1992

Intentional Introductions of Non-Indigenous Species: A Case Study of Policy and Management Affecting Crassostrea gigas

Gwynne D. Brown
College of William and Mary - Virginia Institute of Marine Science

INTENTIONAL INTRODUCTIONS OF NON-INDIGENOUS SPECIES: a case study of policy and management affecting *Crassostrea gigas*

A Thesis

Presented to

The Faculty of the School of Marine Science

The College of William and Mary in Virginia

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

---

by

Susan Gwynne Day Brown

1992

This thesis is submitted in partial fulfillment of the requirements for the degree of

Master of Arts

Susan Gwynne Day Brown

Susan Gwynne Day Brown

Approved December 1992

N. Bartlett Theberge, Jr., LL.M.
(Chairman)

James T. Carlton, Ph.D.

Mohamed Faisel Abdel-Kariem, D.V.M.

Robert W. Grabb

Roger L. Mann. Ph.D.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

I would like to thank my major professor, N. Bartlett Theberge, whom along with Susan Carter, supported me in my work and during rough times beyond the realm of graduate school. I would also like to thank the members of my Advisory Committee: Dr. Roger Mann and Dr. Jim Carlton for their superior knowledge in the subject, Dr. Mohamed Faisel for his time and concern with matters beyond the thesis, and Robert Grabb for making me look beyond the science into the "real" world of public management.

Most of all, I wish to thank my parents and especially my husband, Bob, who was there for everything.

ABSTRACT

Intentional introductions of non-indigenous species into the marine environment, although harder to control than terrestrial introductions, are inadequately regulated. They are potentially beneficial and potentially harmful. New industries may be formed, or conversely, native fisheries may be harmed by competition, disease, or associated organism introduced with the desired species.

The policies and management affecting introductions of non-indigenous species were examined on international, federal, regional and state levels. Specifically, the potential introduction of *Crassostrea gigas*, the Japanese oyster, into the waters of Virginia, Maryland, Delaware, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire and Maine, was analyzed to determine similarities among states.

It was found that authority over intentional introductions is granted to individual states, with very little federal input. International and regional organizations do not have any authority, but rely on political pressure. It is the general policy of all ten coastal states to prohibit the introduction of a nonnative species without a permit. There are not, however, any specific guidelines developed by either state or federal authorities.

Guidelines need to be developed on a federal level and required to be enforced by state authorities. The International Council for the Exploration of the Seas (ICES), has developed guidelines which could serve as a template for federal agencies. States, in addition to following federal guidelines, should be required to seek outside advise from an advisory organization (for example, ICES or the American Fisheries Society) to whom states opposing the introduction could also respond. The advisory organization would examine both points of view, and recommend the best course of action.

INTENTIONAL INTRODUCTIONS OF NON-INDIGENOUS SPECIES

Introduction

The Virginia Institute of Marine Science (VIMS) submitted a request to the Virginia Marine Resources Commission (VMRC), in March of 1990, to perform open water experiments with the Japanese oyster, *Crassostrea gigas*, in the lower Chesapeake Bay. The objective was to ascertain the tolerance and resistance of *C. gigas* to two major disease causing agents endemic to the Bay, *Haplosporidium nelsoni*[1] and *Perkinsus marinus*[2] (Perkins, 1990); both have had a severe impact on the native Eastern oyster, *Crassostrea virginica*. Scientists were unable to guarantee that all of the oysters proposed for the experiment, would be triploid, and therefore sterile. The request was denied.

The Virginia Institute of Marine Science resubmitted its proposal to the VMRC, presenting evidence that the oysters would be triploid. The VMRC approved the experiment, however, the oysters died in a New Jersey laboratory prior to shipment. New questions regarding triploidy of the oysters proposed for introduction, have

---

[1]*Haplosporidium nelsoni* was formerly described as *Minchinia nelsoni*, and is commonly referred to as MSX.

[2]*Perkinsus marinus* was originally known as *Labyrinthomyxa marina*, then *Dermocystidium marinum* (thus the common name, Dermo).

influenced the Commissioner of the VMRC to suspend the experiment. Scientists from Rutgers University, in New Jersey, submitted a request similar to that of VIMS, which was also denied. Maine scientists are currently proposing *C. gigas* for introduction into the Gulf of Maine.

Demand for the introduction of aquatic species to rejuvenate failing fisheries, and for their utilization in aquaculture, will increase. What governs intentional introductions of aquatic non-indigenous species? Are the laws controlling these introductions capable of preventing potential associated problems or, conversely, are they designed to prevent introductions and therefore the potential benefits? If the introduced species becomes a nuisance, who is liable?

This thesis examines the possible introduction of *Crassostrea gigas* into the coastal waters from Virginia to Maine, in an analysis of the current international, federal, regional, and state policies governing intentional introductions of non-indigenous marine species. Positive and negative components are identified as are areas which have not been addressed by international, federal or state legislation.

Crassostrea gigas was chosen to illustrate the policy and management affecting intentional introductions of an aquatic non-indigenous species, because of the current interest in introducing it, and availability of information

regarding past introductions. The success of *C. gigas* on the west coast of the United States, in British Columbia, and in France, show that financial benefits can be gained from its introduction. In contrast, possible transportation of disease causing agents or of associated organisms are two risks which could accompany an uncontrolled introduction of *C. gigas*.

Review of the legal and scientific literature examined issues applicable to the policy and management of all marine introductions, focusing on those areas pertinent to an introduction of *C. gigas*. The literature review was divided into the following areas:

- definitions pertaining to introductions of non-indigenous species
- analysis of the species involved (*C. gigas*, *C.virginica*, and *Ostrea edulis*)
- the circumstances that precipitated the potential introduction (the histories of the northeast oyster industries)
- previous introductions of *C. gigas*
- local diseases and parasites as well as those associated with the species of introduction
- other potential problems associated with intentional introductions of non-indigenous species (i.e. competition, hybridization, etc.)
- international, federal and state documents governing

Definitions

When addressing the issue of non-indigenous species the first obstacle is that of definition. When is an organism an exotic? Is a non-indigenous species the same as an exotic or nonnative species? What is the difference between an animal that has been transferred and one that has been transplanted?

The definitions vary from one document to another. The following examples represent various points of view which illustrate the problem and show the need for standard definitions.

Exotics - Exotic organisms, by definition, do not occur naturally in the area of introduction. Differences in definition, however, arise depending upon whether a country's border, state's border, or the native range of the species was selected as the delineation point between exotic and native species. Species are often identified as exotics if they are introduced by man into a foreign country (Ferguson, 1990; Kohler and Stanley, 1984; McCann, 1984; Presidential Executive Order No. 11987, 1977). Executive Order No. 11987 includes all U.S. territories, for example Puerto Rico and Guam, within its definition of "United

States." Obviously introductions which originate from within the country are not addressed by the Order.

States, in contrast, often use their own state lines to delineate between a native and exotic species. In a state survey by Hocutt (1984), of those states that responded, 65% defined an "exotic" as not native to the state, 12.5% replied not indigenous to North America, and only two referred to an exotic as an organism existing outside of its native range or basin.

Introduced Species - Definitions produced by The International Council for the Exploration of the Seas (ICES), in conjunction with the European Inland Fisheries Advisory Commission (EIFAC), define introduced species as "any species intentionally or accidentally transported and released by man into an environment outside its present range" (ICES, 1990). ICES and EIFAC consider introduced species to be synonymous with non-indigenous species (Rosenfield and Mann, 1992).

Native & Nonnative - A state's border, country's border, or the species' natural range delineates whether a species is native or nonnative. The 1977 Presidential Executive Order defines native species as those which exist naturally (presently or historically) in the U.S., using the territories of the United States to delineate between a

native or nonnative species.

McCann (1984), in contrast, defines a nonnative species as one which has been "introduced by man into an ecosystem outside its original native range."

Transferred versus Transplanted - The transfer of species is often described as the movement of that species within its geographical range (Gaffney and Allen, 1990; Ferguson, 1990) whereas a transplanted species has been moved outside its native range, but within the territory of a country (McCann,1984; Kohler & Stanley, 1984). In contrast, ICES and EIFAC consider them synonymous: "any species intentionally or accidentally transported and released within its present range" (ICES, 1990; Rosenfield and Mann, 1992).

For the purposes of this paper, non-indigenous species will refer to those species released into an area outside of their present range. By definition, the zoological range is the real limit, all "political" limits are artificial. An introduction will be defined as the release of a non-indigenous species.

Biology of the Oyster

Three species of oyster are discussed in the following pages: *Crassostrea virginica* - the native oyster of the east coast; *Ostrea edulis* - the dominant commercial oyster in Maine; and *Crassostrea gigas* - the species under consideration for introduction. Emphasis is placed on *C. virginica* and *C. gigas* since *O. edulis* is harvested only in Maine, and is not being considered for introduction by the other northeastern states. Relevant predators, diseases, and associated pests are discussed later.

Crassostrea virginica (Gmelin)

Also called the Virginia, Eastern, or Atlantic oyster, *Crassostrea virginica* was described by Gmelin in 1792. It exists along the east coast of North America from the Gulf of St. Lawrence to the Gulf of Mexico and in the West Indies. *Crassostrea* are reef forming oysters suited to an estuarine environment due to tolerance of euryhaline conditions (Chesapeake Executive Council, 1989; Hargis and Haven, 1988; Kennedy and Breisch, 1981; Quayle,1988).

The eggs of *C. virginica*, and those of other *Crassostrea* sp., are discharged into the water column where external fertilization takes place, as do subsequent stages

of development. Approximately twenty-four hours after fertilization, the eggs have developed into the larval form. The larvae remain a part of the plankton, transported by water currents for two to three weeks. The oyster larvae are then ready to settle (the process of attaching to a hard substrate) and metamorphose to the sessile, attached form (Hargis and Haven, 1988). Three to four years are typically required for *C. virginica* to reach market size (generally 3 inches along the longest axis); however, in culture market size has been reached in twenty-two months (Mann et al., 1991).

Temperature and salinity are important factors influencing an oyster's growth, spawning and survival. The values reproduced below from Mann et al. (1991), are the salinity and temperature ranges of *C. virginica* for adult growth and spawning and for larval tolerance. Optimal values are given in parentheses.

	Temperature (degrees C)	Salinity (ppt)
Adult Growth	5-34 (28-32)	>5(12-27)
Spawning	18-25 (23)	>8
Larval tolerance	20-33	8-39 (10-29)

Crassostrea gigas (Thunberg) - Also called the Japanese, Pacific or Miyagi oyster, *C. gigas* was described by Thunberg in 1795. The name Miyagi can be misleading as there are

several stocks of *C. gigas*, each named for its place of origin in the Japanese Islands, and each having different characteristics. The fastest growing oyster strain of the species *C. gigas*, Hokkaido, comes from the northern most island of Japan. *C. gigas* Miyagi, in comparison, sustains moderate growth, and has been introduced into British Columbia and Washington, U.S.A. An even slower growing oyster, *C. gigas* Hiroshima, exists further south and is identifiable by its deep shell. *C. gigas* Kumamoto, the fourth strain, resides in the extreme south of Japan, also has a deep shell but stunted growth. It too was imported into Washington (Quayle, 1988). Since Miyagi-like strains are being considered for introduction (Mann et al., 1991), the following discussion will refer to their characteristics.

The temperature and salinity ranges of *C. gigas* for growth, larval tolerance and spawning are reproduced according to Mann et al. (1991), with optimal values appearing in parentheses.

	Temperature (degrees C)	Salinity (ppt)
Adult Growth	3-35 (11-34)	10-42 (35)
Spawning	16-30 (20-25)	10-30 (20-30)
Larval Tolerance	18-35 (30)	19-35

C. gigas grows faster than *C. virginica* and *O. edulis*,

reaching market size in one to two years (Dean, 1979).

Ostrea edulis - Also known as the European oyster, the discussion on *O. edulis* will remain brief since Maine is the only northeastern state where it exists. It remains important, however, because it is an example of a beneficial, non-indigenous oyster already present on the east coast. *O. edulis* is a cold water oyster (Mann et al., 1991) and does best in clear waters. The clear, cold waters of Maine are more suitable than those in the Chesapeake Bay.

Unlike oyster species of *Crassostrea*, fertilization takes place in the inhalant chamber of *O. edulis* where the larvae remains during the initial stages of development (Quayle, 1988). *O. edulis* grows faster than *C. virginica*, reaching market size in two to three years (Dean, 1979).

History of the Northeast Oyster Industry

The present oyster population along the northeast coast is a fraction of the size of precolonial stocks. Middens left by Indians, and oyster reefs large enough to be hazardous to navigation, attest to the large quantities of oysters which previously existed there (Dean, 1979; Hargis and Haven, 1988). These reefs are thought to have created benthic communities unique from the nearby silty bottoms, providing a rich environment for many species (Mann et al., 1991).

Due to the oyster's ability to filter up to fifteen liters of water per hour (Hargis and Haven, 1988), precolonial oyster stocks filtered the waters of the Chesapeake Bay in less than four days. It now takes approximately 325 days (Newell, 1989). Today, smaller oyster stocks are not nearly as capable of reducing the hypoxic and anoxic effects of eutrophication (Mann et al., 1991).

The Chesapeake Bay - Virginia and Maryland

Approximately twenty million bushels of oysters were harvested annually from the bay between 1875-1885. Before 1900, Maryland's dredge fleet was harvesting greater than

ten million bushels a year and Virginia hand tongers produced between six to seven million bushels of oysters per year (Hargis and Haven, 1988).

Virginia was the largest producer of oysters on the east coast by the 1900's, even though annual harvests had decreased to 4-7 million bushels. Another decrease occurred in the late 1920's; however, the major declines began in 1960, one year after the discovery of MSX (Hargis and Haven, 1988).

Hargis and Haven (1988) best described these trends of the Bay oyster industry using the six different phases summarized below:

Phase I: a period of underutilization between more than 350 years ago to the mid 1800's.

Phase II: a period of increased demand (coinciding with an increased population) between mid 1800's to 1894.

Phase III: a plateau of annual harvests from 1894 to 1912.

Phase IV: a gradual decline from 1912-1932, attributed to over-harvesting and later the depression.

Phase V: a gradual increase from 1932 to 1959.

Phase VI: a drastic decline from 1959 to present.

The drastic decline from 1959 to present, is attributed

to the oyster disease MSX, caused by the parasite *Haplosporidium nelsoni*. MSX also decimated oyster populations further north. Annual harvests of oysters in the Delaware Bay declined from 7.5 million pounds of meat in 1957, to less than 100,000 pounds the following year (Kennedy and Breisch, 1981).

209,000 bushels of oysters were commercially harvested from Virginia waters in 1989 (Mann et al., 1991). This was less than half of that harvested during the previous two years (Chesapeake Executive Council, 1989). Since 1985 the James River has become Virginia's main source of market size oysters (Chesapeake Executive Council, 1989; Hargis and Haven, 1988). This situation further jeopardizes Virginia's industry, because the James River supplies much of the seed for planters and rejuvenation efforts.

Maryland oyster stocks have also declined dramatically, even though Maryland contains lower salinity areas of the Bay which are less susceptible to MSX and Dermo. Harvests decreased from 3.2 million bushels to 565,146 bushels between 1973 to 1987[3] (Chesapeake Executive Council, 1989).

Disease is not the only factor contributing to high oyster mortalities. Oyster populations in very low salinity, disease free areas, have also declined (Hargis and Haven, 1988). Over-fishing, deterioration in water quality,

---

[3]All bushels are not necessarily the same. The Virginia bushel is 3003.9 cu in whereas the Maryland bushel is 2800.7 cu in (Hargis and Haven, 1988).

and decrease in habitat conditions are all probable contributors to the decline. Destruction of habitat has occurred from channel dredging, farming, and construction. These activities increase the sediment load, negating the availability of clean, hard substrate surfaces necessary for settlement. Sewage and agriculture have increased the amount of nitrogen and phosphorous in the water resulting in hypoxic and anoxic conditions. Sewage, though not affecting oyster mortalities, also increases the coliform bacteria count. If the coliform bacteria count is too high, it results in the closing of oyster grounds to harvests (Chesapeake Executive Council, 1989).

Delaware

Today, Delaware's waters support a small commercial dredge boat fishery, which reopened in 1991 after five years of closure. Aquaculture is considered too expensive by many and is rarely practiced. Disease has had a major effect on Delaware's oyster industry. MSX, discovered in 1957, significantly depleted oyster stocks. Dermo has also been reported. Possible introduction of Dermo may have originated from shucking houses which import out of state oysters to maintain their businesses (Tinsman, J., Division of Fish and Wildlife, Delaware, 1992, personal communication).

New Jersey

Approximately 5 million pounds of meat were harvested from New Jersey's waters in 1940. Harvests were slightly more than 8 million pounds by the early 1950's, but by the end of the decade, the population decreased due to the effect of MSX (Elston, 1990). Dermo has also been detected in Delaware Bay.

Today, in the New Jersey portion of the Delaware Bay, approximately seventy-five boats are licensed to dredge for oysters. Many boat owners, however, did not participate in the small harvests of 1990 and 1991, but kept their boats licensed in hopes of better harvests in the future[4]. Oysters on the Atlantic coast are intertidal and harvesting by hand is the only technique permitted (Critchlow, G., New Jersey Division of Shellfish, personal communication, 1992).

Connecticut

Oyster beds in Connecticut were effected by over-harvesting in colonial times. Many beds were depleted by the 1700's. This resulted in one of the first laws regulating the taking of oysters in 1762. The Township of New Haven prohibited the taking of oysters during the summer spawning months (Schneiders, R., Environmental Intern, Connecticut Department of Agriculture).

---

[4]New Jersey has a limited entry law whereby no new licenses are being issued, except to those people licensed during the previous year (N.J. Regul. 7:25A-1.5).

Oystermen began cultivating beds due to the decrease in stock. Large imports of oysters, up to two million bushels annually, from New Jersey and the Chesapeake Bay, were transplanted onto prepared beds. Today, more than 40,000 acres are under culture (exclusively bottom culture), with a small group of oystermen still harvesting natural beds (Volk, J., Connecticut Department of Agriculture, personal communication, 1992).

New York

Oyster landings in New York have oscillated from twenty-five thousand bushels to one hundred thousand bushels in recent years. The peak occurred around 1950 when 1.25 million bushels were harvested. Today, the decrease in industry is attributed to a "change in customs," not disease. Oystermen rely on wild harvests, not aquaculture. Only one or two oyster companies still exist (Fox, D., New York Department of Environmental Conservation, personal communications, 1992).

Rhode Island

Rhode Island supported a large commercial oyster industry before the 1938 hurricane. Today, few people harvest oysters commercially. A majority of the areas suitable for tonging are closed due to pollution. Most of the oysters on unpolluted grounds grow in the intertidal

zone and are harvested by hand. Aquaculture is very limited, in part due to controversy over the use of the bottoms. Many in the state consider aquaculture a violation of the "free and common fishery" (Ganz, A. and Karlsson, J., Rhode Island Division of Fish and Wildlife, Department of Coastal Fisheries, personal communication, 1992).

Crassostrea virginica is the only legal oyster in Rhode Island, however Karlsson (personal communication, 1992) noted that an occasional *O. edulis* appears. Karlsson has also discovered a disease similar to Dermo, now identified as *Perkinsus karlssoni* (Karlsson, J., Rhode Island Division of Fish and Wildlife, Department of Coastal Fisheries, personal communication, 1992).

Massachusetts

Commercial harvests in Massachusetts decreased from 16,035 bushels in 1980, to 5,736 bushels in 1990. Recreational harvest decreased from 4,457 bushels in 1980 to 2,339 bushels in 1990 (Hoops, T., Division of Marine Fisheries, personal communication, 1992). The commercial industry is supported both by aquaculture and wild harvests although aquaculture is becoming the dominant contributor.

New Hampshire

New Hampshire has a very small coastline (about eight to eighty kilometers depending upon how one measures it).

Any harvesting is recreational; there is no commercial industry.

Maine

Only restricted populations of *C. virginica* still exist in Maine's waters, although middens left by Indians are evidence that *C. virginica* once thrived there. Low stocks of *C. virginica* prompted authorities to introduce *Ostrea edulis* between 1949-1961. *O. edulis* accounts for 85% of Maine's oyster harvests and is used primarily in off-bottom culture programs (Dean, 1979). The European oyster, however, sustains only marginal spawning populations. Authorities are currently examining *C. gigas* as a candidate for introduction to stimulate economic growth (Shatkin, G., 1992).

The use of *Crassostrea gigas* in introductions

Introductions of *Crassostrea gigas*, both intentional and accidental, have occurred along the Pacific coast from Costa Rica to Alaska, in New Zealand and Australia, and along the Atlantic basin from the North Sea to the Mediterranean Sea and in Morocco (Mann et al., 1991).

C. gigas was officially introduced into France[5] between 1971-1975, utilizing brood stock from Canada and spat from Japan. Production reached 80,000 t by 1976, and 150,000 t by 1991 (Grizel and Heral, 1991). Fifteen years from introduction, France's commercial harvests of *C. gigas* put the nation fourth on the list of oyster producing countries (Mann et al., 1991). The introduction came after the native European oysters, *Ostrea edulis* and *Crassostrea angulata*, were decimated by disease; a situation similar to that which exists in the Chesapeake Bay with the occurrence of MSX and Dermo. *C. gigas* demonstrates resistance to both European diseases (*Bonamia ostreae* and *Marteilia refringes*) (Grizel and Heral, 1991; Mann et al. 1991).

---

[5]Unofficial introductions make it difficult to trace early introductions; however, spat from Japan was probably introduced into the Bay of Marennes-Oleron in 1966. There is also some question as to whether the origin of the virus effecting *C. angulata* was related to these early introductions, but this has not been proven (Grizel and Heral, 1991).

The introduction of *C. gigas* into New Zealand was accidental. Six specimens were found in 1971, and by 1978 *C. gigas* had become a major contributor to New Zealand's oyster industry (Bourne, 1979). The native rock oyster industry, based on *Saccostrea glomerata*, a slower growing oyster, has since been replaced by *C. gigas* (Synopsis of the Oyster Ecology Workshop: *C. gigas*, 1991).

C. gigas is the only commercial oyster in British Columbia. Introduction of the Pacific oyster arose because of declining native stocks of *Ostrea lurida*. Establishment of the Japanese oyster occurred over approximately 30 years, utilizing seed imported from Japan[6] and Washington State. *Crassostrea virginica* was introduced prior to *C. gigas*, but only limited and sporadic breeding resulted. There is a residual population of the Virginia oyster in Nicomekl River, a tributary to Boundary Bay, where it coexists with *C. gigas* (Bourne, 1979).

Culture of *Crassostrea gigas* in the United States has occurred throughout the twentieth century. Both Miyagi and Kumamoto strains have been introduced into the Pacific waters of California, Oregon, Washington, Alaska, and Hawaii. The culture of *C. gigas* on the west coast relies predominantly on a hatchery system, not on "wild stocks" as in the east (Chew. 1979).

---

[6]Between 1929-1932, four million oysters were imported from Japan (Bourne, 1979).

C. gigas was introduced into the state of Washington in the early 1900's because of the decline of the Olympia oyster industry and the lack of success of *C. virginica* (Synopsis of the Oyster Ecology Workshop: *C. gigas*, 1991). The state of Washington, which has areas noted for natural seed production, also raises seed in several commercial hatcheries. Most of the Washington State oyster industry is based on cultured intertidal beds. Cultured intertidal beds also represent the majority of California's industry, but California depends almost entirely on hatchery reared seed. Oregon relies on in-state and out-of-state hatchery reared seed, and utilizes a variety of oyster culture techniques including raft culture (Chew, 1979).

Introductions of *C. gigas* on the east coast of the U.S. have also occurred. *C. gigas* was accidentally introduced into Massachusetts in 1974 when several dozen oysters were mistakenly shipped with quahogs. The quahogs were being used in raft culture studies and the oysters were cultured along side. The japanese oysters reached market size within one and a half years; one year faster than native oysters raised in the same manner. Further experiments conducted in a salt water pond resulted in spawning, but there was no evidence of settlement (Hickey, 1979).

Earlier introductions of *C. gigas* into Massachusetts occurred in 1944. Turner introduced six bushels of cultch off of Cape Cod which grew successfully but did not spawn

(Dean, 1979). Dow and Wallace introduced *C. gigas* into Maine, but most of the oysters died. Only eleven oysters reached maturity, but again no evidence of successful reproduction. Between 1971 - 1973 further studies were done in Maine, but were discontinued due to controversy. It appears that releases have occurred throughout New England without establishment (Dean, 1979). Since *C. gigas* failed to become established, it is not possible to conclude that future introductions would be risk-free. Previous releases in these areas are therefore poor evidence for future scenarios.

Diseases of *Crassostrea virginica* and *Crassostrea gigas*

Disease is one of the major concerns associated with the introduction of a non-indigenous species. The impact disease can have on a population is illustrated by the effect of MSX and Dermo on the Virginia oyster. When considering an introduction, examination of diseases associated with the non-indigenous species is needed, as well as an examination of diseases existing in the area of introduction.

MSX and Dermo are presented below since they are relevant to the events leading up to the possible introduction of *C. gigas*. Other diseases of *C. virginica* and *C. gigas* are identified in the appendix and referred to in discussion.

MSX - *Crassostrea virginica*

Now known to be caused by the protozoan *Haplosporidium nelsoni* (formerly *Minchinia nelsoni*), MSX has also been called "haplosporidiosis of the American Oyster" and the "Delaware Bay Disease." The acronym developed after discovery of a "multinucleate sphere unknown," hence MSX. The parasite, which invades almost all tissues, is believed to require another host species, presently unknown, in order

to complete its life cycle. It was first recognized in 1957 in the Delaware Bay, where mortalities reached 90-95% by 1960 (Elston, 1990). The disease affected oyster stocks in the Chesapeake Bay in 1959 (Hargis and Haven, 1988).

Infection and mortality of oysters from MSX have oscillated due to changes in environmental conditions. With drought in the 1980's, came a resurgence of disease in the Chesapeake and Delaware Bays. Mortalities can reach as high as 100% in some areas, most occurring at salinities between 20 ppt and 30 ppt (Elston, 1990). MSX exists predominantly in areas where the fall salinity is greater than 15 ppt, yet not in high salinity waters such as occur on the Eastern Shore of Virginia. Oysters are infected in the warmer months, from late May to October. Most mortalities occur in late summer and early fall (Hargis and Haven, 1988).

MSX requires pathological or microscopic assessment for confirmation. Infected oysters typically exhibit pale digestive glands, mantle recession, and a watery consistency. In advanced infections, fouling along the interior margin of the left valve occurs, and raised yellow-brown deposits in the interior of the valve are often observed[7] (Elston, 1990).

---

[7]Parasites similar to *Haplosporidium nelsoni* are seen in *C. gigas* without known mortality. In one instance, as with MSX, the epithelium of the digestive gland contained spores (Burreson, 1991; Mann et al., 1991).

Dermo - *Crassostrea virginica*

Previously identified as *Dermocystidium marinum* and *Labyrinthomyxa marina*, Dermo is now known to be caused by a parasite, *Perkinsus marinus*. Similar to MSX, it infects almost all tissues, does not like low salinities (less than 12-15 ppt), and occurs primarily in the warmer months (June-October in the Chesapeake Bay). Dermo's effects decrease when the temperature is less than 25 degrees (Quayle, 1988), and when salinities are lower than 12-15 ppt, but can persist in over-wintering oysters in salinities less than 5 ppt (Elston, 1990). Dermo can be transmitted over a distance of 50 feet when in direct contact with the water, but is severest in dense populations (Elston, 1990; Hargis and Haven, 1988). It is also believed to be spread by a gastropod parasite, *Boonea impressa*, which can increase severity of the disease in an already infected oyster (Elston, 1990).

The first mortalities of *C. virginica* attributed to Dermo occurred in the Gulf of Mexico in 1940. Its current range extends northward to the Delaware Bay. Mortalities as high as 100% have been recorded, usually with 30-50% mortality the first year (Elston, 1990; Quayle, 1988).

Macroscopic indicators of Dermo are weakened shell closure and gape, and a decrease in growth several months prior to mortality. Heavy infections are detected microscopically with Lugol's iodine stain (Elston, 1990).

Possible Problems Associated with the Introduction of a Non-indigenous Species

The release of a non-indigenous organism into an area outside of its present range has the potential to alter communities. Introductions into marine environments present a greater risk than those on land. It is more difficult to run risk-free tests, and open water introductions are harder to control. The following, an introduction to the potential hazards associated with non-indigenous species, is not intended to argue that introductions should never be allowed, but to illustrate the need for caution.

Introductions are controversial because it is "virtually impossible to predict how an exotic organism will behave in a new environment" (Courtenay, 1979). The effects of an introduction can occur on several different levels. First consider the "target species," the organism that is "intentionally transported and liberated" (Carlton, 1992) for grow out purposes, pest control, and other reasons. There are also "non-target species," organisms that accompany the "target species" either in the transport medium, as the transport medium, or in/on the target species (Carlton, 1992). Introductions can occur by other means (hulls of ships, ballast water, etc.), but as the topic of

this paper is intentional introductions, those vectors will not be discussed except to cite specific examples of problems which arose as a result of an introduction.

The Introduction of Associated Organisms - The introduction of associated species is one of the greatest risks of intentional introductions. The risks pertaining to the introduction of the desired species, for example, competition and disease, also apply to the introduction of associated organisms.

The global culture of oysters is considered "the greatest agency of all that spreads marine animals to new quarters of the world" (Elton, 1958). The completion of the transcontinental railroad in 1869 brought large shipments of *C. virginica* across the United States for introduction into California's waters. Ironically, while *C. virginica* did not become established, many other species did (Nichols et al., 1986).

Several species have been introduced as a result of releases of *C. gigas*. Table 1 lists several examples of associated organisms introduced with the Japanese oyster off the Pacific coast of North America.

Table 1

Examples of associated organisms introduced with *C. gigas* into the west coast waters of North America

Scientific Name	Description	Reference
Tapes japonica	Manila clam	2,3,4
Trapezium liratum	clam	4
Ceratostoma inornatum	oyster drill	1,2,3,4
Musculista senhousia	mussel	4
Batillaria attrementurium	gastropod	1
Mytilicola orientalis	parasitic copepod	1,2,4,5
Limnoria tripunctata	woodborer	1,3
Sphenophyra sp.	protozoan	4
Tylocephalum sp.	tapeworm	4
Pseudostylochus ostreophagus	turbellarian flatworm	1,2,3
Sargassum muticum	brown algae	3,5
Undaria pinnatifida	brown algae	5
Laminaria japonica	brown algae	5

(References:1) Bourne, 1979; 2) Chew, 1979; 3) Quayle, 1988; 4) Rosenfield and Kern, 1979; 5) Rueness, 1989)

Only one of the species listed in Table 1, the Manila clam, has become economically beneficial, supporting a major fishery. Others, however, have become pests. *P. ostreophagus* preys upon newly settled oysters by drilling a small hole in their shells. *Mytilicola orientalis* exists

in the lower intestines of oysters and mussels, decreasing the condition factor of the host (Quayle, 1988). It has been introduced, and affected native bivalves in France as well (Farley, 1991).

Host for Non-indigenous Diseases or Parasites - Diseases and parasites can be introduced into uninfected areas by transfers[8] or introductions of host species. The transfer of oysters with *Haplosporidium nelsoni* into the waters of Wellfleet, Massachusetts resulted in the introduction of MSX. The introduction of *Bonamia ostreae* into Puget Sound, Washington and into French waters was attributed to infected oyster seed originating in Connecticut (Farley, 1991).

Competition with a Native Species - Competition between a non-indigenous species and an endemic species can occur on a spatial level and/or on a food level. Competition on the spacial level is one of the concerns with an introduction of *Crassostrea gigas*. *C. gigas* can reach market size, three inches, within one to two years. *C. virginica*, in comparison, requires three to four years to grow to market size (Mann et al., 1991). Large spatfalls of *C. gigas* could compete with *C. virginica* by crowding out the slower growing

---

[8]The "transfer" of an organism refers to the movement of a species to an area within its natural range.

Eastern oyster (Andrews, 1979; Nelson, 1979).

Habitat Destruction - Habitat destruction is often associated directly with man, e.g. the destruction of rain forests; however, non-indigenous organisms can also severely alter the natural habitat of a native species. For example, in Florida two non-indigenous aquatic plants (*Lichornia crassipes* and *Pistia stratiotes*), have covered the surfaces of canals and ponds (Courtenay, 1979). Plants which once survived below the surface die due to lack of light.

Uncontrolled Population Growth - The risk of uncontrolled population growth is greater in marine environments than on land because it is easier to control terrestrial organisms. Introduced agricultural species are genetically different from their ancestors. Many require care in order to survive, therefore, uncontrolled population growth is rarely a threat in terrestrial environments (Courtenay, 1979). Control is difficult, however, in aquatic environments. The zebra mussel, *Dreissena polymorpha*, was unintentionally introduced into the Great Lakes through the dumping of ballast water. It is "expected to infest over two-thirds of the continental United States" if left uncontrolled (Title 16 U.S.C., sec. 4701).

Conflict with a Native Fishery - For a non-indigenous

species to affect a native fishery, there either has to be ecological or biological effects (i.e competition, disease), and/or economic effects (resulting from the replacement of one fishery by another because of economic, not biological reasons). A North American crayfish, *Pacifasticus leniusculus*, was introduced into Britain; unfortunately, the "crayfish plague" caused by the fungus *Aphanomyces astici* was also introduced. Ecosystems were stressed, and it "caused irreparable shifts in species diversity and damaged traditional fisheries" (Thompson, 1990).

There is concern that *C. gigas* would effect the native fishery, based on *C. virginica*. The accidental introduction of *C. gigas* in New Zealand displaced the native rock oyster industry (Synopsis of the Oyster Ecology Workshop: *Crassostrea gigas*, 1991). The introduction has not created economic problems because the two species possess the same market value; however, *C. gigas* has also been found on some of New Zealands green mussel beds, a very valuable commodity (Shatkin, G. 1992).

Fouling - Fouling organisms attach to or impair man-made objects; removal and prevention are costly. The zebra mussel has colonized on water pipes, boat hulls and other manmade hard surfaces. The high density growth of the small mussel on effluent and intake pipes and other industrial structures is estimated to cost $5,000,000,000 to remove by

the year 2000 (Title 16 U.S.C., 4701).

The Asiatic clam, *Corbicula manilensis* is another example of a fouling organism. Introduced into the Pacific Northwest, it clogs irrigation pipes and canals (Courtenay, 1979).

Fouling also occurs on other organisms. An introduced fouling organism which attached itself to spat or to cultch thus preventing setting could compete with oysters for substrate.

Financial Cost as a Result of an Introduction - There are the financial costs related to the problems caused by introductions (fouling,etc.), possible economic losses of native fisheries, and also the financial costs related to the introduction. The latter is especially true if the species does not become established on its own (Nelson, 1979). Establishment also takes time. The time lag between introduction and financial gain may be greater than an investor wishes to wait.

Quarantine of Non-indigenous Species Prior to Introduction - The issues of quarantine arise on two separate levels. The first concerns the quality of inspection, either from the state or country of origin, or in the state or country of importation. It is uncertain whether an organism can accurately be diagnosed disease free

(Hickey, 1979; Nelson, 1979; Rosenfield and Kern, 1979). Histochemical and histopathological examinations of the shipment may not detect some pathogens which are in a state of remission. In addition, often ten percent or less of a shipment may be inspected (Carlton, 1991).

Breakdown of quarantine measures can also occur at culture facilities. For example, species raised in coastal ponds have been introduced into the ocean during storms when the ponds were flooded (Courtenay, 1979).

Genetic Impacts of Introductions - Gaffney and Allen (1990) describe genetic effects as either direct or indirect. Direct effects (i.e hybridization) occur "when the gene pool of the native population is open to the introgression of genes from the introduced population." Indirect effects are a result of natural selection or "alterations in gene frequencies (which) result from ecological interactions with the introduced organism."

Hybridization between *C. gigas* and *C. virginica* has never been witnessed in the wild and "all attempts to produce hybrid adults of the two species have been unsuccessful" (Synopsis of the Oyster Ecology Workshop: *Crassostrea gigas*, 1991). Gaffney and Allen (1990), however, suggest that if less viable, sterile hybrids are the result of cross fertilization, the gametes of both species would be wasted. This is supported by instances

where the two coexist without the existence of a hybrid (Bourne, 1979); the belief being that any hybrids produced were not viable and thus never reached maturity.

Due to the widespread larval dispersal of oysters, Gaffney and Allen (1990) believe that the waste of gametes should not be of significance. Greater concern lies with the indirect effects, which depend on the ecological interaction of the two species about which little is known (Gaffney and Allen, 1990). It is suspected that *C. gigas* will out compete *C. virginica* when the two overlap; however, it is also believed that *C. virginica* may have greater tolerance than *C. gigas* in the intertidal zone (Synopsis of the Oyster Ecology Workshop: *Crassostrea gigas*, 1991).

International, Federal, Regional, and State Policies Regarding the Intentional Introduction of Non-indigenous Species

The intentional introduction of non-indigenous species is governed by international, federal, regional, state, and, in rare instances, local authorities. Depending upon which is involved, the roles of each vary from advisory, to development and enforcement of policy.

International

The International Council for the Exploration of the Seas (ICES), the European Inland Fisheries Advisory Commission (EIFAC) [a regional commission of the Food and Agriculture Organization (FAO)], and the International Animal Health Code of the Office des Epizootics (OIE), are three international agencies which address the issue of introductions. The influence these entities possess varies from country to country. International guidelines do not have the enforcement of law, but rely on political influence for effectiveness. For example, the "codes of practice" developed by EIFAC and OIE contain guidelines which each member country is free to "accept, modify, or reject any or all parts" (deKinkelin, P. and Hendrick, R.P., 1991).

The following briefly discusses ICES' 1990 Revised Set of Guidelines. The ICES Working Group on Introductions and Transfers of Marine Organisms, consisting up of representatives from each member country, convenes annually to consider proposed and ongoing introductions and modifications in the code (Sindermann, 1991). The first section of the code recommends that the country considering a new introduction present ICES with information regarding the "candidate species," its habitat, origin, stage in life cycle, and associated organisms. The Working Group analyzes the information and gives advice. ICES recommends that "appropriate authorities" from the importing country examine the "candidate" in its native environment. Authorities should also consider the need for the introduction and possible interactions with native species. Prior to reaching a final decision, possible impacts should be assessed and past introductions of the species analyzed (ICES, 1990).

Once a species has been approved for introduction, brood stock should be quarantined for a "sufficient time to allow adequate evaluation of its health status" and any effluent of the hatchery sterilized. Only F1 or later generations should be introduced. Communications with ICES continue throughout the process (ICES, 1990).

For introductions and transfers already in action, ICES recommends the inspection of shipments upon arrival and the

development of an established brood stock. Quarantine and disinfection of effluent is encouraged the same as above (ICES, 1990).

Federal

The following federal laws, regulations, and Executive Order, are those most likely to effect an intentional introduction of an aquatic non-indigenous species.

The Lacey Act

The enactment of the Lacey Act in 1900, made it one of the first federal wildlife laws.[9] The Act attempts to conserve wildlife by regulating commerce. The Lacey Act originally contained two parts. The first outlawed interstate trafficking of birds and other wild animals killed in violation of state law (which at the time referred to fur-bearing mammals and migratory birds) (Bean, 1983). The second part prohibited the import of injurious animals, and still operates towards that purpose today (Legislative History, P.L. 97-79).

Fish were regulated separately under the 1926 Black Bass Act. Originally the Act applied to the illegal taking, purchase, sale or possession of black bass, but was expanded

---

[9]The Lacey Act was named after its creator Congressman Lacey, who was careful not to "prohibit the taking of .. wildlife" because at the time, the states had "ownership" of the wildlife and thus control over it.

to include all fish. The Lacey Act and the Black Bass Act were both later amended to include fish or wildlife illegally taken in a foreign country. Until the Black Bass Act's repeal in 1981 (at which time much of the Lacey Act was also repealed and rewritten), the two acts coexisted, performing similar functions.

The 1981 Lacey Act amendments combined the two acts and gave them more enforcement power by raising the civil and criminal penalties. Today, the first section of the revised Lacey Act appears as Chapter 53 of Title 16 U.S.C., sections 3371-3378 entitled "Control of Illegally Taken Fish and Wildlife." Section 3372 declares that it is unlawful to "import, export, transport, sell, receive, acquire, or purchase any fish, wildlife or plant taken, possessed, transported or sold in violation of any law, treaty, or regulation of the United States or in violation of any Indian tribal law" as well as violation of any state or foreign law (16 U.S.C. 3372). This section also requires the marking of containers in accordance with existing commercial practices.

The marking of containers was one of the few parts of the Lacey Act that was relaxed (Bean, 1983). In contrast, to increase the enforcement ability of the act, the maximum for civil penalties was doubled to $10,000 and 1 year, and the maximum for criminal penalties was increased to $20,000 and 5 years (Legislative history, P.L. 97-79).

The importation of injurious wildlife is addressed in Title 18 of the United States Code, section 42. This section forbids the importation of a few identified species, but more importantly gives the Secretary of the Interior authority to regulate importation of any "wild mammals, wild bird, fish (including mollusks and crustacea), amphibians, reptiles or the offspring or eggs of any of the foregoing" (18 U.S.C. sec. 42). The noteworthy absentees are plants, which are regulated under The Plant Pest Act [7 U.S.C., sections 147(a), 149, 150 (aa), 150 (jj)].

Created under authority of the Lacey Act, Title 50 of the Code of Federal Regulations section 16.13 entitled "Importation of live or dead fish, mollusks, and crustaceans, or their eggs" pertains to the introduction of *Crassostrea gigas*. This section confirms that individual states have authority over introductions. No "live fish, mollusks, crustacean, or any progeny or eggs thereof, may be released into the wild except by the State wildlife conservation agency having jurisdiction over the area of release or by persons having prior written permission from such agency." This does not include those organisms listed as being injurious in Title 50 of the Code of Federal Regulations, section 16.13. A permit for importation into the U.S. is not required; only the completion of a written declaration to be filed with the District Director of Customs at the port of entry (50 CFR 16.13).

The Department of Interior, in 1973, proposed that all foreign wildlife be considered injurious. It would create a "clean list" of those animals considered low risk and allowed to be imported without a permit. Protests, however, from the pet trade community, and the difficulty the change would have placed on research institutions importing animals for study, helped to defeat the proposal (Bean, 1983).

Under section 16.13 of Title 50 of the Code of Federal Regulations, a state has the authority to introduce any species it chooses, including *C. gigas*, unless that species is present or added to the "injurious" list. The latter act is considered unlikely for *C. gigas* already exists in the United States, and as defined by Executive Order No. 11987, is not an exotic species.

Executive Order No. 11987, Exotic Organisms

Executive Order No. 11987, signed in 1977 by President Jimmy Carter, addresses the issue of exotic organisms "in furtherance of the purposes of the Lacey Act (18 U.S.C. 42) and the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 et seq.)." It calls for restriction of the importation and exportation of exotic species by executive agencies. The Order also stipulates that Federal funds for exports of exotics be restricted if the exotics are to be introduced into a foreign country. Section 3 of the Executive Order stipulates that the Secretary of the

Interior, in consultation with the Secretary of Agriculture and other agency heads, create regulation to implement the Order. To date, no regulations have been promulgated.

The intent of the Executive Order was to strengthen the Lacey Act; however, the Order weakened the Act by its definition of exotics. Exotics are defined as "all species of plants and animals not naturally occurring, either presently or historically, in any ecosystem of the United States," which includes all U.S. territories. Species could be transported anywhere within those areas without consideration of their impact by Executive Order No. 11987. An introduction of *C. gigas* originating in the state of Washington, to the east coast of the United States would not be restricted; yet an introduction across the border of Maine to Canada would be subject to consideration.

Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (16 U.S.C. sec. 4701-4751) was developed subsequent to invasion of the zebra mussel into the Great Lakes via release of ballast water. Much of the act addresses the introduction of the zebra mussel and the mussel's eradication. Although ballast water was the mode of introduction which led to the Act, the Nonindigenous Aquatic Nuisance Prevention and Control Act does not limit

itself to this vector of introduction. The Act's purpose is to prevent unintentional introductions of aquatic nuisance species, no matter the mode of introduction. The Act also serves to fund research involved in the study of introductions of aquatic nuisance species, as well as aids states in prevention control (Kern and Rosenfield, 1991).

In contrast to Executive Order 11987, the Act addresses non-indigenous species versus exotics. It defines non-indigenous species as "any species or other viable biological material that enters an ecosystem beyond its historic range" (16 U.S.C. sec. 4702). The Act defines "aquatic nuisance species" as "a nonindigenous species that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, aquacultural or recreational activities dependent on such waters" (16 U.S.C. sec. 4702).

Section 4722 of the Nonindigenous Aquatic Nuisance Prevention and Control Act calls for an aquatic nuisance species program, led by a "Task Force." The Task Force is designated to develop a program to prevent unintentional introductions of aquatic nuisance species. As intentional introductions are a pathway to unintentional ones, technically they should also fall under this act. Intentional introductions, however, are mentioned only in a small section of the act (section 4727 of Title 16, U.S.C.). They include introductions which resulted from accidental

releases of non-indigenous species from aquaculture facilities (Intentional Introductions Policy Review Options Paper, Spring 1992).

Entitled "Intentional Introductions Policy Review," section 4727 requires that the Task Force, in cooperation with state, regional, and local entities, "identify and evaluate approaches for reducing the risk of adverse consequences associated with intentional introductions of aquatic organisms." In order to fulfill its duties, the Task Force formed the "Intentional Introductions Policy Review Committee" which is currently preparing a draft document to be submitted to Congress. Once evaluated by Congress, the report could lead to the development of new regulations. These regulations, if developed, could become the most relevant piece of Federal legislation addressing intentional introductions (Intentional Introductions Policy Review Options Paper, Spring 1992).

The Endangered Species Act

The Endangered Species Act (16 U.S.C. sec. 1531-1544) would affect an introduction of a non-indigenous species only if the species itself were endangered, or if the introduction could affect an endangered organism. Those species not yet listed, but awaiting evaluation, are also protected. "Each federal agency shall confer with the Secretary on any agency action which is likely to jeopardize

the continued existence of any species proposed to be listed" [16 U.S.C. sec. 1536(a)(4)].

The National Environmental Policy Act (NEPA)

The National Environmental Policy Act (NEPA) (42 U.S.C. sec. 4321-4370) would affect the introduction of non-indigenous species if a federal agency were involved with the introduction. The Act requires that federal agencies file environmental impact statements to be included with "proposals for legislation and other major federal actions significantly affecting the quality of the human environment" (42 U.S.C. sec. 4332). This forces the agencies not only to identify the probable "adverse effects" of the project, but also to look at alternatives[10].

<u>Regional</u>

Potomac River Fisheries Commission - The Potomac River Fisheries Commission has jurisdiction over the tidal portion of the Potomac River. The Commission regulates the oyster industry within its jurisdiction, but in order for a non-indigenous species to be intentionally introduced into the Potomac River, members from both Virginia and Maryland would have to accept the proposal (Article 1V of the Potomac River

---

[10]Raft culture of a non-indigenous oyster could involve the federal government if the proposed culture sight existed in navigable water. The National Environmental Policy Act could then require the federal agency involved (i.e. the Army Corp of Engineers) to file an environmental impact statement.

Compact). Maryland is against the introduction of *C. gigas*, therefore this is unlikely to occur.

Atlantic States Marine Fisheries Commission -

> The Atlantic States Marine Fisheries Commission (ASMFC) shall have the power to recommend to the states party hereto the stocking of the waters of such states with fish and fish eggs, or joint stocking by some or all of the states party hereto, and <u>when two or more of the states shall jointly stock waters, the Commission shall act as coordinating agency for such stocking.</u>
>
> (Article 1V)

The underlined section above could be interpreted to indicate that the ASMFC has control over "joint stocking" of waters. This could have applied to the open water experiments, involving *C.gigas*, proposed by New Jersey and Virginia, with the ASMFC as the "coordinating agency." Whether this was the intention of the paragraph is unclear. Article IV fails to define either "joint stocking" or "waters"[11].

---

[11]The ASMFC Interjurisdictional Shellfish Transport Committee has issued a position statement discouraging the open water testing of <u>C. gigas</u>. If open water testing were considered "joint stocking" then the ASMFC could control the experiments. Virginia and New Jersey, however, would most likely argue that open water tests with sterile oysters do not constitute "joint stocking."

State

Virginia - Virginia Marine Resources Commission

(Virginia Code Annotated, 1992)

The laws pertaining to the introduction of non-indigenous marine species are under section 28.2-825, entitled "Importing fish, shellfish or crustacea for introduction into waters of Commonwealth; penalty." The state prohibits the importation of fish, shellfish or crustacea with the intent to introduce them into state waters unless either: 1) the species is on the Commission's approved list and originates from a state or water also on the approved list, or; 2) if the person importing the species receives written permission from the Commissioner.

A written notification containing such information as species, origin, quantity, destination, and time frame of the introduction must be submitted to the Commissioner thirty days prior to the importation. The concurrence of the Director of the Virginia Institute of Marine Science is required prior to addition or removal of a species from the approved list of species or to add or delete a state or water from the approved list of states or waters.

No lists of approved states, waters, or species currently exist. The commissioner, therefore, has authority to accept or deny proposals for the introduction of non-indigenous marine species (Travelstead, J., Chief of the Fisheries Division, VMRC, personal communication, Nov.

1992).

Maryland - Maryland Department of Natural Resources (Maryland Natural Resources Code Annotated, 1991; 1991 Regulation)

Maryland defines "native species" as "any species of fish which historically has lived, grown, and reproduced in Maryland's waters." "Naturalized species" refer to species, though not native, have "lived, grown, and reproduced in Maryland for more than ten years." Nonnative species are those which are neither native nor naturalized (Md. Reg. .08.02.14.03). A permit is required to import shellfish, and will only be issued if the imported shellfish will not be harmful to Maryland shellfish (Md. Reg. .08.02.08.01).

Maryland is against the introduction of nonnative species. It forbids aquaculture of nonnative species that would be released into unconfined waters or contaminate the ecosystems of native or naturalized species (Md. Reg. .08.02.14.03). *Crassostrea virginica* is the only species of oyster approved for aquaculture (Md. Reg. .08.02.14.07).

Under Maryland statute 4-11A-12 only *C. virginica* may be planted, cultivated, sown, or protected. Statute 4-743, titled "Quarantine of Shellfish" states that the Department may prohibit by regulation the importation of any shellfish, and quarantine "any area within the state populated by any destructive diseases, deleterious genetic characteristics,

dangerous parasites or other biological threat."

Delaware - Department of Natural Resources and Environmental Control, Division of Fish and Wildlife
(Delaware Code Annotated, 1991 supp.)

The prior approval of the Department is needed in order to plant a species of oyster other than *C. virginica*. Title 7, section 2110 of the Delaware statutes, declares it unlawful to bring seed oysters of <u>any</u> species into the state without the written permission of the department.

New Jersey - Department of Environmental Protection
(New Jersey Statutes Annotated, 1991 supp.)

The laws pertaining to the introduction of foreign oysters are under Article 6, in the New Jersey Statutes Annotated. Section 50:1-34 states that:

> no oysters native to, or brought directly or indirectly, from any foreign country or any other state shall be planted or lodged in the waters of this state without written permission issued by the commissioner, after notice to the council, for each separate shipment.

The application for import should include the species, its most recent location, and origin. If approved, the information above must accompany each shipment (via tagging or on the billing statement).

The "nature, species, quantity, proposed location, and the condition of the oysters" must be inspected and/or examined prior to import. If the commissioner believes the introduction will not be harmful to the native oyster or its industry, that shipment will be allowed under specified conditions (species, quantity, destination, etc.) (N.J. Statutes Annotated, 50:1-35).

In practice, the introduction and associated information is considered by one of the two New Jersey Shellfish Councils, dependant upon location of introduction (the Delaware Bay or the Atlantic). The proposed introduction is also analyzed by the Shellfish Transport Committee. The Council and the Shellfish Transport Committee make individual recommendations to the Director of the Department of Shellfish. The Director examines the proposal and submits it to the Commissioner, who has final authority (Critchlow, G., Department of Shellfisheries, New Jersey, personal communication, 1992).

Connecticut - Department of Agriculture, Aquaculture Division (Conn. General Statutes Annotated, 1992 supp.)

Introductions of "fish, wild birds, wild quadrupeds, reptiles and amphibians" are regulated by the Department of Environmental Protection (Conn. Gen. Stat. Ann. sec. 26-55, 1991 Supp.). Shellfish, however, are under the jurisdiction

of the Department of Agriculture (John Volk, Department of Agriculture, Aquaculture Division, 7/24/92, personal communication).

Connecticut addresses the introduction of a non-indigenous oyster under Chapter 491 of the General Statutes. Statute 26-224, "Deposit of injurious substances in tidal waters or on oyster ground. Penalty," states that if a person "wilfully and knowingly" deposits any oyster other than the species "*Ostrea virginica*" in tidal waters or on oyster grounds, they will be fined up to $200 or six months in jail for each bushel of nonnative oyster.

New York - Department of Environmental Conservation
(New York Consolidated Laws Service Annotated Statutes with Forms, 1991 supp.)

Under New York law "in no case shall oysters other than the species *Crassostrea virginica* be planted or transplanted in New York waters without procuring a permit from the department" (N.Y. Consolidated Laws Service, 13-0323).

Rhode Island - Department of the Environment, Environmental Management Branch, Fish and Wildlife Division
(General Laws of Rhode Island, 1991 supp.)

It is a Department policy not to permit the introduction of non-indigenous species, nor to permit the importation of any out of state seed oysters. Ironically,

there is one island, Block Island, whose waters do not fall under the jurisdiction of the Department; the island did import *C. virginica* from Connecticut (Ganz, Department of Coastal Fisheries, Rhode Island, personal communication, 1992).

Rhode Island statutes 20-10-5 and 20-10-12 establish procedures for approval of aquaculture activities and require a permit to possess, import, and transport a species involved in aquaculture. The review of the Commissioner of the Environmental Management Branch is needed to determine that the activities will not harm native fisheries or adjacent marine life. The commissioner has authority under 20-10-12 to regulate the possession, import, and transport of those species used in aquaculture.

Massachusetts - Division of Marine Fisheries

(Mass. General Laws Annotated, 1991)

It is the general policy of Massachusetts to prohibit the introduction of exotic or non-indigenous species. State statutes give the Division of Marine Fisheries the authority to issue permits and set the conditions of an introduction. A special permit is required to "plant, transplant or introduce for the purpose of transplanting seed or adult oysters, into any waters or onto any shellfish areas within the Commonwealth" (322 CMR, sec. 3.03). These permits and conditions thereof are considered equal in power to

regulation. Violation can result in fines up to 1000 dollars (Hickey, 1990). In this same publication *C. gigas* is described as an "unwanted species," therefore it is unlikely that *C. gigas* would be approved for introduction into Massachusetts' waters.

New Hampshire - Department of Fish and Game
(New Hampshire Revised Statutes Annotated, 1991)

Although New Hampshire does not have a commercial industry, an introduction into state waters could effect a neighboring states. Under New Hampshire Code of Administrative Rules, the Director is authorized to prohibit importation of any organism into "waters under the jurisdiction of the state if deemed injurious to resources of the state" (N.H. Fis. 703.02).

N.H. statute 207:15 "Releasing Fish and Wildlife," states that it is illegal to introduce any "living fish, the fry or eggs thereof" without a permit from the executive director. Under 207:14a the Director is authorized to exempt certain species from the permit process.

Maine - Department of Marine Resource
(Maine Revised Statutes Annotated for use in 1990-1991)

Maine Statute 6071 under title 12, prohibits the

importation of live marine organisms without a permit. Permits are issued by the commissioner if the organism in question is not deemed dangerous to indigenous marine life or the native environment. A hearing will be held prior to the issuance of a permit for a non-indigenous organism which has not previously been considered.

Maine has a "Pathology Program" designed to improve pathological assessment of shellfish prior to their introduction. This also applies to stock to be exported (Me., Title 12, sec. 6075).

Discussion

Current legislation does not adequately address intentional introductions of non-indigenous species into the marine environment. International guidelines, though adequate, have no authority even though many introductions, including those of *Crassostrea gigas*, have historically occurred across national borders. The Federal government also has little control over introductions, in part because of poorly written legislation, and because of the federal government's policy to preserve state autonomy.[12] Regional commissions, such as the Atlantic States Marine Fisheries Commission, exercise little, if any influence, which leaves control of introductions to the individual states.

Whereas implementation of programs at the state level is necessary, individual states should not serve as the sole decision-making authority since the impact of an introduction may extend beyond state borders. This possibility is magnified when open water introductions are considered.

Analysis of the proposed open water testing of *C. gigas*

---

[12]During amendment, it was stated that the Lacey Act should not be viewed "as increasing the Federal role in managing wildlife, but as a Federal tool to aid States" (Legislative History P.L. 97-79).

into waters of the northeastern United States, illustrated problems with the policies and management affecting intentional introductions. It is not the intent of this study to judge whether *C. gigas* should or should not be introduced (that would depend on the individual introduction); but rather to illustrate how current legislation does not adequately regulate intentional introductions, and to identify means by which to improve methods of addressing the problems.

Contradictions among definitions, and the variation of terminology associated with introductions, are major inadequacies highlighted in the literature. For example, species native to the United States, as defined by Presidential Executive Order No. 11987, are often not considered native to an individual state. Introductions of *C. gigas* from the west coast of the United States to the east coast would not be questioned by this Order even though the two areas contain very different habitats. The same applies to introductions originating from Guam since Guam is a territory of the United States. In contrast, under Maryland law, *C. gigas* is a nonnative species (Md. Reg. .08.02.14.03).

Presidential Executive Order No. 11987 is limited because it addresses only a portion of introductions, those originating from outside of U.S. territories. A more

appropriate approach utilizes the term non-indigenous, versus exotic. The Nonindigenous Aquatic Nuisance Prevention and Control Act, for example, defines non-indigenous species as "any species or other viable biological material that enters an ecosystem beyond its historic range" (16 U.S.C. sec. 4702). This definition overcomes the differences between federal and state viewpoints of "native" or "exotic." The Act does not, however, currently regulate intentional introductions. It is also unclear whether "viable biological material" mentioned within the definition, applies to genetically altered native species.

The lack of development of cohesive guidelines for intentional introductions was highlighted in examination of state, regional, and federal legislation affecting the proposed introductions of C. gigas. All of the states surveyed prohibit introductions of non-indigenous species without first obtaining a permit. This is, however, where the similarities end. Two states, Connecticut and Maryland, specifically forbid the introduction of any oyster other than *Crassostrea virginica* (Conn. Gen. Stat. Ann. sec. 26-224 and Md. Nat. Res. Code Ann. sec. 4-11A-12). Maryland, a neighboring state of Virginia, has publicly opposed the introduction of *C. gigas*, but does not have any authority over Virginia's decision-making process. Rhode Island's

policy is not to permit the introduction of a non-indigenous species (or even to import seed oysters of the species *C. virginica* from out of state) (Ganz, Department of Coastal Fisheries, Rhode Island, personal communication, 1992). Massachusetts forbids the introduction of a non-indigenous oyster without a permit, but considers *C. gigas* to be an "unwanted species" (Hickey, M., 1990).

Discrepancies also exist between state and regional authorities. The Interjurisdictional Shellfish Transport Committee of the Atlantic States Marine Fisheries Commission has issued a position statement discouraging open water testing of *C. gigas*, but this Committee has no regulatory authority. Virginia, New Jersey and Maine (as well as the other states) have the authority to decide individually whether or not a non-indigenous species should be introduced (50 CFR 16.3).

The decision making process, therefore, varies from state to state. Information sought by the permitting agency is not always specified, but when it is, usually regards: species, origin, quantity, and destination. The states surveyed, however, do not follow guidelines regarding any part of an introduction.

<u>Guidelines which reduce the risks associated with intentional introductions are clearly needed</u>. Development of federal guidelines is necessary to assure that

intentional introductions are examined adequately. States would be required to adopt these guidelines. Similar to the Chesapeake Bay Preservation Act (Va. Code Annotated, sec. 10.1-2100), where state government provides minimal guidelines for localities to enforce, the federal government would provide guidelines regarding introductions for the states to enact. A state could adopt more stringent guidelines, but not ones that are less rigid. State authorities still control introductions, but analogous to the Coastal Zone Management Act (Title 16 U.S.C. sec. 1451-1464), would have to meet federal standards.

The U.S. Fish and Wildlife Service within the Department of the Interior would serve as the lead agency in the development of federal guidelines. The Service is already responsible for 50 CFR Part 16, the importation of injurious wildlife, and also the Nonindigenous Aquatic Nuisance Prevention and Control Act (16 U.S.C. sec 4701-4751).

Guidelines developed by the Working Group of the International Council for the Exploration of the Seas (ICES) are one example[13] of existing guidelines which adequately cover all phases of an introduction: the decision-making process, the introduction, and post-introduction. Prior to

---

[13]The American Fisheries Society and the European Inland Fisheries Advisory Commission also have developed criteria to be addressed prior to an introduction, and could be considered as a prototype for federal guidelines. ICES was selected only as an example.

introduction, ICES advises to fully examine the species under consideration, its habitat, associated organisms, and previous introductions, as well as possible interactions with endemic species, ecological considerations, and genetic considerations.

Regarding *C. gigas*, examination by Virginia, New Jersey, and Maine, of the Japanese oyster and its proposed introduction, would then be required to follow guidelines similar to those described by ICES. Although the scientists proposing the open water testing of *C. gigas* intend to voluntarily follow ICES' guidelines, others may not.

Each introduction of *C. gigas* should be examined separately as each presents different risks. The introduction of a triploid oyster significantly reduces the risk, since those problems associated with the reproduction of the species are eliminated (i.e. competition and fouling). There should be a need for the introduction; *C. gigas*, for example, could be introduced solely on the grounds that its filtering capabilities could aid in cleaning the waters of the bay. When possible the "development of native species or of species stocks, through scientific management and aquaculture practices (including breeding and genetic manipulation)" should be encouraged (Sindermann, 1992). For example, an introduction aimed at identifying what makes *C. gigas* less susceptible to *Haplosporidium nelsoni* and *Perkinsus marinus* so that the

knowledge gained could be applied to the native oyster, would be regarded as more appropriate than one that proposes to introduce *C. gigas* in large numbers into areas where it would compete with *C. virginica*.

Introductions have the potential to affect the ecosystems of other states, therefore states potentially affected should be involved in the regulatory process. A state agency is able to make an informed decision by following guidelines similar to those established by ICES. This should not, however, be the final decision. States should be required to utilize advisory organizations already in existence, such as ICES or the Exotic Fish Section of the American Fisheries Society. Other states opposing the introduction could also respond to the same advisory organization. The advising agency would weigh all of the arguments, both for and against the introduction.

The introduction, therefore, would first be addressed at the state level, following guidelines developed by the federal government. The state would have authority to veto the introduction if it felt the introduction would not be in the state's best interests. If the state approved the introduction, the information gathered would be forwarded to an advisory agency, as would any complaints from neighboring states. The advisory agency, after considering the introduction, would make recommendations regarding the risk

of the introduction, whether it should proceed and ways to lower the risks.

Once the state considering the introduction has received the counsel of the advisory organization, the state makes the final decision of whether to proceed. If it chooses to do so, the introduction would be directed and monitored by the appropriate state agency. The federal government would not interfere as long as the introduction followed the established guidelines and did not produce deleterious effects in the area of introduction. Communication with the advisory agency would continue, increasing both the state's and advisory agency's knowledge about introductions.

Requiring states to seek outside advice from the same advisory organization, improves the current situation where neighboring states do not have input into the process of introduction. Non-indigenous species are unaware of state borders, therefore, a state should not be allowed to introduce a species without consideration of other jurisdictions within the organism's possible range. State autonomy has been maintained, but opposing state governments have a stage to voice their concerns. Outside agencies may also provide information on how to lower the risk of the introduction by suggesting alternative methods or alternative species.

If a state proceeds with an introduction, an opposing

state has the legal system for recourse. A federal court would decide whether the introduction should continue. Imposed guidelines give both the state and the person or organization performing the introduction an advantage; by following the guidelines, they have done everything legally necessary to prevent a problem. Unfortunately, should a problem develop, the question of liability cannot be answered satisfactorily until the issue actually arises in the courts.

One of the most important areas which needs to be addressed is the quarantine and establishment of brood stock in order to decrease the risk of introducing disease or associated organisms. The guidelines developed by a federal agency must address requirements similar to those of ICES, regarding quarantine, establishment of brood stock, and introduction of only F1 and subsequent generations. The known diseases of *C. gigas* are presented in Table II to aid in illustrating the effectiveness of these practices in preventing the spread of disease and associated organisms.

Table II

Disease of C. gigas

Disease	Etiology	Lab Diagnosis	Reference
Hematopoietic Neoplasia	unknown	microscopic examination of blood, histological examination of tissue	1,2,3
Malpeque Bay	unknown		2,4
Viral Diseases			
Oyster Velar Virus	iridovirus	Electron Microscope	1,2,3
Hemocytic Infection Virus	iridovirus	Electron Microscope	1,3
Gill Necrosis Virus	iridovirus	Electron Microscope	1
Bacterial Diseases			
Bacillary Necrosis (Vibriosis)	*Vibrio*	culture of bacteria & tissue examination	1,2,3
Hinge Ligament Disease	"gliding"	microscopic examination	2
Nocardiosis	*Nocardia* (actinomycete bacterium)	microscopic examination	1,2
Rickettsiae	intracellular bacteria		1,2,3
Protozoan Diseases			
Marteiliasis (Aber Disease)	*Marteilla refringes*	histological examination	1,2,3
	Haplosporidium spp.		1
	Marteilioides chungmuensis	life cycle	1,3
Denman Island Disease	*Mikrocytos mackini*	microscopic examination	1,2,3,4
Fungal Diseases			
Shell Disease	*Ostracoblabe implexa*	microscopic examination	2

References:1)Burreson, 1991; 2)Elston,R., 1990; 3)Mann et al., 1992; 4)Quayle, D.B., 1988

Quarantine of *C. gigas*, establishment of brood stock, and introducing only F1 or future generations, drastically reduces the risk of introducing diseases or organisms. This prevents introduction of the diseases listed in Table II, with exception of the viruses and *M. chungmuensis*; the latter because its life cycle is unknown. If the brood stock is limited to the state of Washington, then the risk is further reduced since neither pathological viruses of *C. gigas*, nor specimens of *M. chungmuensis* have been reported there. The metazoan parasite, *Mytilicola orientalis*, can also be controlled by quarantine of brood stock (Burreson, 1991).

Currently, species imported into the country do not require a permit at the port of entry. A written declaration with the District Director of Customs is the only requisite (50 CFR 16.13). State requirements regarding quarantine and the establishment of brood stock, would negate the need to change this practice. Once a shipment reached the site of quarantine (even shipments originating from inside the country), the contents of the package would be inspected. Any contents other than the species of import (i.e. transport medium such as seaweed) would be destroyed. The quarantine of the species must cover the dormant stages of suspected diseases. Any effluent from the hatchery would be sterilized.

Summary

Examination of the international, federal, regional and state policies, affecting the potential introduction of *Crassostrea gigas* into the northeastern United States, illustrates that intentional introductions of non-indigenous, marine species are not adequately controlled. Appropriate language, for example, the use of non-indigenous versus exotic, is needed so that all intentional introductions are regulated. Organisms are not limited by political boundaries, therefore, the terms which define and govern their management must incorporate zoological characteristics. Secondly, since introduced organisms may spread to neighboring states, those states should have input into the decision-making process. Finally, although the ten states surveyed prohibit the importation and introduction of marine organisms without a permit, none have developed guidelines to control the introduction process.

I propose that federal guidelines, similar to those developed by ICES, be enforced by state authorities. Incorporated within the guidelines would be a "review" by an advisory agency to whom opposing states could submit their concerns. The state proposing the introduction still would have final authority, but must consider the advice given by

the advisory agency. Included within the guidelines must be measures regarding the quarantine of non-indigenous species, and the development of brood stock. These activities are crucial in preventing the introduction of non-endemic diseases and associated organisms. While it would be hard to eliminate all of the risks associated with intentional introductions, appropriate guidelines governing the process of introduction, significantly lowers them.

Appendix

Seaside Haplosporidiosis - *C. virginica*

Seaside Haplosporidiosis, often referred to as SSO, is caused by *Haplosporidium costale* and was first discovered in 1959 in the high salinity waters of Virginia and Maryland. The disease, which infects almost all tissues except epithelium, caused a significant number of mortalities between 1959-1961 in the seaside bays of Virginia. The more serious cases of the disease occur in May and June from Cape Henry, Virginia north to Cape Henlopen, Delaware. Mortalities can reach as high as 50%, but the annual mortality rate in Virginia is 12-14% (Elston,1990; Hargis and Haven, 1988).

Confirmation of the parasite by pathological examination is only possible from March to June (Elston, 1990). Signs of an infected oyster include gaping, poor condition, and possibly discoloration; these signs which occur with other diseases as well. Elston (1990) reported that only *C. virginica* was infected, however, Hargis and Haven (1988) stated that the parasite kills both native and imported oysters.

Denman Island Disease - *C. gigas*

As the name indicates Denman Island Disease occurs at Denman Island, B.C. and also in the nearby Strait of George. It was most likely introduced with *C. gigas*. It is caused by a protozoan parasite, *Mikrocytos mackini*, which lives in glycogen storage cells and infects vesicular connective tissue cells (Burreson, 1990; Elston,1990; Mann et al., 1992). Annual mortalities can reach as high as 53%, but usually fluctuate around 34%. Quayle (1988) found mortalities only occurring in oysters older than two years, but younger oyster could be infected. Most oysters infected live at lower tide levels.

The disease appears in the warmer months, with peak mortalities between May and July; approximately 10% of those infected survive (Elston, 1990; Quayle, 1988).

Pathological examination is required to confirm the disease. Signs of the disease include yellow-green inflammatory lesions of the mantle and gonads, or the formation of deep pustules on the mantle and body (Burreson, 1990; Elston, 1990; Mann et al., 1991; Quayle, 1988). Ironically, many of the oysters infected retain a good condition factor (Quayle, 1988).

Marteiliasis - *O. edulis*

Also known as Aber disease, Marteiliasis is caused by a protozoan *Marteilia refringes*. The parasite infects the

connective and digestive tissue of the European oyster throughout May and August on the Atlantic coast of Europe. Mortalities, which can reach as high as 90%, are related to formation of spore stages in the epithelium of the digestive tubules (Elston, 1990).

The disease is manifested only in *O. edulis*, however, the parasites have been found in *C. gigas* (Burreson, 1990; Elston,1990; Mann et al., 1991). Histological examination by pathologists determines the presence of the parasite. Outward signs include pale yellow digestive glands, a slimy and shrunken visceral mass, and a colorless mantle (Elston, 1990).

Marteilioides chungmuensis - C. gigas

Marteilioides chungmuensis is a protozoan related to *M. refringes*. Infections have occurred in the eggs of *C. gigas* in Korea and Japan, but it is not known to cause mortalities. There is a question as to whether or not it is in California waters (Burreson, 1990; Mann et al., 1991).

Nocardiosis - *C. gigas*

Also known as "fatal inflammatory bacteraemia," "focal necrosis," and "multiple abscess," Nocardiosis may be the disease associated with summer mortalities in the northwest. The actinomycete bacterium *Nocardia* causes the disease and occurs throughout the body via the blood. Signs include

small raised green to yellow lesions or nodules on the mantle (Burreson, 1990; Mann et al., 1991), and on the gills, adductor, and heart (Elston, 1990). Burreson (1990) also reports that similar nodules occur in *C. virginica*.

Oysters infected with Nocardiosis have been found in Matsushima Bay, Japan, California, Washington and British Columbia. It is probably more widespread since scientists believe the bacteria to be ubiquitous and acquired from the environment. Annual mortalities can reach 30% (Elston, 1990), but the prevalence of the disease on the Pacific northwest is reported to be around 18% (Burreson, 1990; Mann et al., 1991). Confirmation of the bacteria requires microscopic examination.

Rickettsia - *C. gigas* and *C. virginica*

Caused by an intracellular bacteria, Rickettsia effects the diverticula cells in both *C. gigas* and *C. virginica* (Burreson, 1990; Elston, 1990; Mann et al., 1991).

Vibriosis of Larvae and Juveniles - *C. gigas* and *C. virginica*

Vibriosis, as the name implies, is a bacterial disease caused by bacteria of the genus *Vibrio*. It occurs naturally and is not normally pathogenic. The most serious mortalities (100% of larvae) arise in hatcheries with poor hygiene (Burreson, 1990; Mann et al., 1991). *Vibrio* most

likely enters the hatchery either through the seawater source, the brood stock, or the food source. Diagnosis requires culture of the bacteria and tissue examination but should be expected if slow larval growth and failure to set occur (Elston, 1990).

Hinge Ligament Disease of juveniles

Bacteria in "hinge ligament disease" destroy the ligament binding the valves of juvenile oysters. As a result, the oyster cannot open for feeding and respiration, and other bacteria may be able to enter. The effect of the bacteria appears to increase as temperatures elevate from 5-20 degrees celsius (Elston, 1990).

Although it is likely that the bacteria occur in nature, "hinge ligament disease" has only been seen in hatcheries. Confirmation of the disease requires microscopic examination of the ligament tissue but one should expect it if a large percentage of juveniles die (Elston, 1990).

Hemic Neoplasia - *C. gigas* and *C. virginica*

Hemic neoplasia is also known as the following: hemic, hematopoetic, hematopoetic neoplasm, hemocytic neoplasia (HCN), hemic proliferative disease, leukocyte neoplasia, sarcomatous neoplasia, sarcomatoid proliferative disorder, disseminated sarcoma, and atypical hemocyte condition

(Elston, 1990). The disease resembles leukemia in vertebrates where "tissue invasion of abnormal blood cells" transpires (Burreson,1990; Mann et al., 1991).

C. gigas in Matsushima Bay and *C. virginica* in parts of the Atlantic coast from the Chesapeake Bay to Long Island Sound and in the Gulf have been infected with the disease but the causative agent is unknown. Infection appears from October through March and can kill entire populations of some species. It is not, however, as serious in oysters. Bivalves infected with the disease fail to reproduce follicles and have swollen tissues due to the proliferation of abnormal blood cells (Elston, 1990).

Malpeque Bay Disease - *C. virginica*

Another disease of unknown etiology, Malpeque Bay Disease, first occurred in 1915 in the Canadian Province of Prince Edward Island (Elston, 1990; Rosenfield and Kern, 1979). By 1939 the disease spread to all of the oyster areas of the island with mortalities reaching 100%. A disease resistant stock was developed by 1922. When the disease invaded the mainland, disease resistant oysters were successfully imported to the mainland thus increasing their resistance (Quayle, 1988). Visceral shrinkage, a decrease in growth and spawning, and translucence are all signs of the disease (Elston, 1990).

Shell Disease - *Crassostrea*

First reported in 1894, shell disease occurs in species of *Crassostrea*, though to a much lesser degree than in other bivalves. The fungus *Ostracoblabe implexa* infects mostly younger bivalves and weakens their shells. The disease first appears as bright white spots in the growing margin of the shell which later becomes raised. Besides diagnosis on the basis of shell lesions, microscopic examination confirms the presence of the fungus (Elston, 1990).

Oyster Velar Virus Disease (OVVD) - *C. gigas*

A hatchery disease, Velar virus has only been reported in Washington State. Larvae are the only known life stage to be infected but similar viruses occur in adult *C. gigas* and in the Portuguese oyster in France. Believed to be an irodovirus, it infects the epithelium of the velum of larvae, causing mortalities up to 100% (within a hatchery tank) (Elston, 1990). There is, however, no established link between mortalities and the disease (Burreson, 1990; Mann et al., 1991).

The disease occurs in the spring (logical as it is a larval disease) until the end of spawning, affecting larvae at least ten days after spawning. The larvae lose the cilia and develop blisters on their velum. Pathological examination of the tissue yields lesions characteristic of the disease (Elston, 1990).

Other Viruses

A herpes-like virus discovered in Maine infects *C. virginica*. Mortalities occur at elevated temperatures (28-30 degrees celsius) however the link has not been proven (Elston, 1990).

Another virus, Hemocytic Infection Virus (HIV), caused lesions and eventually mass mortalities in *C. angulata* in France during the 1970's. There is speculation that the virus was introduced with *C. gigas* (in which it does not cause disease) but this has yet to be proven. No known cases have been reported in the Pacific northwest (Burreson, 1990; Mann et al., 1991).

Hexamitiasis - *C. gigas* and *C. virginica*

A cold water disease associated with the parasite *Hexamita nelsoni*, there is some question as to whether the parasite causes the illness or enters because of illness. *H. nelsoni* appears in cold waters (around 6 degrees celsius and not greater than 12 degrees celsius) and occurs in the cells of the blood stream in dying oysters. It has been reported in both *C. gigas* and *C. virginica*, but is not considered to be a problem (Elston, 1990).

Bucepalus haimeanus and *B. cuculus* - *C. virginica* and *O. edulis*

These flatworms attack the reproductive and digestive

tissues of oysters. Signs include white patches around the gonadal area (Elston, 1990).

Nematopsis ostrearum and *N. prytherchi* - *C. virginica*

Both gregarine parasites, *N. ostrearum* spores appear in the mantle of *C. virginica* and spores of *N. prytherchi* are found in the gills, however neither is lethal (Elston, 1990).

Bibliography

Andrews, J.D. 1979. Scenario for introduction of *Crassostrea gigas* to the Atlantic coast of North America. pages 225-231 in R. Mann, editor. Exotic Species in Mariculture. Massachusetts Institute of Technolgy Press, Cambridge, Massachusetts.

Bean, M.J. 1983. The evolution of national wildlife law. Environmental Defense Fund, Inc. Praeger Publishers. 449pp.

Bourne, N. 1979. Pacific oysters, *Crassostrea gigas* (Thunberg), in British Columbia and the South Pacific Islands. pages 1-51 in R. Mann, editor. Exotic Species in Mariculture. Massachusetts Institute of Technology Press, Cambridge, Massachusetts.

Burreson, E.M. 1990. Unpublished report. Risk analysis for introduction of diseases with the Japanese oyster, *Crassostrea gigas*. Report submitted to the Virginia Marine Resources Commisssion from the Virginia Institute of Marine Science, March, 1990. 6pp.

Carlton, J.T. 1987. Patterns of transoceanic marine biological invasions in the Pacific ocean. Bulletin of Marine Science, 41(2): 452-465.

Carlton, J. T. 1992. Dispersal of living organisms into

aquatic ecosystems: the mechanisms of dispersal as mediated by aquaculture and fisheries activities. pages 13-47 in A. Rosenfield and R. Mann, editors. Dispersal of Living Organisms into Aquatic Ecosystems. Maryland Sea Grant College, College Park, Maryland.

Chesapeake Executive Council. 1989. Chesapeake Bay oyster management plan. Chesapeake Executive Council Publication. Annapolis, Maryland. 28pp.

Chew, K.K. 1979. The Pacific oyster (*Crassostrea gigas*) in the west coast of the United States. pages 54-79 in R. Mann, editor. Exotic Species in Mariculture. Massachusetts Institute of Technology Press, Cambridge, Massachusetts.

Connecticut General Statutes Annotated. 1992 supp.. Sections 26-55 and 26-24.

Courtenay, Jr., W.R. 1979. Biological impacts of introduced species and management policy in Florida. pages 237-257 in R. Mann, editor. Exotic Species in Mariculture. Massachusetts Institute of Technology Press, Cambridge, Massachusetts.

Dean, D. 1979. Introduced species and the Maine situation. pages 149-161 in R, Mann, editor. Exotic Species in Mariculture. Massachusetts Institute of Technology Press, Cambridge, Massachusetts.

deKinkelin, P. and Hedrick, R. P. 1991. International Veterinary Guidelines for the Transport of Live Fish or

Fish Eggs. Annual Rev. of Fish Diseases, pp. 27-40.

Delaware Code Annotated. 1991 supp., Title 7, sec. 2110.

Elston, R.A. 1990. Mollusc diseases: guide for the shellfish farmer. Washington Sea Grant Program. University of Washington Press, Seattle, Washington. 73pp.

Elton, C.S. 1958. The ecology of invasions by animals and plants. Methuem & Co. LTD., London, England. 181pp.

Farley, C. A. 1991. Mass mortalities and infectious lethal diseases in bivalve molluscs and associations with geographic transfers of populations. pages 133-148 in A. Rosenfield and R. Mann, editors. Dispersal of Living Organisms into Aquatic Ecosystems. Maryland Sea Grant College, College Park, Maryland.

Ferguson, M.M. 1990. The genetic impact of introduced fishes on native species. Can. J. Zool. 68: 1053-1057.

Gaffney, P.M. and S.K. Allen, Jr. 1990. Genetic aspects of introduction and transfer of molluscs. Institute of Marine and Coastal Science. New Jersey Agriculture Experiment Station Publication No. D-32001-3-90.

Grizel, H. and Heral, M. 1991. Introduction into France of the Japanese oyster (*Crassostrea gigas*). J. Cons. int. Explor. Mer, 47:399-403.

Hargis, Jr., W.J. and D.S. Haven. 1988. The imperilled oyster industry of Virginia: a critical analysis with recommendations for restoration. Va. Sea Grant Marine

Advisory Services. Virginia Institute of Marine Science. Special report No. 290 in Applied Marine Science and Ocean Engineering. 130pp.

Hickey, J.M. 1979. Culture of the Pacific oyster, *Crassostrea gigas*, in Massachusetts waters. pages 129-148. in R, Mann, editor. Exotic Species in Mariculture. Massachusetts Institute of Technology Press, Cambridge, Massachusetts.

Hickey, J.M. 1990. Massachusetts regulatory aspects concerning the importation of shellfish. State of Massachusetts publication.

Hocutt, C.H. 1984. Toward the development of an environmental ethic for exotic fishes. pages 374-386 in W.R. Courtenay, Jr. and J.R. Stauffer, Jr., editors. Distribution, Biology and Management of Exotic Fishes. The Johns Hopkins University Press, Baltimore Maryland. 430pp.

ICES. 1990. Revised Code of practice to reduce the risk of adverse effects arising from introductions and transfers of marine species. 7pp.

Intentional Introductions Policy Review Options Paper. 1990. Intentional Introductions Policy Review Committee. 12pp.

Kennedy, V.S. and L.L. Breish. 1981. Maryland oysters: research and management. Maryland Sea Grant College. University of Maryland and Tidewater Administration.,

Md. Department of Natural Resources, UM-SG-TS-81-04, 286pp.

Kohler, C.C. and J.G. Stanley. 1984. A suggested protocol for evaluating proposed exotic fish introductions in the United States. pages 387-406 in W.R. Courtenay, Jr. and J.R. Stauffer, Jr., editors. Distribution, Biology and Management of Exotic Fishes. The Johns Hopkins University Press, Baltimore, Maryland.

Legislative History P.L. 97-79. Lacey Act Ammendments of 1981. Senate report No. 97-123. 21pp.

Mann, R. 1979. Exotic species in aquaculture: an overview of when, why and how. pages 231-254 in R. Mann, editor. Exotic Species in Mariculture. Massachusetts Institute of Technology Press, Cambridge, Massachusetts.

Mann, R., E.M. Burreson, and P.K. Baker. 1991. The decline of the Virginia oyster fishery in the Chesapeake Bay: considerations for introduction of a non-endemic species, *Crassostrea gigas* (Thunberg, 1793). Journal of Shellfish Research: vol.10, No. 2, pp 379-388.

Maine Revised Statutes Annotated. 1990. Vol. 6, Title 12, sec. 6071 and sec. 6075.

Maryland Laws and Regulations, 1991. Laws and regulations concerning the Commercial Harvests of Oysters, Clams, Conchs, Surf Clams and Ocean Quahogs, Oyster and Clam Culture, and Lobsters. Maryland Tidewater

Administration of Natural Resources, Tidewater Administration.

Massachusetts General Laws Annotated. vol. 19, 1991.

McCann, J.A. 1984. Involvement of the American Fisheries Society with exotic species, 1969-1982. pages 1-7 in W.R. Courtenay, Jr. and J.R. Stauffer, Jr., editors. Distribution, Biology and Management of Exotic Fishes. The Johns Hopkins University Press, Baltimore, Maryland.

Nelson, J.R. 1979. Desirability of introducing *Crassostrea gigas* into the East coast oyster industry of the United States. pages 232-236 in R. Mann, editor. Exotic Species in Mariculture. Massachusetts Institute of Technology Press, Cambridge, Massachusetts.

Newell. R.I.E. 1989. Ecological changes in the Chesapeake Bay Research: Are they the result of overharvesting the American oyster (*Crassostrea virginica*)? in: Understanding the Estuary: Advances in Chesapeake Bay Research. Chesapeake Research Consortium Publication No. 129: 536-546.

New Hampshire Revised Statutes Annotated. 1991.

New Jersey Statutes Annotated. 1991 supp.. Article 6, sec. 50:1-34 and 50:1-35.

New York Consolidated Laws Service Annotated Statutes with Forms, 1991 supp..

Perkins, F. O. 1990. A request to the Virginia Marine

Resources Commission from the Virginia Institute of Marine Science. submitted: March 27, 1990.

Presidential Executive Order No. 11987, 3 C.F.R. 16 (1978).

Quayle, D.B. 1988. Pacific oyster culture in British Columbia. Can. Bull. Fish. Aquat. Sci. 218: 241pp.

Rhode Island General Laws, 1991 supp., sections 20-10-5 and 20-10-12.

Rosenfield, A. 1992. Risks associated with translocations of biotic agents. pages 3-11 in A. Rosenfield and R. Mann, editors. Dispersal of Living Organisms into Aquatic Ecosystems. Maryland Sea Grant College, College Park, Maryland.

Rosenfield, A. and F.G. Kern. 1979. Molluscan imports and the potential for introduction of disease organisms. pages 165-189 in R. Mann, editor. Exotic Species in Mariculture. Massachusetts Institute of Technology Press, Cambridge, Massachusetts. 363pp.

Rosenfield, A. and R. Mann. 191. Dispersal of living organisms into aquatic ecosystems. Maryland Sea Grant College, College Park, Maryland. 417pp.

Rueness, J. 1989. *Sargassum muticum* and other introduced Japanese macroalgae: Biological pollution of European coasts. Mar. Pollut. Bull.; vol. 20, no. 4: 173-176.

Schneiders, R. Shellfishing in Connecticut. Environmental intern for the state of Connecticut.

Shatkin, G. 1992. unpublished. The Proposed Introduction

of the Pacific Oyster (*Crassostrea gigas*) to the Gulf of Maine. Submitted to the Maine Aquaculture Innovation Center, August 7, 1992. 46pp.

Sindermann, C.J. 1991. Role of the International Council for the Exploration of the Sea (ICES) in matters concerned with the transfer and introduction of marine organisms. pages 351-360 in A. Rosenfield and R. Mann, editors. Dispersal of Living Organisms into Aquatic Ecosystems. Maryland Sea Grant College, College Park, Maryland.

Synopsis of the Oyster Ecology Workshop: *Crassostrea gigas*. 1991. Rapporteurs J. Sutherland and R. Osman. Annapolis, Maryland. Oct. 28-30. 6pp.

Tiedje, J.M. et al. 1989. The planned introduction of genetically engineered organisms: ecologocal considerations and recommendations. Ecology, vol. 70, No. 2, pp. 298-315.

Thompson, A.G. 1990. "The Danger of Exotic Species." World Aquaculture 21(3), Sept., pp. 25-32.

Va. Code Annotated Title 28.2 sec. 825.

VMRC Tech. Rep. No. 89-01. 1989. Biography of the Virginia oyster fishery. Virginia Marine Resources Commission, Fisheries Management Division. 111pp.

VITA

SUSAN GWYNNE DAY BROWN

Born in Warrenton, Virginia, 7 October 1966. Graduated from Foxcroft School, Middleburg, Virginia in 1984. Received a Bachelor of Arts degree with majors in Biology and Psychology from The University of Virginia at Charlottesville in 1988. Entered Masters program at the Virginia Institute of Marine Science, College of William and Mary in 1990. Completed M.A. degree, College of William and Mary, December 1992.