the economic and ecological hazards.
5. Establish a program of research and technology and assistance to states in the management of zebra mussels.

Management Measures

I. Section 1204 of Title 1 - Calls for states to create comprehensive management plans for aquatic nuisance species. The focus of the plan is to develop state management measures to aid in the prevention of and control of aquatic nuisance species. In developing the plan states should involve local and regional governments as well as public and private entities that will share expertise on the subject of aquatic nuisance species.

Section 1201 of Title 1 - Establishes a federal aquatic nuisance species task force. The task force shall develop and implement a program for the United States to prevent introduction and dispersal of aquatic nuisance species, to monitor, control and study such species and to provide related information.

II. Workshop on Aquatic Biotechnology and Research Safety (September 28, 1994)-- *U.S. Department of Agriculture*

The above workshop resulted in a draft by the working group called "Performance Standards for Safely Conducting Research with Genetically Modified Shellfish." The goal of the voluntary performance standards is to aid researchers in assessing the ecological safety of research activities with genetically altered fish, and all other fish, mollusks, and crustaceans. Emphasis is on the relative safety of releasing organisms expressing novel hereditary traits.

Summary of Draft *Performance Standards for Safely Conducting Research With Genetically Modified Fish and Shellfish* (August 4, 1993)

Section 1 --Ecological Safety Assessment.

Characteristics and traits of the modified organism and the parent organism are considered. Interactions of the modified organism to the ecosystem and native species are also studied to identify any possible hazards. If no hazard is found, the research can proceed without concern for the release of the organism. However, if there are hazards identified or not enough information has been acquired, appropriate confinement measures are suggested.

Sec. 1A--Standards apply only to certain modified organisms. If acclimation by the introduced species is possible in accessible ecosystems then the standards apply. If the organism can not acclimate and survive in the ecosystem there is no need for further use of the standards.

Section 2 --Risk Management.

Risk management is used only when a hazard is identified. If a hazard is identified, implementation of protective measures to reduce the likelihood of escape of modified organisms from the research site will be employed. Protective measures include: selection of culture methods, operation management and practices, and inspection.

<u>Lead Agencies</u>

Aquatic Nuisance Species Act - US Fish and Wildlife Service

State Regulations/Legislation/Policies

Maine

Legislation\Regulation

Ch.24: Importation of live marine organisms.

This law is intended to eliminate entry of organisms into coastal Maine waters that are dangerous to indigenous marine life. The introduction of live marine organisms is prohibited unless a detailed permit is obtained from the commissioner.

Management Measures

To aid in the management of introductions a permit system has been adopted.

Permit criteria for any live marine organisms include, but are not limited to. information on:

- Species, life cycle stage and quantity to be imported.
- Area of origin.
- Area and date of proposed introduction.
- An explanation of the known habitat and biological and behavioral characteristics of the species as well as epifaunal and associated species.
- Statement of examination by an approved marine laboratory certifying that the organism is free of infections, pests or parasites.
- A valid fish health inspection.

Permit criteria for shellfish are similar. The Commissioner will issue a permit only if it is found to a reasonable degree of certainty that those actions will not endanger the indigenous marine life or it's environment. Some considerations are:

- effects of any previous introductions of the same or similar species.
- The relationship with the species introduced to the rest of the ecosystem of the area.
- Potential effects of possible associated diseases or infections.

Lead Agency

Department of Marine Resources

New York

Legislation/Regulation

Ch.456 of the laws of 1991-- This law requires New York Department of Environmental **Conservation** (DEC) to develop two management plans to reduce environmental and public safety **risks** associated with exotic species introductions.

Coastal Policies

Policy 7 and policy 44 of the Coastal Management Program apply generally to exotic species introductions.

Policy 7. Significant coastal fish and wildlife habitats will be protected, preserved, and where practical restored so as to maintain their viability as habitats.

Policy 44. Preserve and protect tidal and fresh water wet lands and preserve the benefits derived from these areas.

Management Measures

Nonindigenous Aquatic Species Comprehensive Management Plan (1993 pg.1-39) -- developed by the New York State Department of Environmental Conservation in response to the Federal Aquatic Nuisance Prevention and Control act of 1990. New York is the only state to date that has completed an approved plan. The plan contains four specific goals. These are:

- •Reduce the potential for future introductions of non-indigenous species.
- •Reduce the potential for non-indigenous species that have been introduced into New York Waters to spread into uncolonized waters.
- •Minimize harmful economic, ecological, and social impacts resulting from organisms already introduced, or proposed for introduction into the waters of New York State.
- •Educate the public on the importance of preventing non-indigenous species introductions.

Lead Agencies

New York Sea Grant and *New York State Department of Environmental Protection* -- Initiates policies related to controlling and managing nonindigenous species introductions.

Bureau of Fisheries -- Conducts monitoring activities.
Division of Water -- Issues permits for chemical and thermal zebra mussel treatment.

Rhode Island

Legislation/Regulation

- 12.08 Hybrid Striped Bass Cultured Striped Bass
  Aquaculture reared or hybrid Striped Bass entering Rhode Island for sale or resale must display a tag stating that they are aquaculture products.

Management measures

Introductions of exotic marine species are managed by a case-by-case permit process.

Lead Agency

Division of Fish and Wildlife

Connecticut

NA

New Hampshire

Introductions of exotic marine species are dealt with on a case-by-case basis with public hearings and a permit process.

Massachusetts

Legislation/Regulation

NA

Coastal Policies

These regulatory policies apply generally to aquatic nuisance species.

Policy 1 -- Protect ecologically significant resource areas for their contributions to marine productivity and value as natural habitats.
Policy 2 -- Protect marine resource areas of unique productivity, preservation and restoration, and areas of critical environmental concern; ensure that activities impacting such complexes are designed and carried out to minimize adverse effects on the marine environment.

Management Measures

Division of Marine Fisheries reviews species introductions for aquaculture on a case by case basis and follows protocols established by the Interstate Shellfish Sanitation Commission.

Other tools and management approaches

A Model of Comprehensive State Management Plans For Aquatic Nuisance Species:

The plan was developed after the workshop entitled *ANS/Coastal Management Programs: Toward a Regional Strategy in the Great Lakes Basin*

Purpose -- To provide guidance to state agencies (primarily great lakes states) for implementation and development of a state aquatic nuisance species management plan. The model is a guide to writing a state management plan, detailing what should be included and leaving room for state-specific information.

References

Some of the material regarding federal legislation and summaries of workshops were based on paper in *Proceedings of the Conference and Workshop: Introductions & Transfers of Marine Species; Achieving a Balance between Economic Development and Resource Protection, ed. Richard DeVoe 1992, S.C. Sea Grant Consortium. 198pp.*