PROCEEDINGS of the Northeast Conference on Non-Indigenous Aquatic Nuisance Species

January 25, 1995 † Cromwell, Connecticut

Conference Coordinators

Nancy Balcom, Connecticut Sea Grant College Program
Eileen Jokinen, Connecticut Institute of Water Resources, University of Connecticut

Acknowledgements

Many thanks to the researchers, individuals, and organizations who submitted papers or posters on their work with non-indigenous aquatic plants and animals, enabling conference participants to share in their knowledge. We look forward to continuing this dialogue in the years to come.

The Connecticut Sea Grant College Program is part of a national network of university-based programs in coastal and Great Lakes states, established by Congress in 1966 and modeled after the Land Grant Colleges, administered through the National Oceanic and Atmospheric Administration, and supported by federal and state funds. Connecticut Sea Grant fosters the wise use of marine and coastal resources through research, outreach, and education.

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PROCEEDINGS of the Northeast Conference on Non-Indigenous Aquatic Nuisance Species

A regional conference sponsored by

Connecticut Sea Grant Marine Advisory Program
Connecticut Sea Grant College Program

Connecticut Institute of Water Resources
The University of Connecticut

January 25, 1995
Radisson Hotel and Conference Center
Cromwell, Connecticut

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Editor

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Conference Coordinator

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Preface

While zebra mussels have cornered the market for the non-indigenous aquatic nuisance species most likely to receive research attention and dollars, they are by no means the first or the last exotic species to arrive in the Northeast region or the United States, nor are they the only ones causing problems. When I first began to get my feet wet in the subject area of non-indigenous species about four years ago, it was because of zebra mussels. While the mussels continue to receive my attention, I have begun to realize the magnitude of the impacts non-indigenous species in general can have both ecologically and economically. Some "aquatic immigrants" make their mark subtly; others are considered harmful. Still others are introduced intentionally, because they hold some value--such as brown trout and walleye, which are popular targets of anglers.

When we think of the "typical rocky New England coast", periwinkle snails and green crabs come to mind as some of most familiar organisms--yet long ago these species were immigrants to New England. It's hard to imagine what the true native New England rocky intertidal ecosystem looked like!

This regional conference evolved out of the growing need to share information about non-indigenous aquatic nuisance species and their control among researchers, regulatory agencies, lake associations, environmental groups, and educators in the Northeast. The Northeast Sea Grant Programs, together with the Vermont Department of Environmental Conservation, have developed public outreach programs that have their foundations in zebra mussels, but have grown to include other problematic species as demands for information on exotic species control in general have increased. I look to conferences such as this one as one way to bring the relatively small cadre of individuals with concerns in these areas together to share their research results and control techniques, so that more informed decisions can be made at the state and local levels. I also hope that from this conference the seeds were planted to establish a regional chapter of the National Association of Exotic Pest Plant Councils. With 29% of the Northeast's plant species estimated to be introduced species, it is apparent that this area deserves the attention of a coordinated, regional approach.

I hope you find the papers and abstracts contained within this proceedings volume interesting and useful. The authors deserve a round of thanks for sharing their research results with you and encouragement to continue their studies of these non-indigenous aquatic nuisances. I hope you join me in looking forward to the second Northeast conference on introduced species, to be sponsored by the Northeast Sea Grant Programs sometime in 1996.

Nancy Balcom
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Connecticut Sea Grant Marine Advisory Program

March 22, 1995

Foreword

The Northeast Conference on Non-Indigenous Aquatic Nuisance Species in January 1995, helped set, for the first time, the regional context for biological invasions in freshwater, brackish, and marine ecosystems in lake, river, and coastal habitats of New England and New York. As the 20th century comes to a close, there is evidence that the number of animal and plant invasions into aquatic environments, in the Northeast United States, throughout America, and around the world, has increased considerably. These invasions, seemingly now almost everywhere and in many different habitats, prompted the inclusion of exotic species as one of the top five threats to aquatic biodiversity in the National Research Council's new book, *Marine Biodiversity: Setting a Research Agenda for the Nation* (1995).

Concerns about introduced species are today three-fold: (1) the prevention of accidental introductions and the careful weighing and consideration of intentional introductions, (2) understanding the ecological and environmental impacts and consequences of invasions that have occurred, and (3) attempts to control the abundance and spread of exotic species. All three topics are addressed throughout the papers and abstracts in this volume.

Relative to the first concern, a great deal of attention is now being focused on the transport vectors that would bring new non-indigenous species to, or move exotic species within, America. Internationally, these dispersal vectors include ballast water and ballast sediments; nationally, these vectors include the movement of recreational boats, the fishing bait industry, intentional releases, and a plethora of other vectors. The challenge is often to understand the scale of any one vector, how it compares in importance to other vectors, and the potential of all identifiable vectors to transport harmful aquatic organisms.

Relative to the second matter, we are well behind our terrestrial colleagues in an adequate understanding of how non-indigenous species alter both natural and previously invaded systems. While we often have a plethora of circumstantial and correlative evidence on the impacts of invasions, experimental studies are still relatively rare in aquatic environments. The "good news" is that we are now seeing an increased number of experimental programs, and these will almost certainly yield data that will increase our predictive abilities.

Finally, the third challenge, that of controlling exotic species, has an old history in terrestrial environments, a younger history in freshwater communities, and a very limited history in brackish and marine systems. In essence, this trichotomy parallels our perception of the "openness" of these systems in terms of whether we can control either the abundance of exotic species or their spread away from the initial inoculation site.

Controlling populations of exotics continues to be approached through both classic methods (mechanical, thermal, chemical, and so forth) and through the continued development of newer technologies (ultraviolet, ultrasound, electrical-magnetic fields, new chemical approaches, and so on). The application of biocontrol to freshwater ecosystems -- through the introduction of herbivorous insects, carnivorous fish, or other organisms, to control a target invader -- has been ongoing for decades (with a wide range of failures and successes). In contrast, the field of marine biocontrol remains as a largely theoretical construct.

Controlling the spread of exotic species means, in large part, controlling the secondary vectors that transport species away from the invasion hub -- and this often means extensive educational campaigns to inform the public, the press, and industry. The Sea Grant program has been one of the distinguished leaders in these campaigns, producing an extensive series of books, booklets, pamphlets, wallet cards, posters, and videos, to tackle the difficult task of public education. It is in this arena that there is perhaps the greatest hope of real control of invasions, closing the loop back to our first concern -- first order prevention.

While invasions continue on a regular basis, there is increased hope that in the coming years, with the greatly increased interest in exotic species, and the concomitant increase in research and education, invasions will slow to a trickle. The Northeast Conferences on Non-Indigenous Aquatic Nuisance Species will provide an important opportunity to monitor our progress and success.

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May 2, 1995

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A Potential Agent of Biological Control for Eurasian Watermilfoil

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We have been evaluating the potential of a North American aquatic weevil, *Euhrychiopsis lecontei,* to serve as an agent of biological control for Eurasian watermilfoil *(Myriophyllum spicatum).* We have examined the effects of this weevil on Eurasian watermilfoil and native macrophytes in lab feeding trials and in the field. In the lab, weevils had a significant negative effect on Eurasian watermilfoil but did not effect native plants. We introduced weevils into enclosures in two lakes dominated by Eurasian watermilfoil. In both lakes there was significantly less Eurasian watermilfoil biomass in enclosures with weevils than in controls. Over the past five years we have followed weevil abundance and the decline of a Eurasian watermilfoil population in a small Vermont lake. Currently, there are only two thin beds of Eurasian watermilfoil while native plant populations are well established throughout the lake. The results from these studies suggest that a North American insect may be a suitable control agent for this non-native aquatic weed. Native biological control agents, when they can be found, offer potential advantages over classical biological control agents; they may have little impact on non-target native species which have coexisted with the control agent, and may save the time and expense of foreign research and quarantine procedures.

Growth Interactions and Effects of Exotic and Native Wetland Plants on Detrital Pathways and Nutrient Cycling in Freshwater Hudson River Wetlands

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Lythrum salicaria (purple loosestrife) is an exotic wetland plant that has displaced many native wetland species, such as the cattail *(Typha angustifolia)*. Pilot studies performed at the Louis Calder Center have demonstrated some factors which affect the growth and decay of these species. Flooding has little effect on cattail growth, but inhibits growth in *Lythrum* by >50%. During interspecific competition, submersion reduces *Lythrum* growth, but *Lythrum* strongly outcompetes *Typha* (3.3 vs. 0.6 g/shoot) in emersed conditions. Mesocosm seedling invasion studies (ten cattail ramets plus 25, two week old *Lythrum* seedlings) were run at three moisture treatments (+18 cm, 0 cm, -10 cm water level) to simulate spring invasion of a cattail swamp by *Lythrum*. A decomposition experiment compared mass loss from leaves of these species over 1, 8, 15, 22, 45, 75, 142, 180, 218, 270, and 330 days in pond microcosms; decay coefficients were calculated. Current fieldwork at wetland sites of the Hudson River National Estuarine Research Reserve examines the decomposition rates of these plants in pure and mixed habitats for a one year period from 11/94 to 11/95. Laboratory experiments manipulating salinity and water depth (suggesting tidal effects) compare effects on seed germination and seedling growth in mono and mixed culture. This work will aid in determining causes for the success of invasive species in wetland communities and their effects on nutrient cycling and will help develop effective management methods.

Biological Control of Purple Loosestrife (Report to the National Biological Service)

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Purple loosestrife *(Lythrum salicaria)* is a wetland perennial introduced to North America from Europe in the early 19th century. The plant now occurs in dense stands throughout the northeastern United States, southeastern Canada, the Midwest, and in scattered locations in the western United States and southwestern Canada. Newly created irrigation systems in many western states have supported further establishment and spread of purple loosestrife. This plant is a classic example of an introduced species whose distribution and spread has been enhanced by the absence of natural enemies and the disturbance of natural systems, primarily by human activity. Although noted for the beauty of its late summer flowers, which also provide a nectar and pollen source for bees, loosestrife has few other redeeming qualities. Large, monotypic stands reduce the biotic diversity of wetland systems by replacing native plant species and thereby eliminating the natural foods and cover essential to many wetland wildlife inhabitants, including waterfowl. The plant is currently listed as a noxious weed in 13 states, where its importation and distribution are prohibited.

No effective method is available to control purple loosestrife, except where it occurs in small, localized stands and can be intensively managed. In such isolated areas, uprooting the plant by hand and ensuring the removal of all vegetative parts can be effective. Other control techniques that have been used include water-level manipulation, mowing or cutting, burning, and herbicide application. Although sometimes successful in eliminating small and young stands, these methods are costly, require continued long-term maintenance, and in the case of herbicides are nonselective and can be environmentally degrading.

Presently, the most promising control measure for purple loosestrife is the application of classical biological weed control procedures. This is the deliberate use of natural enemies such as insects, mites, nematodes, and pathogens to reduce weed densities to tolerable levels. Results of insect surveys and screening tests conducted in conjunction with the U.S. Department of Agriculture's Agricultural Research Service and the International Institute of Biological Control in Europe have identified five species of beetles as potential control agents for purple loosestrife. Each of these species show enough host specificity for purple loosestrife to be introduced with no ill effects to native North American plants.

Hylobius transversovittatus is a root-mining beetle that deposits its eggs in the lower stem of the plant. After hatching, the larvae destroy the nutrient source for leaves by feeding on root tissue, thus completely destroying mature plants. Two leaf-feeding beetles, *Galerucella pusilla* and *G. calmariensis* seriously affect growth and seed production of this profile plant by feeding on its leaves. Two additional flower-feeding beetles, *Nanophyes brevis* and *N. marmoratus*, attack the ovaries and severely reduce the seed production.

The root-mining beetle and two leaf-feeding beetles were introduced to North America in 1992. They presently occur in 16 states and a number of provinces across Canada. Efforts are underway to rear large numbers of these insect species for further distribution and establishment of colonies in states and provinces across the United States and Canada.

A petition to introduce the two flower-feeding beetles was approved by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service. Initial collection of these insects in Europe for release into the United States took place in 1994.

Our strategy is to achieve long-term control of purple loosestrife through provision of a simple, yet diverse collection of natural enemies. Purple loosestrife is now a naturalized weed that will be a part of most North American wetlands forever. However, the introduction of this select group of insects should result in replacement of monotypic stands of loosestrife by native vegetation and an overall decrease in the occurrence of the plant. We predict a reduction of purple loosestrife abundance over the next 15-20 years to approximately 10% of its current level over approximately 90% of its North American range.

Screening Criteria for Potential Invasive Non-Indigenous Plants: A Florida Model

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In much of Florida, non-native nuisance plants threaten remaining natural ecosystems. Invasive exotic plants are a form of biological pollution that invades aquatic and terrestrial landscapes, both natural and disturbed sites. Most non-native plants die if released into a new environment, but the few that live and reproduce may spread explosively. Because such exotics are found by few (if any) predators, parasites, or other competitors in their new homes, once established they often out-reproduce, out-grow, and displace entire native plant communities.

Of the 3,500 plant species found in Florida, about 900 are exotic. Many were imported for use as landscape ornamentals, others for their decorative quality for aquarium hobbyists. Of the 123 species listed by the Exotic Pest Plant Council, 20 are aquatic or wetland invaders.

Early detection, eradication, or prevention are the only sure controls for some of these species. Once the plants are established, exotic plants are extremely difficult and expensive to control.

Presently, Florida's aquatic plant managers and regulatory agencies are unable to assess the weed potential of an imported aquatic plant before the species has become naturalized and demonstrates itself to be problematic. By that time, complete eradication may become costly or impossible.

Florida law requires a permitting system to protect waters from the introduction and growth of noxious aquatic plants. Species known to have created problems in other locations world-wide and are suspected to pose a threat to Florida's waters are designated as *Class 1 Prohibited Aquatic Plants* in which possession, collection, transportation, cultivation, and importation are prohibited in Florida without a permit. *Class 2 Prohibited Aquatic Plants* include those considered to be highly invasive and noxious in Florida, but may be cultivated (not imported or collected from the wild) in regulated nurseries and sold only out of state.

Development of standardized procedures to assess aquatic plant weed potential would be useful for determining which species should be designated as prohibited aquatic plants.

Aquatic plant growth and development *in situ* is influenced by many abiotic and biotic factors acting in concert. The current inability to effectively predict aquatic plant growth capacity makes it difficult to anticipate potential problems. Spencer and Bowes (1985) compared the weed potential of *Limnophila sessiliflora* and *Hygrophila polysperma* to that of hydrilla under static culture conditions (non-sterile conditions). On the basis of physiological measurements of photosynthesis, photorespiration, dark respiration and analysis of reproductive potential under different environmental regimes, it was concluded that neither *Limnophila* nor *Hygrophila* could effectively compete with hydrilla. However, their findings were questioned by Van Dijk *et al.* (1986) when they found that *Hygrophila* was significantly more competitive with hydrilla in flowing waters. These researchers suggested that limitations in carbon availability in static culture tests may prevent accurate determinations of maximum growth potential. Clearly, culture systems had to be developed to screen and compare aquatic plant growth and regeneration potential under <u>non-limiting</u> culture conditions of light and temperature as well as nutrient and carbon availability.

Because *in vitro* whole plant and tissue culture systems had been used to study the physiological factors controlling development in aquatic plants, it was thought that these systems could also be modified to provide non-limiting culture conditions to screen aquatic plant growth potential. The idea was supported by observations made by Kane *et al.* (1989, 1991). While working with several *Myriophyllum* species, they documented inherently high capacities for rapid axillary branching and adventitious shoot production from isolated tissues cultured *in vitro*.

Procedures for successful *in vitro* establishment of 15 species has been completed, and screening experiments have been completed for the following 13 species: *Lythrum salicaria, Ipomoea aquatica, Limnocharis flava, Polygonum perfoliatum, Hygrophila polysperma, Myriophyllum spicatum* and *M. laxum, Lagarosiphon sp., Crassula helmsii, Trapa natans, Pontederia rotundifolia, Eichhornia azurea,* and *Vossia cuspidatum. Hydrilla verticillata,* both monoecious and dioecious, are established in sterile culture, but testing is not complete at this time.

Studies indicate that in known weedy aquatic species such as *Crassula helmsii, Limnophila sessiliflora,* and *Hygrophila polysperma*, there are highly significant positive correlations between the capacity for both shoot regeneration from nodal segments and adventitious shoot formation and aquatic weed potential. This capacity for adventitious shoot regeneration was not apparent in obligate aquatic species like *Hydrilla* and *Lagarosiphon.* This data suggests that the capacity for regeneration from adventitious shoots may be taxon-specific.

Additional aquatic plant species currently under evaluation include: *Egeria densa, Eichhornia crassipes, Pistia stratiotes, Pontederia cordata,* and *Vetiveria zizanioides.*

Introduction of a New *Antithamnion* to Long Island Sound

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Millstone Nuclear Power Station environmental monitoring includes monthly qualitative algal collections at ten rocky intertidal sites in the vicinity of the power plant. In August 1986, we first collected specimens of an *Antithamnion* that did not conform to descriptions for any *Antithamnion* of which we were aware. Since that time, the alga has been found at all of our sampling sites, occurs in all months of the year, and has been collected at least 80 km distant from the site of initial collection. It is presently the most common epiphyte on local populations of *Chondrus, Corallina,* and *Ulva,* but is also found on most low intertidal and shallow subtidal macroalgal species and on rock surfaces. The rapid spread and current high abundance of this plant are puzzling, as tetrasporangia, biosporangia, and sexual reproductive structures are absent. Propagation apparently occurs entirely through fragmentation and subsequent reattachment of the fragment.

The *Antithamnion* species newly found in the Millstone area closely resembles, both morphometrically and in its lack of reproductive structures, a plant reported by Verlaque and Riouall (1989) to be recently introduced to the Mediterranean, and called by them *A. nipponicum*. However, Athanasiadis and Tittley (1994) validated the combination *Antithamnion pectinatum*, and referred both the Mediterranean and Millstone populations to this new epithet. Introduction of a foreign algal species to Long Island Sound is not an unprecedented event, with the introduction of *Codium fragile* (Sur.) Hariot subsp. *tomentosoides* (van Goor) Silva in the late 1950s an obvious example. The east end of Long Island Sound is particularly conducive to species introduction, with high volumes of commercial and recreational boat traffic.

Aquatic Animals

Northeast Conference on Non-Indigenous Aquatic Nuisance Species

Population Dynamics of the Asiatic Clam, *Corbicula fluminea*, at Three Electrical Power Facilities in the Lower Connecticut River

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Since May 1990, when Asiatic clams were first removed from the service water system of the Connecticut Yankee electric generating station, this exotic species has been monitored at three electrical power facilities: Connecticut Yankee (CY), Middletown Station (MS), and South Meadow Station (SM). The Asiatic clam continues to persist in the lower Connecticut River in spite of harsh winter conditions, which have killed up to 99% of the population each year. The patterns in summer fecundity and growth of clams have remained similar from 1991 through 1994, even though densities have fluctuated enormously. Population densities peaked in 1992, when clams exceeded 25,000/m^2 at MS, but have remained below 1,000/m^2 in 1993 and 1994. Spawning and the release of juveniles occurs nearly continuously from June to September, may occur twice a year for some larger clams, and peaks during the warmest (25-30 °C) month, August. Growth and reproduction appear to require water temperatures above 16-18 °C. Growth is size dependent, with peak growth rates of >1 mm/wk for small adult clams (9-10 mm). Growth slows to less than 2 mm per growing season (May to November) for clams larger than 36 mm. High winter mortalities appear to be limiting this population, but thermal discharges, springs, and deep waters appear to be refuges during harsh winters. The potential for periodic population explosions will continue to threaten industrial raw water systems because low winter mortalities followed by high summer growth and reproduction, as noted, could quickly return river populations to concern levels.

Development and Utilization of Genetic Probes for Studying the Planktonic Ecology of the Zebra Mussel *(Dreissena polymorpha)*

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A key issue in the management of zebra mussel populations is early, rapid, and accurate detection of the planktonic forms of the mussel. To date, simple and reliable methods for the enumeration of zebra mussel veligers in the water column at low densities do not exist. A species-specific genetic probe, targeting the 18S ribosomal RNA (rRNA) molecule of *D. polymorpha*, is being developed to study the planktonic ecology of the zebra mussel, *in situ*. The complete 18S rRNA gene from the zebra mussel has been amplified by the Polymerase Chain Reaction, cloned into a plasmid vector, and is being sequenced. Preliminary taxonomic characterization, based on approximately one third of the zebra mussel 18S rRNA gene sequence, has been determined and is consistent with phylogenies based on morphological characteristics of other mollusks. The overall homology of the 18S rRNA gene is high (97%) between the zebra mussel and its closest sequenced relative *(Mactromeris polynyma)*. However, variable regions (up to 50% divergence) have also been identified within the 18S rRNA gene. The targeting of oligonucleotide probes to these regions should result in the construction of a zebra mussel specific probe. A variety of techniques have been evaluated to optimize the extraction of 18S rRNA from concentrated water and pure veliger samples. Extraction efficiency was determined by quantitating total 18S rRNA and DNA obtained from water and veliger samples using a probe targeted to a highly conserved region of the 18S rRNA gene (universal probe). Highest veliger detection sensitivities (0.5-5 per liter) were obtained when samples were physically disrupted by vortexing with glass beads followed by heat lysis and proteinase K digestion steps. Similar sensitivities were achieved using either a [^{32}P] labeled or a non-radioactive digoxigenin labeled probe. Following determination of species specificity, the zebra mussel probe will be used to examine the transport and distribution of zebra mussel veligers into pristine environments.

Spread and Demography of Zebra Mussels in the Hudson River Estuary, 1991-1994

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Zebra mussels were first seen in the Hudson River estuary in the spring of 1991. The population arose from two sources: a human introduction into the center of the estuary from an unknown source and fluvial transport of veligers into the head of the estuary from the Mohawk River. Zebra mussels spread rapidly through the Hudson and occupied the entire freshwater part of the estuary (up to a salinity of ca. 5 ppt) by fall 1992. By 1993-94, the population reached 200-360 billion adults (= 1500 - 2500 m^{-2}, estuary-wide) and constituted more than half of the biomass of the macrozoobenthos. The population is concentrated on rocky bottoms, where densities typically are 10,000 - 30,000 m^{-2}; densities on silt and sandy bottoms are only ca. 50 m^{-2}. In contrast to other systems, the native clams of the Hudson scarcely have been colonized by zebra mussels. In the middle 65 km of the estuary, we estimate that zebra mussels filter the entire water column in about a day during the summer. Possibly because of intense adult-larval interactions, year-class strength has varied greatly from year to year. We predict that the population trajectory of zebra mussels in the estuary will be erratic.

The Impact of Zebra Mussel Invasion on Phytoplankton in the Hudson River

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Zebra mussels are an exotic species that have had significant economic costs due to their ability to clog water intake pipes. Additionally, zebra mussels can have dramatic effects on aquatic food chains. The zebra mussel is a benthic grazer and is capable of filtering 1 Liter/individual/day. Further, zebra mussel densities often reach 10,000 animals per square meter. Thus, in many aquatic systems, large quantities of water can be filtered each day. Well-mixed estuaries like the Hudson River Estuary may be particularly sensitive to the impact of benthic grazers as the entire water column is susceptible to zebra mussel grazing.

Documenting the impact of exotic invaders is often difficult as data from pre-invasion time periods are not available. In the Hudson River, however, there exists a long-term data set that allowed us to document the impact of the zebra mussel. Since 1986, data have been collected by a group of scientists at the Institute of Ecosystem Studies on phytoplankton concentration, species composition, nutrient concentration, light regime, and zooplankton abundance. Thus, when the zebra mussel invaded (ca. 1991) and became fully established (1993) we were in a unique position to detect changes in the planktonic community. Further, at the time of the invasion, we had a model of plankton dynamics that indicated the zebra mussels would dramatically impact the Hudson River. Data from 1993 and 1994 validate this prediction as phytoplankton populations have dropped by nearly 10-fold compared to pre-invasion years. Data on zooplankton suggest similar crashes. It is likely that the crash in phytoplankton at the base of the food chain is leading to decreases at higher food chain levels. Whether this impact reaches up to fish populations remains to be seen.

Annual and Seasonal Variations in Zebra Mussel (*Dreissena* spp.) Veliger Density in the Upper Niagara River

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ABSTRACT

This poster will review and compare 1994 zebra mussel (*Dreissena* spp.) veliger density data with those that were collected since 1991. The objective of this analysis is to illustrate differences and similarities in veliger density trends between these years. Three locations along the upper Niagara River were sampled weekly from June 1991 through December 1994.

Generally, veliger density fluctuated in magnitude and spawning duration throughout the four year period. Spawning season occurred early in 1991 and was brief, starting in July and concluding in early September. The 1991 season was characterized by relatively high densities occurring over a short period of time.

The spawning seasons in 1992 through 1994 were much longer than that observed in 1991. In 1992, spawning was observed by mid-July and concluded in November. Two peaks of 20,000/m^3 were observed, one in August, the other in September, 1992. The spawning seasons of 1993 and 1994 did not occur until September and were characterized by moderate to high densities with a single high peak density of 57,000/m^3. 1993 and 1994 spawning seasons were relatively late in the year compared to earlier seasons. Spawning from 1994 was generally similar to 1993 in timing and magnitude. Viable veligers were observed each year during winter months.

This poster will incorporate the four year data set and will summarize inter-annual variations of veliger density in the upper Niagara River.

INTRODUCTION

Zebra mussel populations are established and a permanent component of the ecology of the Great Lakes benthic community. Since 1991, **AquaTech** *Environmental,* Inc. has been monitoring veliger density and documenting seasonality of veligers in Lake Erie and Niagara River. These are minor goals of a greater monitoring program that includes, but is not limited to, documentation of settling rate, growth rate, and assessment of treatment effectiveness.

Documenting changes in veliger density and seasonality is basic to the understanding of zebra mussel ecology. Analyzing veliger density and seasonality, both functions of adult mussel density, can provide insight into the degree of zebra mussel infestation. This study is a compilation of data that summarizes veliger seasonality, tracks variation, and documents differences in veliger density trends from 1991 to 1995. Information generated from this work may help researchers comprehend invasion processes in similar habitats.

METHODS

A total of eleven sites along the upper Niagara River were sampled weekly from June 1991 to February 1995. Sampling was interrupted during winter months due to ice cover limitations. Three sample locations were used to summarize zebra mussel veliger data (Figure 1).

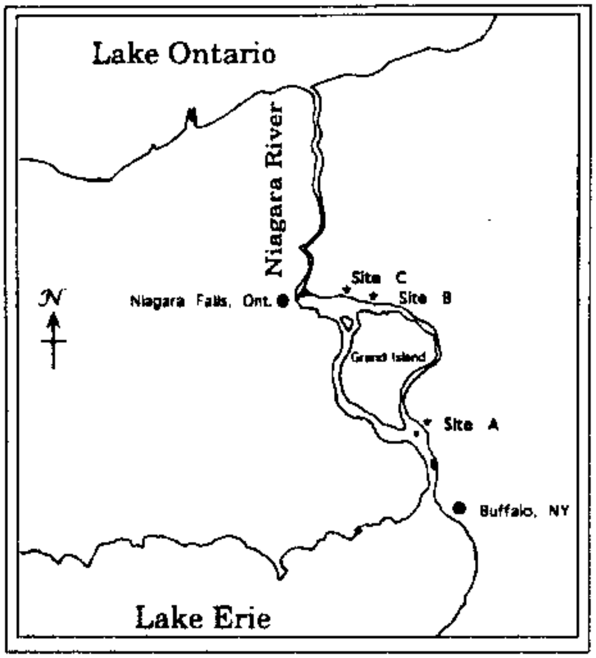

FIGURE 1. Location of sampling sites along the Niagara River.

Zebra mussel veligers were collected by filtering 500-L of water through a 63-µm mesh plankton net using a 0.5 hp centrifugal pump. Water temperatures were recorded using a DigiSense thermocouple thermometer during the collection of the water samples. After filtration, samples were concentrated, placed in Nalgene jars and transported to the laboratory for analysis. All samples were analyzed within an hour of collection.

Water samples were analyzed to determine veliger densities. Veliger densities were determined by counting the entire sample if densities were relatively low (<100/m^3), or by subsampling if densities were particularly high (>100/m^3). A plankton splitter was used to subsample using standard zooplankton laboratory techniques. Samples were analyzed using a Wild M5 stereoscope at 25X, 50X, and 100X magnifications. Crossed polarization microscopy was used when appropriate to aid in the enumeration process.

RESULTS

Generally, veliger density fluctuated in magnitude and spawning duration throughout the four year period (Table 1; Figures 2-6). For this analysis, **spawning season** is defined as the dates when veliger density exceeded approximately **5,000/m^3**. Spawning season occurred early in 1991 and was brief, starting in late July and concluding in early September. Veligers remained at low densities throughout October and were absent by mid-October, 1991. The 1991 season was characterized by relatively high densities occurring over a short period of time.

YEAR	SPAWNING SEASON	DURATION	MAGNITUDE
1991	Early	Short	High
1992	Early	Long	Low
1993	Late	Medium	High
1994	Late	Medium	Moderate

TABLE 1. Relative differences regarding veliger spawning seasons from 1991 to 1994.

The spawning seasons in 1992 through 1994 were much longer than 1991. In 1992, spawning was observed by mid-July and concluded in early November. Veligers remained at densities of less than 3,000/m^3 through December, 1992. Two peaks of 20,000/m^3 were observed, one in August, the other in September, 1992.

Initiation of the 1993 spawning season did not occur until early September. The 1993 season was characterized by moderate to high densities with a single high peak of 57,000/m^3 on 10/7/93. The 1993 spawning season was relatively late in the year compared to the 1992 and 1991 seasons. Densities decreased to less than 5,000/m^3 by late November, 1993 and continued to decline to densities of less than 200/m^3 by February, 1994.

Spawning in 1994 was similar to that which occurred in 1993 in terms of magnitude and seasonality. Initiation of spawning occurred in mid-August, 1994 and continued to late October, 1994. Moderate veliger densities characterized the 1994 spawning season. A peak of 39,600/m^3 was recorded in mid-August.

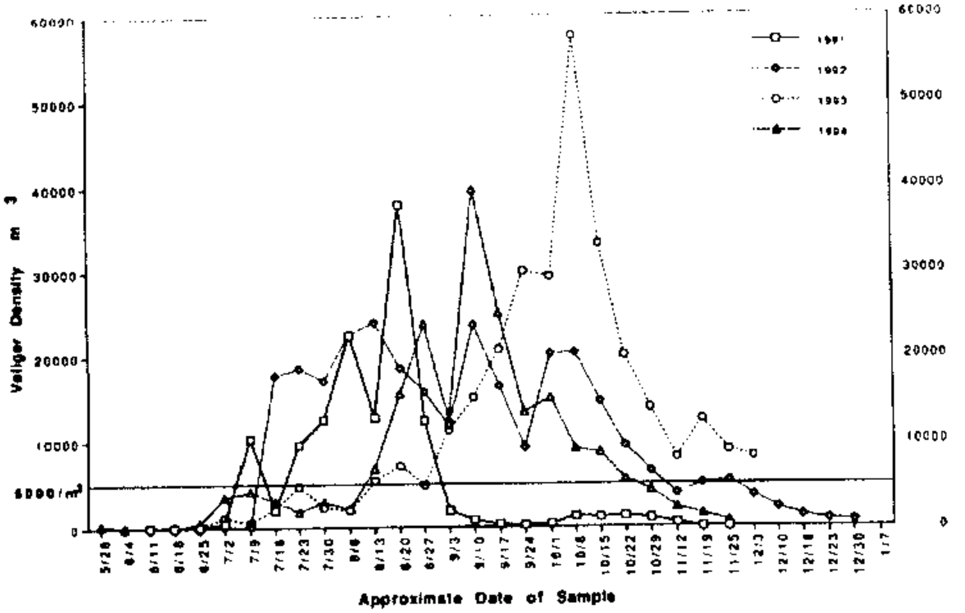

FIGURE 2. Yearly comparison of veliger density at Site A.

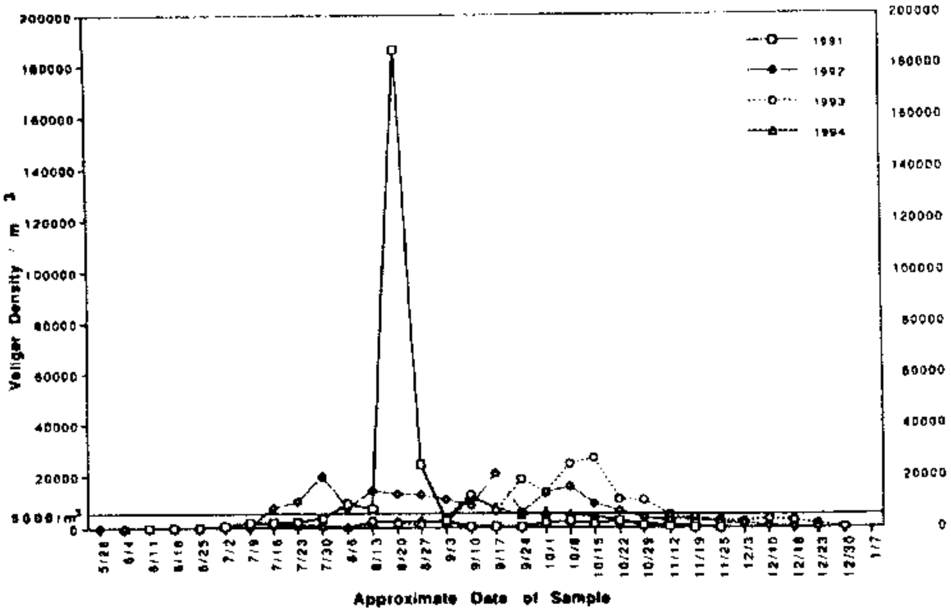

FIGURE 3. Yearly comparison of veliger density at Site B.

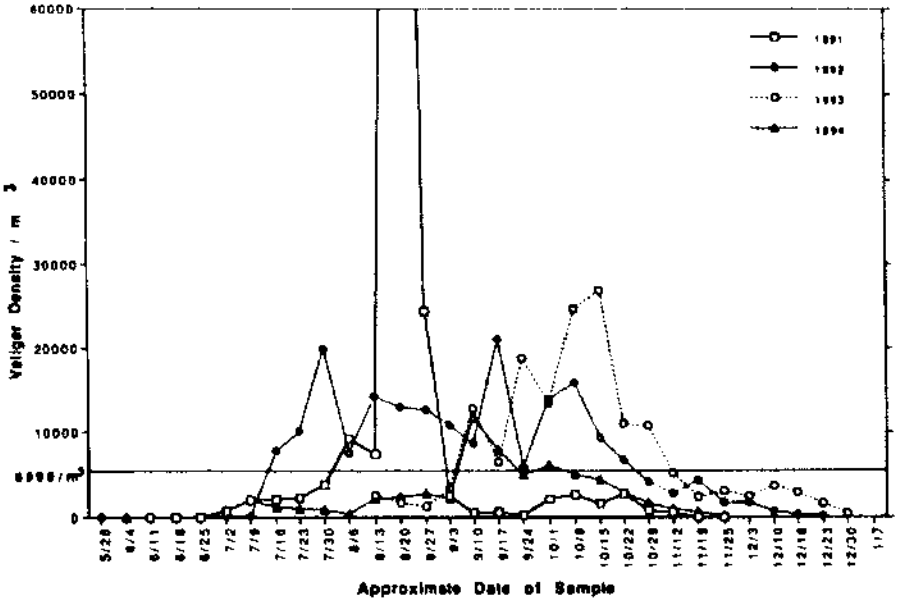

FIGURE 4. Yearly comparison of veliger density at Site B.

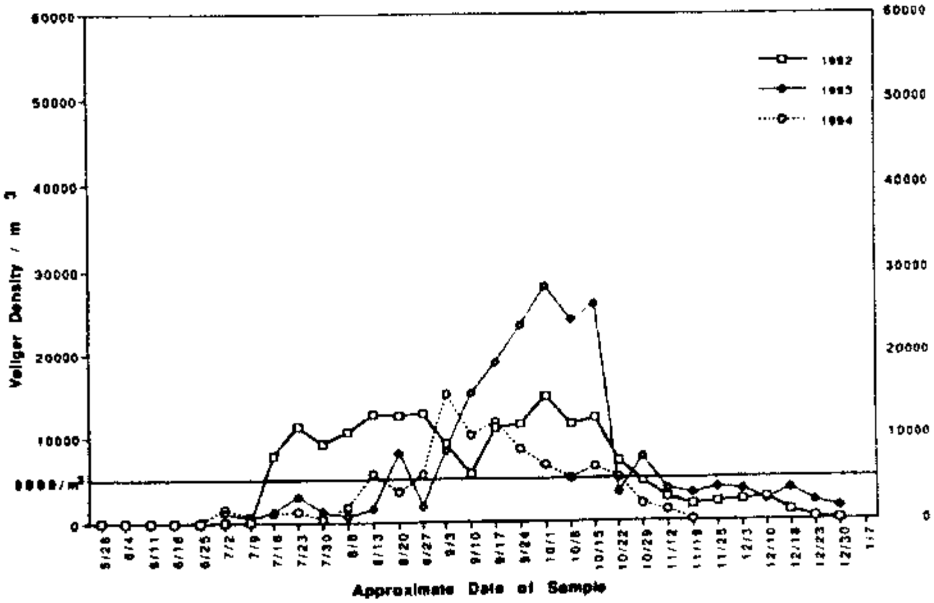

FIGURE 5. Yearly comparison of veliger density at Site C.

Peak veliger densities in 1993 and 1994 were higher than the 1992 peak density of 24,192/m^3, but lower than the 185,000/m^3 found in 1991. More veligers were present in the water column during the 1992 through 1994 seasons than the 1991 season because spawning occurred over a longer period of time. Viable veligers, in extremely low densities, were observed each year between the winter months of January and March. The lowest temperature that viable veligers were observed was 0.5 °C, occurring in March, 1993.

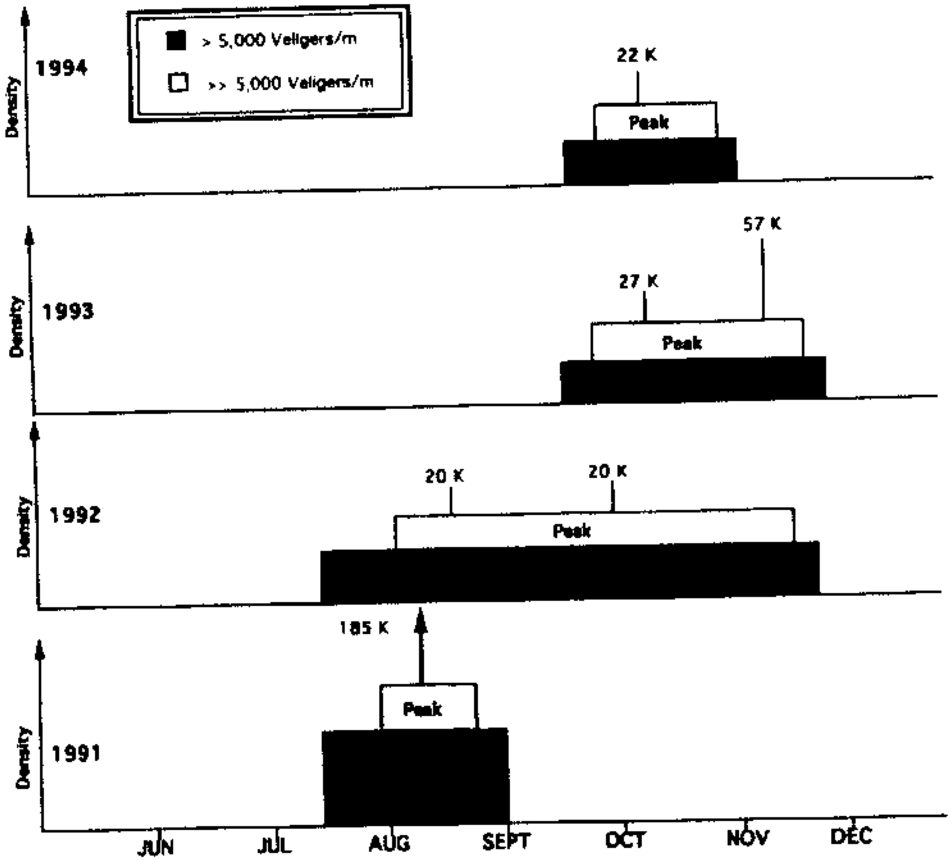

FIGURE 6. Relative differences regarding veliger spawning seasons from 1991 to 1994.

DISCUSSION

Initiation and duration of zebra mussel spawning undoubtedly is dependent on several environmental factors, including water temperature. There has been much conjecture regarding the temperature at which zebra mussels spawn. The initiation of spawning in each of the four years of this study occurred at different water temperatures. In addition to spawning initiation, duration of each spawning season was also variable, even though seasonal water temperature trends were similar in each year of the study. These data indicate that more than water temperature alone is responsible for triggering zebra mussel spawning. Other factors that undoubtedly affect spawning are availability and quality of food (algae) to sexually mature adults. Both of these factors influence the overall health of the adult population, thereby affecting their spawning potential at any given time. Abiotic and biotic factors may influence initiation and duration of spawning and should be investigated in the future.

Veliger density tended to be higher at sample sites closer to Lake Erie than at sites further downstream in the Niagara River. This is probably due to the close proximity to Lake Erie where the largest local mussel population exists. This trend indicates that a portion of veligers found in the Niagara are originating in Lake Erie and settle in the Niagara River as it flows toward Lake Ontario. This would explain the phenomenon of decreasing veliger densities as the distance from Lake Erie increases. The exact ratio of Lake Erie veligers and veligers that are spawned by adult mussels found in the Niagara River remains unknown.

Viable veligers were observed in extremely low densities each year between January and March. These veligers probably spawned in late fall/early winter when development was delayed due to cold water temperature and decreased metabolism. Therefore, the organisms remained in the planktonic, veliger stage instead of developing into the benthic, settled juvenile. The veligers observed during the winter months were very likely resuspended and represent veligers which are in a state of slowed development. Another occurrence of increased veliger density without actual spawning can be explained by high winds causing extreme wave action or turnover that resuspends veligers in the water column.

The 1993 and 1994 spawning seasons were similar in magnitude and seasonality. This is the first time that a repeated spawning pattern was recorded in this reach of the Niagara River and may indicate that major oscillations in spawning events are dampening. This pattern may represent a population which is now stabilizing following several years of a population explosion that occurred immediately after the zebra mussel invasion of the Great Lakes. Continued research efforts will help define factors that affect veliger density in the Niagara River region.

Likelihood of Invasion of the Aquatic Exotic Zebra Mussel, *Dreissena polymorpha* (Pallas), into Rhode Island Freshwater Systems

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ABSTRACT

The zebra mussel, *Dreissena polymorpha,* is an aggressive aquatic exotic organism that has rapidly invaded freshwater systems throughout the United States. This tiny mollusc has caused extensive damage to the intake pipes of utilities, industries, and waterworks plants. Aside from impacting water-dependent facilities, zebra mussels have also altered our native ecosystems. After its introduction into the Great Lakes Basin in 1986, this mussel extended its range into most major river systems and smaller tributaries that flow through the heartland of the United States. Furthermore, the zebra mussel is predicted to inhabit most freshwater systems of North, South, and Central America, provided that a suitable habitat exists.

In July 1993, zebra mussels were sighted in the southern section of Lake Champlain. This recent invasion into the New England region is cause for concern to all New England states and their respective industries, aquaculture facilities, power plants, utilities, boaters and anglers, all of which utilize the freshwater resource. This concern has prompted many states to evaluate the likelihood of a zebra mussel invasion.

Invasion potential is based on whether the appropriate environmental conditions exist for a suitable zebra mussel habitat.Neary and Leach (1992) established the initial water quality criteria as it relates to colonization potential of zebra mussels. Water quality parameters analyzed for the invasion criteria were temperature, calcium ion concentration (mg/L) and pH. This classification system attempts to predict zebra mussel invasion and survival based upon calcium levels (mg/L) and pH, both of which are critical environmental factors that can limit growth and reproduction. Several states have utilized this criteria to evaluate invasion potential.

As of July, 1994, no zebra mussels have been sighted in Rhode Island freshwater bodies. However, the introduction of zebra mussels into Rhode Island waters within the next

several years is likely, given its ability to adapt to a variety of North American habitats. Thus, predicting which freshwater locations are at risk of becoming infested with zebra mussels is essential to developing monitoring, control programs, and management plans for both state and private industries in Rhode Island.

This report attempts to determine some of the potential water bodies in Rhode Island that could experience zebra mussel invasions, given the appropriate water chemistry characteristics and boating activity. First, Rhode Island waters were reviewed using the Neary and Leach (1992) invasion criteria to predict possible invasion locations. Secondly, Rhode Island waters were evaluated to assess the invasion potential using boating activity as the transport vector. Boating activity was analyzed by determining **boat ramp type and boating restrictions** at the particular water bodies reviewed.

For this report, both pH and calcium concentration (mg/L) data for lakes and ponds were obtained from the 1992 Rhode Island Watershed Watch Monitoring Report of 52 lakes and ponds. A second volunteer monitoring program, Citizen's Bank River Rescue, provided water chemistry data from five Rhode Island rivers.

Invasion Potential was rated as "Unlikely", "Possible", and "Probable". These ratings describe the ability of the particular water body to support a zebra mussel infestation. After applying the criteria, 49 lakes and ponds, and three rivers were given "unlikely" ratings. *Barney Pond, Handy Lake, Moshassuck* and *Ten Mile Rivers* all have suitable zebra mussel colonization potential and were rated as "Possible". The *Blackstone, Woonasquatucket,* and *Pawtuxet Rivers* were given "Unlikely" ratings, but displayed a wide range of calcium and pH levels ranging from 1 - 19.5 mg/L, making classification difficult. Other locations with marginal water characteristics were *Olney Pond, Secret Lake, Tiogue Lake, Scott Pond* and *Chapman Pond*. Even though, these areas were given "Unlikely" ratings, these waters could potentially support a zebra mussel invasion if a change in water chemistry occurs.

After reviewing the lake and pond data, only 17 may experience zebra mussel introductions through boating activity. It was determined that the water bodies previously mentioned as possible colonization areas are unlikely to have zebra mussels transported into them through boating activity because of the boating restrictions at these respective locations. *Barney Pond, Handy Lake, Moshassuck* and *Ten Mile Rivers* have limited boating activity with no accessible boat ramps for larger boats and a 10 horsepower limit on motors. Those locations with the greatest potential for zebra mussel introductions by boating activity also displayed marginal water characteristics. *Tiogue Lake, Blackstone, Woonasquatucket* and *Pawtuxet Rivers* are at risk of introducing zebra mussels through boating activity, with poor zebra mussel survival.

In conclusion, zebra mussel invasion into Rhode Island within the next decade is likely. Rhode Island could experience invasions from the inadvertent transportation of mussels by recreational boats and trailers. Survival in many Rhode Island waters appears possible, but given low calcium concentration and pH; long-term survival, growth, and reproduction may be limited.

As a result of this analysis, two GIS (geographic information systems) maps were produced and used for seminars and identification workshops. The first map displays the *Drinking Water Watersheds of Rhode Island* and the second map shows the *Likelihood of Zebra Mussel Invasion into Rhode Island Water Bodies* produced from Watershed Watch data and boating activity information provided by the Rhode Island Department of Environmental Management. A report of this analysis will be updated with the 1994 monitoring data and published in the Spring 1995.

Using GIS to Predict Areas at Risk of Zebra Mussel Invasion in the Mid-Atlantic Region (NJ to NC)

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INTRODUCTION

Scientists believe that nearly every waterway in North America could be infested by the zebra mussel *(Dreissena polymorpha)* within the next 20 years. The zebra mussel has rapidly expanded its range in North America, but has not yet been found in the coastal states of New Jersey, Delaware, Maryland, Virginia and North Carolina. Many of the water bodies in these coastal states could be at risk of invasion by the zebra mussel.

The purpose of this project was to determine those waterways that could potentially be at risk of colonization by the zebra mussel.

METHODS

A list of environmental parameters in which the zebra mussel could and could not survive was developed and included conductivity, dissolved oxygen, pH, temperature, and calcium. Temperature was not used because the waters do not get that warm or cold in the Mid-Atlantic. The EPA storet data system was accessed and latitude, longitude and environmental parameters for each location were obtained for each state from 1988 to 1993. These values were averaged, entered into a Lotus Spreadsheet and imported into the GIS. If mean pH values were <6.9 or >9.5, then the site was not expected to support zebra mussels. When average conductivity values were greater than 22,000 µmhos/cm (13 ppt), the site was not expected to support zebra mussels. If mean calcium levels were <11 ppm and/or mean dissolved oxygen values were <3 ppm, the waterway was not expected to support zebra mussels.

For the GIS, state boundaries, rivers, and streams were obtained from the USGS digital line graphs (DLGs) at a scale of 1:2,000,000 (1973). Lake boundaries were obtained from the USGS DLGs at a scale of 1:2,000,000 (1980).

RESULTS

Maps were produced for each state depicting sites of potential infestation and those areas which potentially would not support zebra mussels. At locations which may not support zebra mussels, those environmental parameters which would be inhospitable to the zebra mussel are shown on the map as blue circles, and those regions which could potentially support zebra mussels are shown as red diamonds. State boundaries, rivers, and streams are depicted on the map and were obtained from USGS digital line graphs.

For New Jersey, most of the waterways in the central and northern region as well as along the Delaware River may support zebra mussels. In Delaware, many of the waters in the central and northern part of the state could be invaded by the zebra mussel. The western and central waterways of Maryland and some regions along the eastern side of the Chesapeake Bay may support zebra mussels. In Virginia, some waters west and north of the Chesapeake Bay are at risk of invasion. For North Carolina, a few water bodies in the far western end of the state are at risk.

DISCUSSION

Many of the water bodies in the Mid-Atlantic region are at risk of zebra mussel invasion. However, the zebra mussel appears to survive at lower salinities than were reported when these maps were produced. Therefore, even fewer water bodies would be at risk of invasion.

This project was funded by NOAA, National Sea Grant College Program, New Jersey Sea Grant College Program, New Jersey Marine Sciences Consortium and Rutgers Cooperative Extension. GIS maps (not shown) were produced by Coastal Environmental Services.

The Ecology of Two Introduced Marine Ascidians and Their Effects on Epifaunal Organisms in Long Island Sound

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ABSTRACT

Since their arrival on the northeast coast of North America, the ascidians *Botrylloides diegensis* and *Styela clava* have become dominant and conspicuous members of many shallow-water protected harbors from Connecticut to Maine. Our work on the population ecology and effects that both species have on natural invertebrate communities in Long Island Sound indicates that on small spatial scales both species appear to have only a limited influence on the distribution and abundance of a variety of native species. Most species avoid settling on *Botrylloides* colonies and the ascidian's primary influence is the usurpation of space for settlement. Longer-term effects of *Botrylloides* on epifaunal community development appear relatively minimal and highly transitory. *Styela* is also capable of reducing larval settlement of native forms but the ascidian apparently has little or no influence on post-settlement dynamics of a variety of fouling species. Some species (e.g., barnacles) show enhanced settlement on the tunics of *Styela* relative to adjacent substrata. Overall, the two ascidian invaders have become well-integrated into resident fouling communities and their presence appears to have had no major effect on the biodiversity of fouling species assemblages found in southern New England harbors and estuaries.

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INTRODUCTION

For the past decade we have been studying various aspects of the ecology of two recently introduced ascidians, *Styela clava* and *Botrylloides diegensis*, in eastern Long Island Sound, CT. Our particular focus has been understanding their population dynamics and the influence they have on resident members of shallow-water sessile epifaunal invertebrates inhabiting the Sound. Both ascidians were first observed on the northeast coastline of North America in the mid-1970's (Carlton 1989; Berman *et al.* 1992) and are now frequently the most conspicuous members of a variety of protected shallow-water habitats (e.g, rocks, pilings, floating docks, piers) throughout their present distribution ranges (Maine to Connecticut).

Our work with *Styela* and *Botrylloides* began by examining the effects the species had larval settlement and post-settlement mortality of the American oyster (*Crassostrea virginica*). Laboratory and field experimental studies revealed that *Styela* was capable of ingesting oyster larvae and that *Botrylloides* reduced local post-settlement survivorship and growth of oysters (Osman *et al.* 1989). Subsequent studies indicated that local density-dependent interspecific competition for substrate, coupled with food depletion, were the likely mechanisms responsible for negative affects the ascidians had on the growth and survivorship of newly settled and juvenile oysters (Zajac *et al.* 1989; Osman *et al.* 1990). In order to assess how these ecological interactions affected oyster population dynamics, we developed a series of qualitative models which examined the effects the ascidians had on different oyster life stages (Whitlatch and Osman 1994). Model results provided important insights regarding which life stages of the shellfish or ascidians should be managed in order to maximize shellfish production.

More recent work has focused on the general affects that resident adult sessile species have on the settlement and recruitment dynamics of both their own and other species (Osman and Whitlatch 1995a; 1995b) and factors controlling their distribution patterns in subtidal habitats in New England (Osman and Whitlatch 1995c, 1995d). This work, which has included studies with *Botrylloides*, indicated that larval settlement onto the exposed surfaces of resident adults was reduced over that of unoccupied substrates. In addition, a common pattern we observed was an enhancement of settlement densities of a number of species on primary substrate adjacent to resident adult species. Field experiments indicated little measurable effect of larval predation by resident species on settlement or recruitment and suggested the most common effect that resident species had on the population establishment was the usurpation of primary substrate that would normally be available for settlement and subsequent growth.

The purpose of this article is to: (a) provide a general description of the natural history of *Styela* and *Botrylloides* and an overview of the population ecology of *Botrylloides* in Long Island Sound, (b) assess the effects that *Styela* has on settlement and recruitment dynamics of other sessile epifaunal species found in the Sound, and (c) present preliminary information on the effects of *Botrylloides* on the early development of fouling assemblages in the Sound.

MATERIALS AND METHODS

Natural history of *Botrylloides diegensis*

Botrylloides diegensis (Ritter and Forsyth) is a sessile colonial ascidian (Order Pleurogona: Suborder Stolidobranchia: Family Styelidae). The species is native to the Pacific Ocean and was released by a biologist into Eel Pond, Woods Hole, MA in 1973. *Botrylloides* has large (> 1mm) non-feeding larvae which are brooded in incubatory pouches. Larvae are capable of swimming up to 12 hr in the laboratory (Berrill 1949) and will settle almost immediately if a suitable substrate is provided in the field (personal observations). After larval settlement and metamorphosis colonies grow by asexual multiplication. Zooids are 1-2 mm long and colony development is often serpentine-like in nature, giving the impression the zooids are arranged in rows or chains. While *Botrylloides* colonies are typically orange to reddish-orange in color, various shades ranging from white and yellow to purple have been observed (personal observations).

The ascidian appeared in eastern Long Island Sound in the late 1970's (personal observations) and presently extends north from the Gulf of Maine to Connecticut (Carlton 1989; Berman *et al.* 1992). In Long Island Sound, *Botrylloides* colonies have been observed westward at least to Bridgeport Harbor, CT. Colonies are typically found throughout protected shallow subtidal areas (to approximately 4 m depth) in the Sound and they can be found encrusting a variety of hard substrates including rocks, pilings, buoys and buoy lines, floating docks, eel grass (*Zostera marina*), and a variety of macroalgal species (personal observations). Occasional colonies have been found on a variety of benthic epifaunal invertebrates (e.g., crabs, snails, mussels, oysters, *Styela*). *Botrylloides* appears extremely opportunistic and is frequently the most conspicuous (often because of its bright color) member of fouling communities throughout the Sound. Cursory observations indicate that *Botrylloides* is capable of overgrowing almost every common epifaunal species in the Long Island Sound except for the ascidians *Botryllus schlosseri* in the late summer (e.g., Grosberg 1981), and *Diplosoma maldonaldi*, which is sporadically found in Long Island Sound waters.

Natural history of *Styela clava*

Styela clava (Herdman) is a solitary ascidian (Order: Pleurogona; Suborder: Stolidobranchia; Family: Styelidae). Adults are generally 5-15 cm long with a yellow-grey to brown club-shaped body, a narrower stalk and tunic holdfast. The tunic usually bears conspicuous tubercles and irregular longitudinal wrinkles and grooves. In California, *Styela* grows 1-1.5 cm per month until individuals are about 8.5 cm. Individuals live 12-18 months (Abbott and Newberry 1980). Fertilization is external and recruitment generally occurs from mid-July to late September in Connecticut waters (personal observations).

Styela is native to the Philippines, but is currently widely distributed throughout the world. For example, the ascidian is found on Asiatic shorelines, Japan, Australia and northwestern European harbors and both coasts of the United States. It was discovered near Plymouth, England in 1953 (originally described as *Styela mammiculata* Carlise) and has spread to other parts of southern England (Millar 1970) and the French channel coast (Monniot 1970). Abbott and Johnson (1972) suggest that *Styela clava* (originally identified as *Styela barnharti*) likely appeared on the California coast in the late 1920's and now ranges from San Diego to San Francisco.

Styela first appeared on the east coast in Long Island in 1973 (Carlton 1989). It is typically found in harbors and has become a prominent member of the epifaunal communities in these habitats. The ascidian can be found on many different types of hard substrates (e.g., piers, floating docks, buoy lines, lobster traps) in Long Island Sound, where densities of 5-15 individuals 100 cm^{-2} are not uncommon (personal observations). Anchored by a tunic holdfast and held more or less erect in the water by a long stalk, *Styela* tends to be more commonly found in cryptic habitats than *Botrylloides* (e.g., under overhanging structures). Individuals can also be found on vertical surfaces free from obstructions (personal observations) and in areas generally not exposed to strong wave or current action (Abbott and Johnson 1972; personal observations).

Study sites

Most of our field work has been conducted adjacent to the University of Connecticut's Avery Point Campus, located in Groton, CT. While several field sites have been studied, data presented in this study were primarily collected at two sites (Sites 1 and 2) located on the north side of Pine Island, at the mouth of the Poquonock River and adjacent to Avery Point (41°18'48"n, 72°03'36"W). Both sites are separated by $\approx$200 m and are relatively protected shallow water habitats ($\approx$2-3 m depth MLW). A secondary site, used to collect comparative data on the effect that *Botrylloides* has on early epifaunal community development, is located at the University's Marine Research Laboratory in Noank, CT at the mouth of the Mystic River estuary (Site 3). Salinities at all three sites typically range from 23 to 26 $^{0}/_{00}$ and water temperatures vary seasonally between -1°C to 23°C. Water current speeds, while not quantitatively measured, are primarily tidally-driven and rarely exceed 10-20 cm sec^{-1} (personal observations).

The subtidal fouling communities at all three sites mainly consist of both solitary (*Mogula manhattensis*, *Ciona intestinalis*, *Ascidiella adspersa* and *Styela clava*) and colonial ascidians (*Botryllus schlosseri*, *Botrylloides diegensis*, *Diplosoma macdonaldi*), barnacles (*Balanus* spp.), spirorbid polychaetes (*Spirorbis* spp., *Hydroides dianthus*), arborescent (*Bugula turrita*) and encrusting bryozoans (*Schizoporella errata*, *Crytosula pallasiana*, *Conopeum tenuissimum*, *Electra hastingsae*) and hydroids (*Obelia* sp., *Turbularia crocea*). Osman and Whitlatch (1995 a, b) provide more detailed information on the nature of the fouling communities in the study area.

Botrylloides Population Biology and its Influence on Fouling Community Development

Studies on seasonal and year-to-year variations in *Botrylloides* recruitment were usually conducted from early June to late September. Roughened 100 cm^2 PVC panels were suspended face-down $\approx$1 m below the surface from a floating raft moored at Site 1 between

1989 and 1991 and at Site 2 from 1992 to 1994. A new set of four panels was deployed each week and the number of ascidians recruiting over the seven day time period was enumerated under a dissecting microscope.

Studies on the population ecology of *Botrylloides* were conducted at Site 1 (Malatesta 1991 for details). Briefly, experimental substrates (100 cm^2 roughened PVC panels) were suspended face-downward at ≈ 1 m depth from a floating raft. A total of 24 panels were removed from the site on a weekly basis (June to November), returned to the laboratory, and kept in a flow-through seawater system at all times. Panels were carefully scraped to remove all new recruits of every fouling species except *Botrylloides*. Natural settlement and colony growth of *Botrylloides* was not obstructed or altered. Before being returned to the field, a photographic record of each panel was made using a videotape recorder and camera. Video images, digitized with an image analysis system, were used to calculate the number of colonies and their growth and mortality.

Two experiments were conducted to examine the effects of *Botrylloides* on the establishment and early development of fouling communities. Experiments (deployed at Sites 2 and 3) consisted of deploying 16 panels (in a manner similar to those described previously), ≈ 1 m below the surface at each site. On a weekly basis at each site, all *Botrylloides* colonies were selectively removed from half the panels by gently scraping off new recruits. The remaining eight panels were left untouched. Initially, all organisms on all panels were counted and recorded under a dissecting microscope; in the last two weeks of each experiment panels were censused by videotaping and digitizing with an image analysis system (as above). The experiments ran for five weeks at Site 2, beginning in late July and for six weeks at Site 3, beginning in late August.

Effects of *Styela* on Epifaunal Settlement and Recruitment

Experiments examining the effects of *Styela* on settlement and recruitment of fouling species were conducted at Site 1 using substrates and deployment conditions similar to those described previously (see Sedgwick-Springer 1992 for details). Both experiments used live adult *Styela* (body length: $\approx$8-9 cm), collected from areas adjacent to Site 1, in which their holdfasts were haphazardly attached to the PVC panels with glue.

Settlement experiments were conducted for one-day periods at three separate times during August (noted as Experiment #1, #2 and #3). Results presented in this article (see Sedgwick-Springer 1992 for complete experimental design) include three treatments (7 replicates per treatment) of low (4) and high (16) densities of *Styela*, and blank panels without *Styela* (natural densities of *Styela* at the study site averaged 0-15 individuals per 100 cm^{-2}; Sedgwick-Springer 1992). Panels were examined after 24 hours of exposure for each experiment and all fouling organisms were counted and identified under a dissecting microscope. To control for possible space preemption effects by *Styela* (which represented 4.5% and 18.1% of the surface area of low density and high density treatments, respectively), all settlement counts were normalized to numbers of settlers per 100 cm^2. Data were square-root transformed before analysis and a F_{max} test (Sokal and Rohlf 1981) indicated homogeneity of variances after transformation.

The recruitment experiment used methods similar to the settlement experiments (see Sedgwick-Springer 1992 for details). Results presented in this article include three density treatments with *Styela* (4, 8, 16 individuals per panel) and blank panels which served as control substrates. The panels were deployed and censused (as above) every week 17 July to 30 August. After the recruits were counted and identified, any missing or dead *Styela* were replaced to maintain ascidian density treatments and all panels and *Styela* tunics were cleaned with a small soft brush to remove the recruits before the panels were returned to the field. Panel recruitment counts were normalized (as described above) and data were square-root transformed prior to analysis. A F_{max} test indicated homogeneity of variances following the transformation.

RESULTS

Population biology of *Botrylloides diegensis*

Recruitment studies revealed significant seasonal and year-to-year variations in *Botrylloides* recruit abundance (Fig. 1A). Typically two recruitment peaks ("low" and "high") were found in each year of study. Recruits typically began appearing in mid-June and steadily increased in abundance to 8-10 individuals settling panel^{-1} week^{-1} by mid-July. A slight decrease in recruit abundance was then followed a rapid increase to 40-100 individuals panel^{-1} week^{-1} between late August and early September. Recruit abundance then rapidly declined throughout the remainder of the recruitment season (mid- to late November). *Botrylloides* recruitment patterns showed high year-to-year variation, particularly during the second recruitment peak (Fig. 1A). For example, in 1991 there was no distinctive peak in recruit abundance at any time of the year and recruitment was relatively low, while in 1993 the late summer period of high recruitment was extended through late September.

In Connecticut coastal waters, *Botrylloides* is a semelparous, sub-annual ascidian which has two distinct cohorts per year. This life cycle helps to explain some of the seasonal patterns in recruitment peaks presented in Figure 1A. For instance, the first cohort occurs in early summer, the offspring of those few colonies which have over-wintered (Fig. 1B). Recruitment rates which establish the first cohort are generally low and the resulting colonies have relatively low mortality rates (Table 1). Higher fecundities of the first cohort result in recruitment rates to the second cohort which are higher (and correspondingly more variable) than those established in the first cohort (Fig. 1A).

Mortality rates of the second cohort are higher than the first cohort (Table 1) as a consequence of density-dependent mortality (Malatesta 1991). We found, however, no growth rate differences between the two cohorts (Table 1) and the colonies of this cohort have relatively low fecundities (peaking in late summer), and exhibit a low incidence of fusion relative to the first cohort (Malatesta, personal observations). The second cohort, usually established in the fall (October to November) over-winters to establish the first cohort in the following summer (Fig. 1B, 1C); restarting the annual two-cohort life cycle.

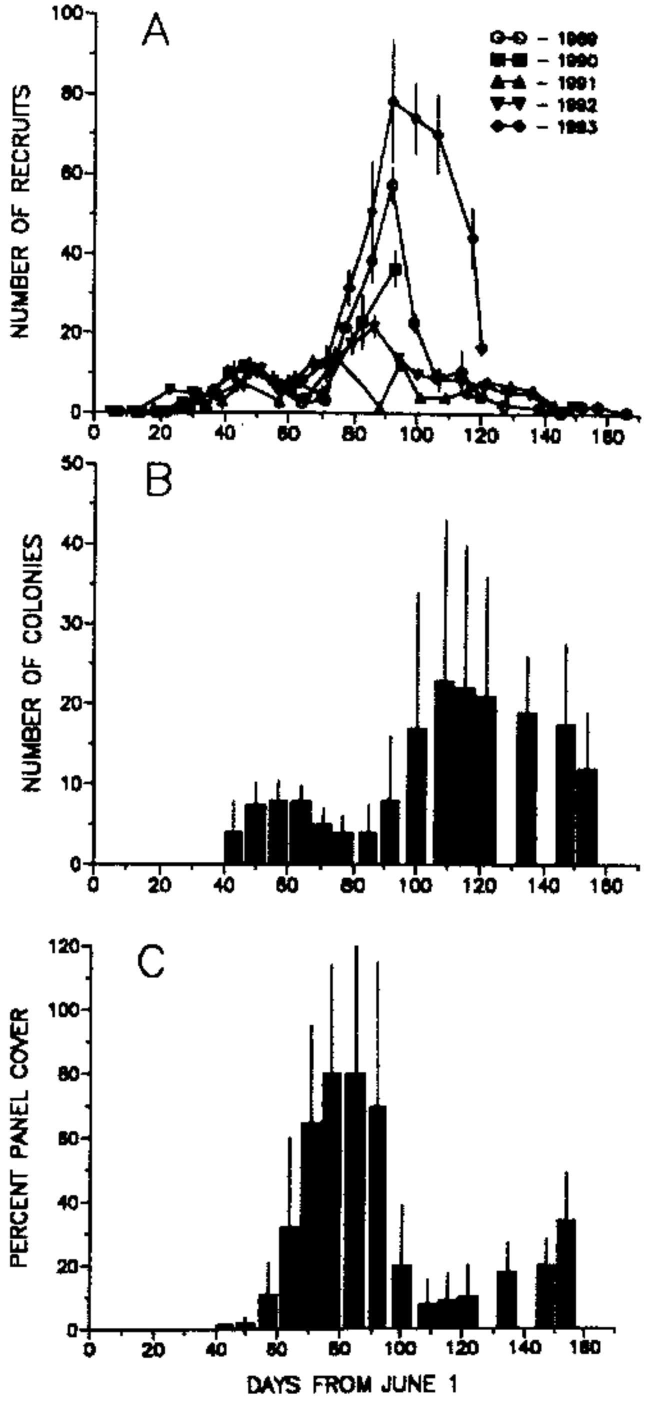

Figure 1. Temporal patterns in the number of recruits (A), colonies (B) and percent of the experimental panels covered (C) by *Botrylloides diegensis*. Recruits = mean per 100 cm^2 ±1 s.e; colonies and percent cover = mean per 100 cm^2 ± 95% confidence limits.

Table 1. Summary of life history characteristics of *Botrylloides diegensis* for the first and second cohorts observed in eastern Long Island Sound. "Low Set" and "High Set" refer to sub-populations within each cohort which received relatively lower or higher settlement rates during the period of data collection (September 1989 to June 1990). Values represent means ±1 S.D.; boldface values indicate cohort averages. Settlement and mortality rates are expressed as the number of individuals settling or dying per week. Growth rates represent size increases in mm^2 day^{-1}.

	COHORT ONE		**COHORT TWO**	
	Low Set	**High Set**	**Low Set**	**High Set**
Settlement	2.8 ±2.3	5.2 ±2.2	12.2 ±5.8	32.8 ±32.8
	(4.0 ±2.5)		**(23.3 ±12.0)**	
Mortality	0.083 ±0.207	0.026 ±0.067	0.155 ±0.092	0.295 ±0.138
	(0.055 ±0.153)		**(0.230 ±0.137)**	
Growth	4.06 ±1.87	5.10 ±2.33	4.10 ±2.55	3.12 ±1.21
	(4.56 ±2.07)		**(3.61 ±2.01)**	

Effects of *Botrylloides* on early fouling community development

The abundances of many of the epifaunal species recruiting at the initiation of the two experiments was quite different between the two study sites (Fig. 2). Site 2 generally displayed significantly higher recruitment than site 3, particularly for the ascidians *Botryllus*, *Mogula*, *Styela*, and *Ascidiella* and the bryozoans *Bugula*, *Bowerbankia* and *Schizoporella*. The only species recruiting at higher densities at Site 3 than Site 2 were *Botrylloides* and the bryozoan *Cryptosula* (Fig. 2).

Figure 3 summarizes the effects that *Botrylloides* had on the colonization of six most abundant species at the two study sites. Despite relatively large between-site differences in the abundances of each of the species, *Botrylloides* appeared to have little affect (positive or negative) on the establishment and early development of the fouling communities at either study site. The exception to this general pattern was the significantly lower barnacle abundance on substrates with *Botrylloides* at Site 2 when compared to substrates without the ascidian. At the termination of the experiment, *Spirorbis* abundance was significantly reduced in the presence of *Botrylloides* at Site 3 (Fig. 3). At site 2, *Mogula* settled in very high numbers had covered most of the experimental substrates by the end of the study (Fig. 4).

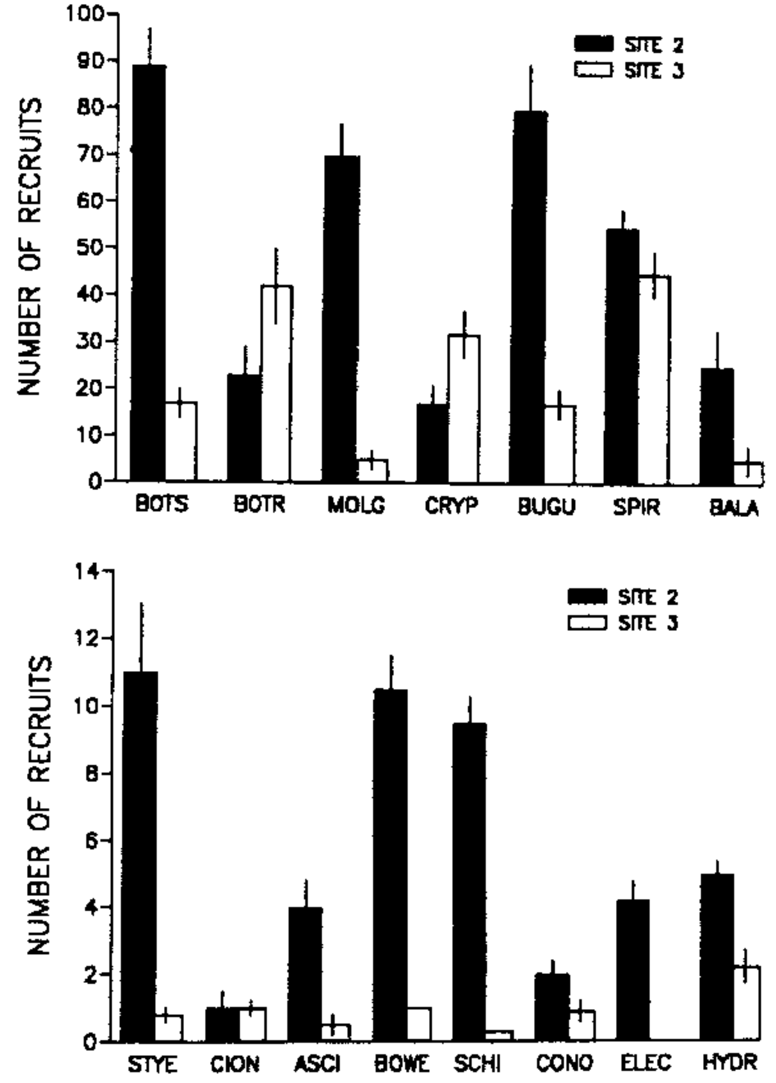

Figure 2. Comparison of the abundances (mean ±1 s.d.) of the most abundant epifaunal species recruiting at study sites 2 and 3 at the initiation of the *Botrylloides* early community development experiment (see text for details). Species shown are: *Botryllus schlosseri* (BOTS), *Botrylloides diegensis* (BOTR), *Mogula manhattensis* (MOLG), *Cryptosula pallasiana* (CRYP), *Bugula turrita* (BUGU), *Spirorbis* spp. (SPIR), *Balanus* spp. (BALA); *Styela clava* (STYE), *Ciona intestinalis* (CION), *Ascidiella adspersa* (ASCI), *Bowerbankia* spp. (BOWE), *Schizoporella errata* (SCHI), *Conopeum tenuissimum* (CONO), *Electra hastingsae* (ELEC) and *Hydroides dianthus* (HYDR).

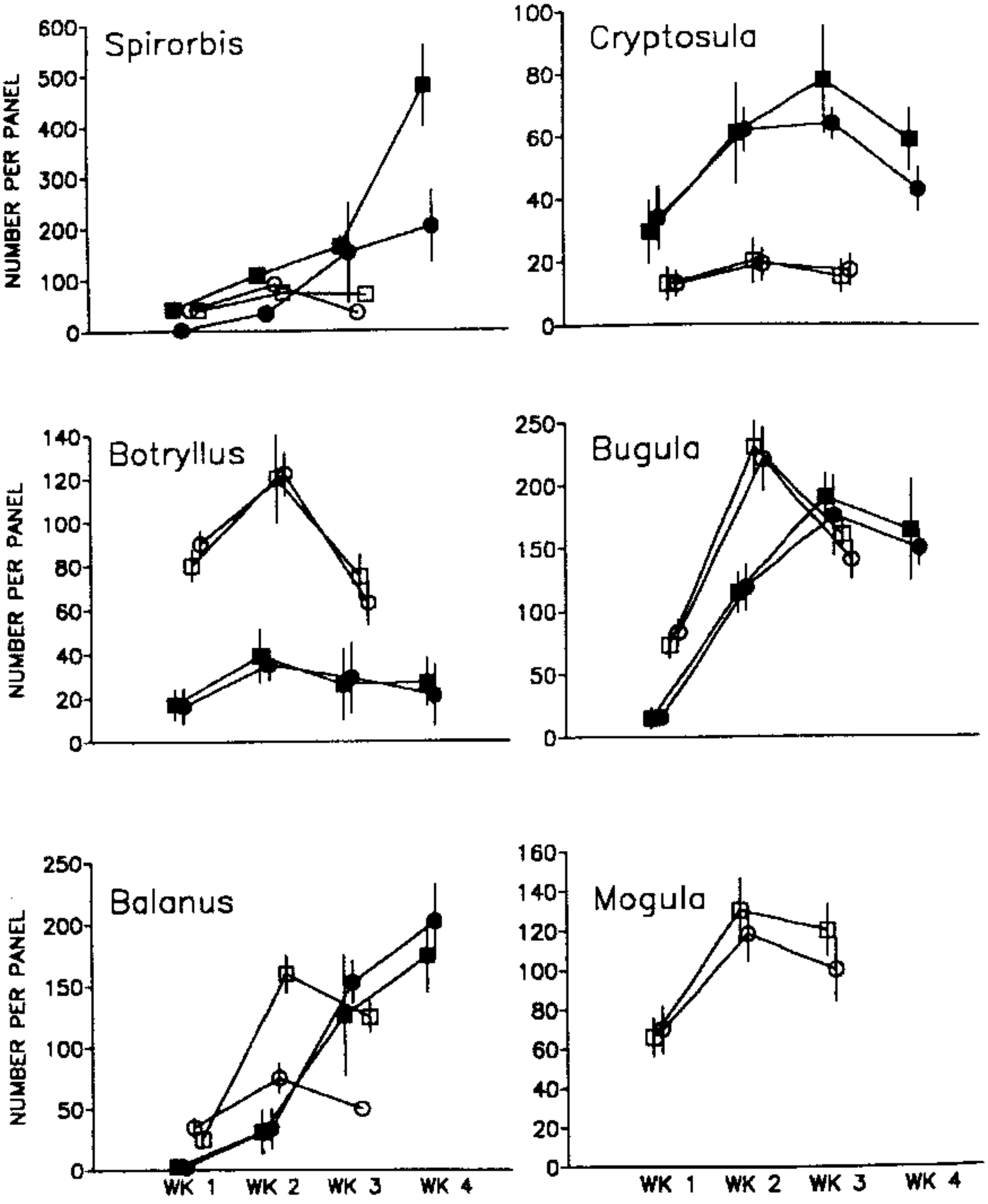

Figure 3. Comparisons of the abundances (mean ±1 s.d) of the dominant epifaunal species on experimental treatment panels with and without the present of *Botrylloides diegensis* (see text for details). Site 2: ○ = substrates with no *Botrylloides* present; □ = substrates with *Botrylloides* present; Site 3: ● = substrates with no *Botrylloides* present; ■ = substrates with *Botrylloides* present.

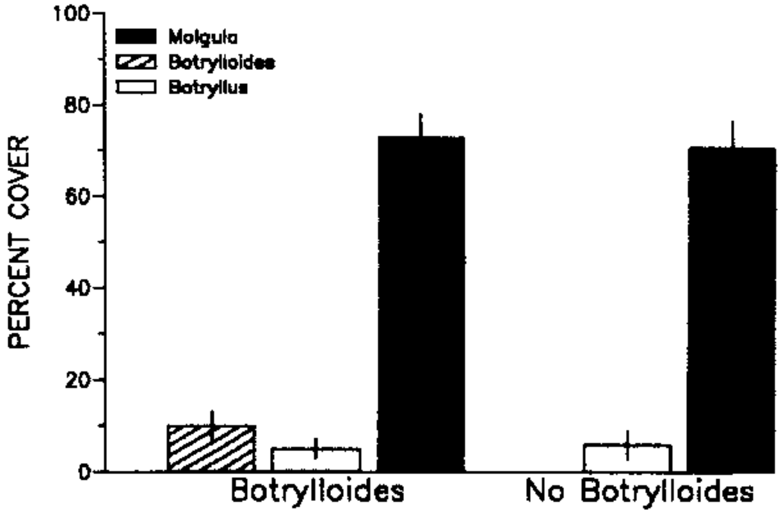

Figure 4. Comparison of the percent experimental panel cover (mean ± 1 s.d.) of the most dominant species at Site 2 at the end of the *Botrylloides diegensis* early community development experiment (see text for details).

Effects of *Styela* on Epifaunal Settlement and Recruitment.

While ten epifaunal species (Table 2) were identified in the settlement experiment, settler abundance was low for most species and data were combined for analysis. Settlement of only two species (*Botryllus* and *Spirorbis*) was high enough (> 10 settlers per panel) to permit individual species analysis. Results were reasonably consistent between the three settlement experiments (Fig. 5): (a) the low-density *Styela* treatment had no effect on total settler number or the abundance of *Botryllus* or *Spirorbis* when compared to control panels; (b) the high-density *Styela* treatment reduced the total number of settlers compared to other treatments; (c) high densities of *Styela* generally resulted in lower numbers of *Spirorbis* and *Botryllus* settlers, especially when settler abundances were high.

Twenty-nine epifaunal species were found during the course of the recruitment experiments (Table 2). Of these, five (*Botryllus*, *Botrylloides*, *Bugula*, *Spirorbis* and *Balanus*) recruited at densities high enough to permit data analysis. A two-way ANOVA (Sedgwick-Springer 1991) revealed only one significant density treatment effect on recruitment (*Spirorbis* on 19 July), and recruitment data from the three *Styela* density

Table 2. Epifaunal species recorded on panels during the three *Styela* settlement experiments and the *Styela* recruitment experiment (see text for details).

Taxon	**Settlement Experiments**			**Recrutiment Experiment**
	#1	**#2**	**#3**	
Botryllus schlosseri	X	X	X	X
Botrylloides diegensis	X	X	X	X
Styela clava	X			X
Diplosoma macdonaldi	X	X	X	X
Ciona intestinalis				X
Mogula manhattensis				X
Bugula spp.	X	X	X	X
Cryptosula pallasiana	X	X	X	X
Bowerbankia spp.	X			X
Acyonidium poloum				X
Conopeum tenuissimum				X
Crisia sp.				X
Electra hastingsae				X
Schizoporella errata				X
Hipothoa hyalina				X
Barentsia spp.				X
Pedicellinia cerunea				X
Campanularia sp.				X
Obelia spp.				X
Tubularia crocea				X
Balanus spp.	X		X	X
Spirorbis spp.	X	X	X	X
Hydroides dianthus				X

Table 2 Continued

Sabella crassicornis				X
Potamilla reniformis				X
Halichondria/Haliclona		X		X
Haliplanella luciae				X
Mytilus edilus				X

In general, the presence of *Styela* had no consistent effect on total recruit abundance in the seven recruitment experiments (Fig. 6A). However, several general patterns were evident when examining the recruitment data species-by-species: (a) during periods of high recruitment of *Botryllus* and *Bugula*, recruit densities were generally significantly lower on the *Styela* treatment relative to control panels (Fig. 6D, 6E), (b) no significant treatment effects were found for *Spirorbis* or *Balanus*, regardless of recruit abundance (Fig. 6B, 6C), and (c) *Botrylloides* recruitment was unaffected by the presence of *Styela* when compared to control substrates (Fig. 6F).

DISCUSSION

Subsequent to their appearance in the mid-1970's, *Styela clava* and *Botrylloides diegensis* have become conspicuous, and often dominant, members of protected shallow-water environments throughout Long Island Sound. Our work has generally concentrated on the population ecology of *Botrylloides* and how both species influence settlement and post-settlement dynamics of epifaunal species in the Sound. These types of studies are important in understanding the basic ecology of the ascidians and the impacts their recent introductions may have had on the distribution and abundance of other resident epifaunal species.

We have found that in Connecticut waters *Botrylloides* is a semelparous, sub-annual ascidian which produces two distinct cohorts each year. Cohorts are established approximately one month apart in the summer and their within-cohort population dynamics are largely driven by very different between-cohort recruitment dynamics. The first cohort is established by relatively low settlement rates and is a product of the reproductive activity of colonies which have over-wintered and survived to reproduce in the early summer. The cohort, which is fast-growing but short-lived (e.g., 30-60 days), has a relatively higher fecundity and correspondingly higher and more variable settlement rate than the second cohort. Colonies in this cohort, in the absence of competitors, can potentially cover ≈ 100% of local available substrates. Colonies, however, die following reproduction and open new space for late summer epifaunal recruitment. The second cohort, in the absence of competitors, generally occupies less space as growth slows as a result of declining water temperatures.

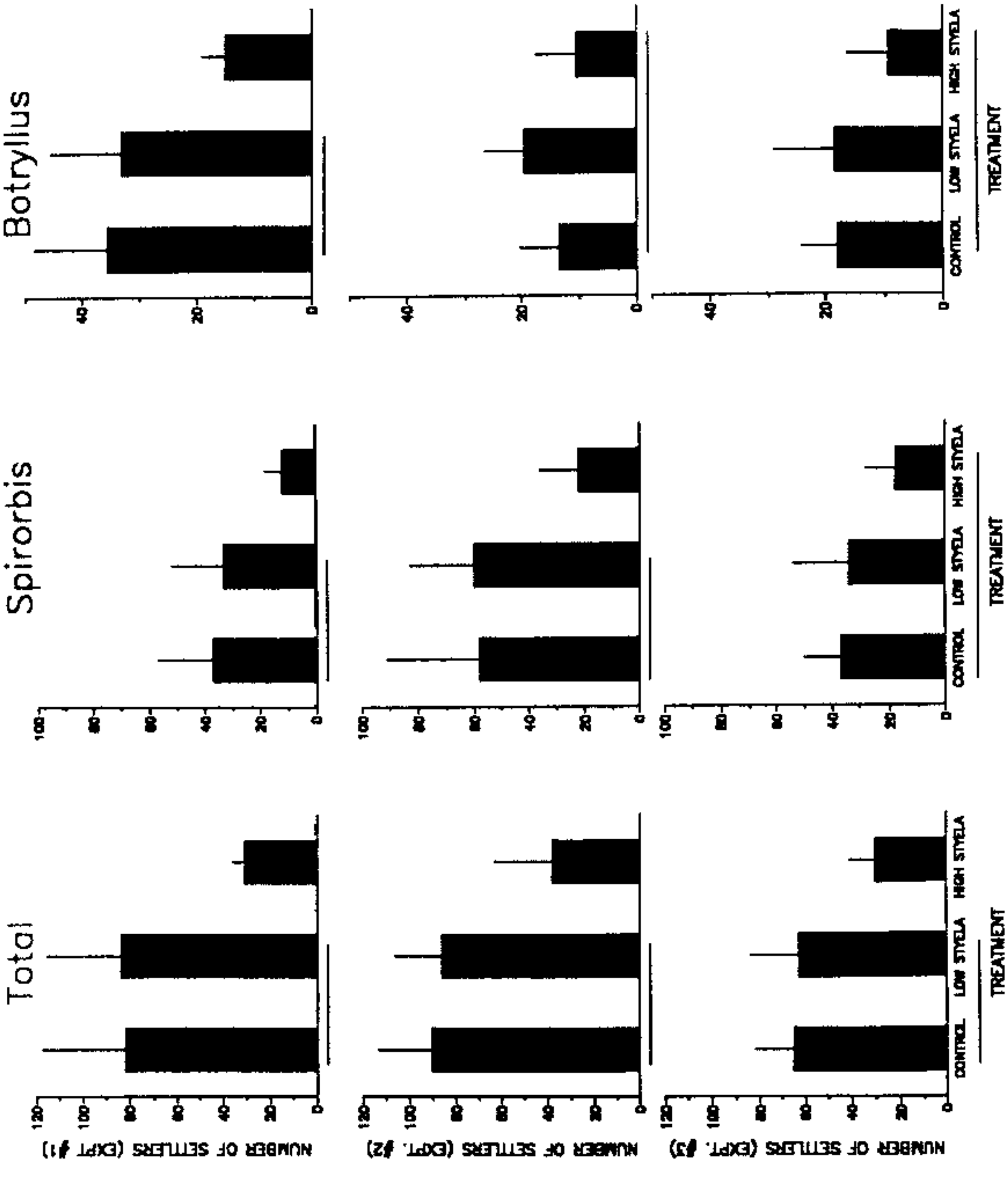

Figure 5. Comparisons of the mean (± 1 s.d.) total number of settlers and number of *Spirorbis* and *Botryllus* settlers found on experimental panels with no, low (4) or high (16) abundances of *Styela clava* present. Data include results of three (Exp. #1; Exp. #2; Exp. #3) separate one-day settlement experiments. Lines connecting histograms indicate no significant differences ($p < 0.05$) between mean treatments.

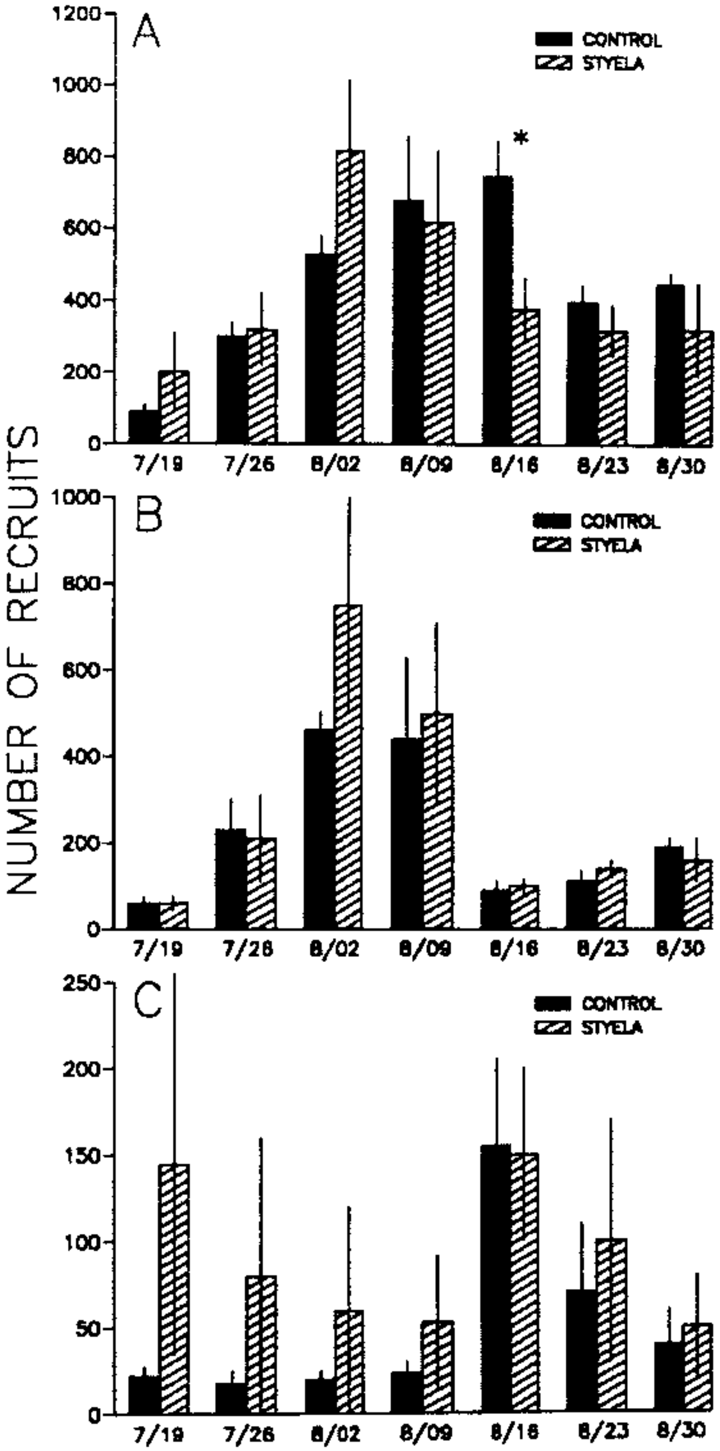

Figure 6. Comparisons of the abundance (mean ±1 s.d) of the number of recruits on experimental panels with and without *Styela clava* being present (see text for details). A = Total recruits; B = *Spirorbis* spp.; C = *Balanus* spp. * = significant ($p < 0.05$) difference in abundance between control and treatment panels.

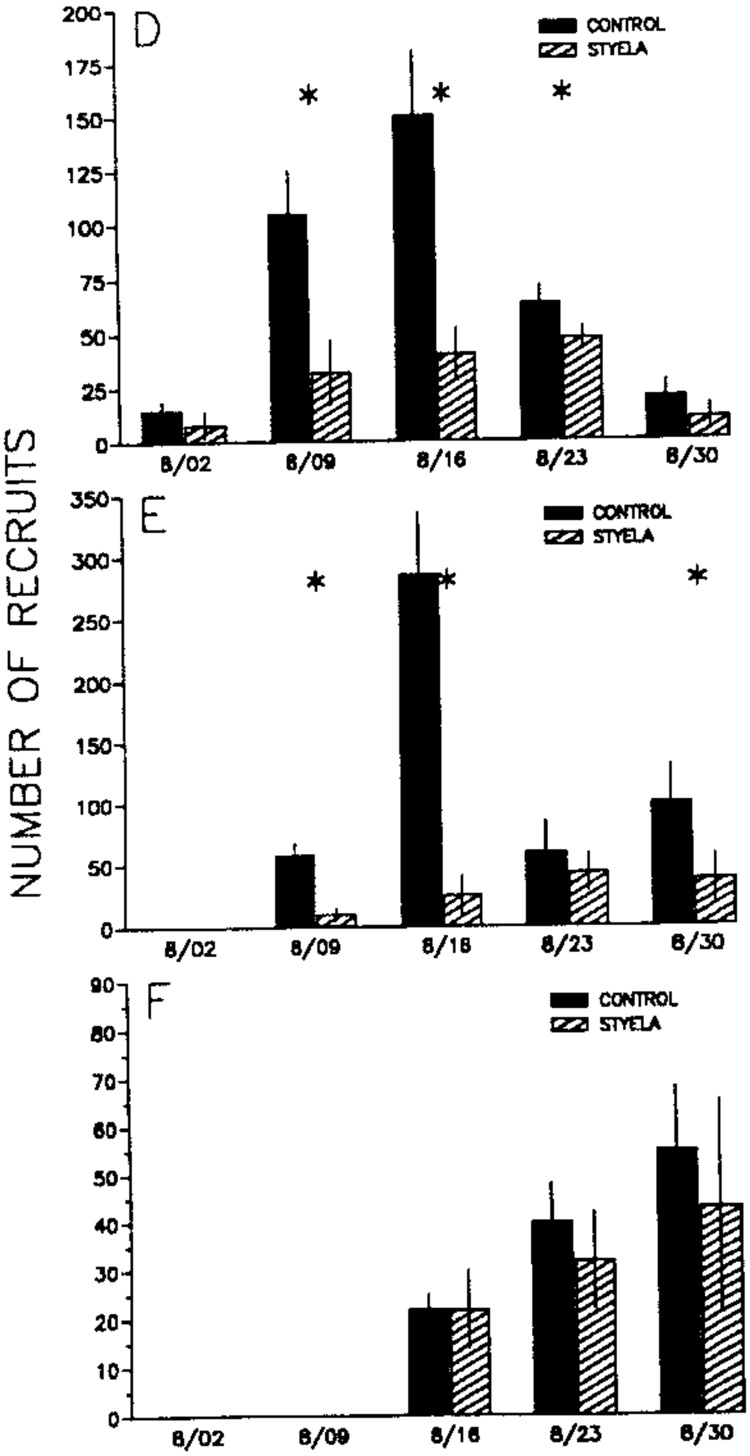

Figure 6 (continued, see previous figure legend). D = *Botryllus schlosseri*, E = *Bugula turrita*, F = *Botrylloides diegensis*

Our previous studies have shown that few species settle on living colonies of *Botrylloides* and that the major effect the ascidian has on epifaunal settlement was to reduce available space for settlers (Osman and Whitlatch 1995 a, b; Frese 1994). Longer-term (e.g., weekly) recruitment studies revealed a similar pattern and recruit densities (e.g., individuals cm^{-2}) on panels with *Botrylloides* were either significantly greater or no different than densities on substrates without the ascidian present. Experimental results presented in this article generally support this work as we found little evidence of significant local effects of *Botrylloides* early epifauna community development.

Studies on *Styela* indicated that high abundances of the ascidians could locally reduce larval settlement over short (e.g, one-day) time-periods. This finding is consistent with previous work which demonstrated that epifaunal settlement generally decreased as the abundance different species of ascidians (*Botrylloides*, *Botryllus*, *Diplosoma* and *Mogula*) increased (Osman *et al.* 1989; Osman and Whitlatch 1995a, b). The specific mechanism responsible for the negative effect that *Styela* had on settlement was likely predation on settling larvae (e.g., Osman *et al.* 1989; but see Young 1989) or the alteration of the local environment caused by the physical presence of *Styela*. For example, Sedgwick-Springer (1992) found that high densities of *Styela* "mimics" (2 ml pipet bulbs [mean length 5.4 cm] glued to panels) and ascidians which had their siphons blocked to prevent feeding, resulted in reduced settlement of some species when compared to control panels. The mixed effects on settler abundance appeared to be related to species-specific differences in settler behavior and size (Sedgwick-Springer 1992).

Longer-term (e.g., weekly) experiments revealed that *Styela* had a more limited and transitory effect on epifaunal recruitment. Only two species (*Botryllus* and *Bugula*) examined were significantly influenced by the presence of the ascidian, and only when recruit abundance was high. Similar to studies on epifaunal settlement, Sedgwick-Springer (1992) found that high densities of *Styela* "mimics" could often result in reduced recruit abundance relative to control panels. Small-scale modifications in the physical environment (e.g., changes in water flow characteristics) resulting from the presence of *Styela* likely contribute to the observed variations in recruitment for some species.

Although not significant, recruit abundance of some species (e.g., *Spirorbis* and *Balanus*) appeared elevated in the presence *Styela*. A variety of species commonly colonize the tunics of *Styela* (personal observations) and Sedgwick-Springer (1992) found that densities of *Balanus* recruits were significantly higher on ascidian tunics when compared to adjoining substrates. Barnacle larvae are known to be rugophilic and have a tendency to settle in grooves and concavities of hard substrata (Crisp and Barnes 1954). Epifauna recruitment onto the tunics of *Styela* is in sharp contrast to our previous findings which showed both settlement and recruitment onto the living surfaces of ascidians was normally very low or non-existent (Osman and Whitlatch 1995a, b). Others have noted the importance of similar biological structures in enhancing habitat complexity or settlement space in fouling communities (e.g., Dean 1981; Bros 1987).

There are an increasing number of examples showing the dramatic effects that alien invaders have on the structure and function of natural aquatic communities (e.g., zebra mussels the Great Lakes; Asian clams in San Francisco Bay; comb jellies in the Black Sea [see Carlton and Geller 1993 for references]). It is also recognized that many types of New England coastal habitats and species have been historically modified by biological invasions of both plants and animals (e.g., salt marshes, green crabs, littorines, *Codium*), and Carlton and Geller (1993) provide compelling evidence as to the pervasive risk coastal habitats (particularly bays and estuaries) have to the threat invasions of alien. Both *Botrylloides* and *Styela* have become well integrated into natural fouling communities along the New England coastline. While they can be spatially dominant, our work to date suggests they have a limited effect on a variety of resident fouling species and there is no evidence they have negatively influenced epifaunal diversity of these habitats. There is, however, anecdotal evidence that *Styela* may be displacing the blue mussel, *Mytilus edulis*, in some habitats in southern New England (Carlton 1989). It is important to recognize, that *Botrylloides* and *Styela* are relatively recent invaders to the northeast coastline and broader-scale studies are needed to fully assess their impact on the ecology of resident species.

Continued studies on mechanisms and consequences of biological invasions in marine coastal habitats are vital for a better understanding and assessment of methods and policies for regulating and managing the coastal zone. Organisms like *Botrylloides* and *Styela* provide excellent model systems to study biological invasion in coastal habitats. They are relatively easy to culture, have limited larval dispersal and can be manipulated under a variety of conditions in the laboratory and field to study the nature of ecological interaction with other species. Information on how invaders integrate themselves into resident communities and at what ecological scales they impact those communities remains an important but poorly understood aspect of marine ecology and resource management.

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Ecological Factors Controlling the Successful Invasion of Three Species of Ascidians into Marine Subtidal Habitats of New England

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ABSTRACT

Three species of sessile marine ascidians, *Botrylloides diegensis*, *Styela clava*, and *Ascidiella aspersa*, have recently been introduced into marine rocky subtidal habitats of New England. Although all 3 species produce short-lived, poorly dispersing larvae, they have spread over a broad geographic area from Connecticut to Maine. Within this range their local distributions are fairly patchy, where they occur in high abundance at some sites while being rare or absent at similar sites nearby. Since 1987 we have been conducting experimental field studies in Vineyard Sound and eastern Long Island Sound, examining the ecological interactions between these ascidians and the native community. We have found that: (1) adult ascidians transplanted to sites where they are rare or absent survive and grow at rates similar to those found at sites where they are abundant, (2) these ascidians are not inhibited from recruiting onto substrates occupied by native species, (3) at field sites where these ascidians are rare, 1-3 day-old recruits are preyed on by at least two species of very abundant small snails, *Anachis lafresnayi*, and *Mitrella lunata*, (4) juvenile 1-2 week-old *Styela* were also preyed upon by fish, mostly the cunner *Tautogolabrus adspersus*, and (5) *Botrylloides* and possibly *Styela* seem to escape predation at an earlier age and smaller size than similar native species.

From our studies we feel that these species are able to invade local communities because: 1) they have short range larval dispersal that allows them to build up abundant local populations, 2) their recruitment is not strongly inhibited by native sessile species, and 3) they are less vulnerable to predation than similar native species.

INTRODUCTION

Three species of sessile marine ascidians, the colonial species *Botrylloides diegensis* and the solitary species *Styela clava* and *Ascidiella aspersa*, have recently been introduced into marine rocky subtidal habitats of New England (Carlton 1989, pers. comm.). *Botrylloides* and *Styela* were first observed in the early 1970's (Carlton 1989, Berman *et al.* 1992), while we first encountered *Ascidiella* in eastern Long Island Sound in the late 1980's. As with most ascidians, all three species produce non-feeding, short-lived planktonic larvae. Other than possible rafting by adults attached to drift debris (or boat bottoms), these larvae are the principal dispersal stage of these ascidians. Several studies that have followed ascidian larvae in the field (Davis and Butler 1989, Stoner 1990) or have examined settlement around adults (Grosberg 1987) have indicated that few travel more than 10 m before settling and most disperse much shorter distances. Given this limited mobility we would expect the speed and range of their geographic spread to be limited. However, both *Styela* and *Botrylloides* have spread over a broad geographic area from Connecticut to Maine in less than 10 years (Berman *et al.* 1992). Contrary to their rapid spread throughout this range, their local distributions along the New England coastline appear to be fairly patchy, often occurring in high abundance at some sites and being rare or absent at virtually identical sites nearby (Osman *et al.* 1990, 1992, Osman and Whitlatch 1995a). These intriguing patterns have lead us to examine 1) what characteristics of these species have contributed to the success of their invasion and rapid spread, 2) whether differences in ecological processes between similar local environments cause the sharp gradients in their local abundance, and 3) how interactions with native fauna may affect long-term changes in their local or regional distribution.

As part of a series related studies begun in 1987 (Osman *et al.* 1989, 1990, 1992, Osman and Whitlatch 1995a, Whitlatch *et al.* 1995, Zajac *et al.* 1989), we have been examining the ecological interactions between introduced ascidians (principally *Botrylloides* and *Styela*) and the native community. A variety of experimental field studies were conducted in both Vineyard Sound near Woods Hole, MA and eastern Long Island Sound near Groton, CT. Several general patterns have emerged from these studies:

First, in both localities we have found ascidian-dominated epifaunal communities at some sites and epifaunal communities dominated by bryozoans and other sessile invertebrates (often with no ascidian species present) at similar sites less than 1 km away. These patterns pre-date the arrival of *Botrylloides*, *Styela*, or *Ascidiella* within the New England region. For example Grave (1933) found dominant ascidians in Eel Pond, Woods Hole, MA prior to the invasion of any of the three species. This dominance was again found at this site by Grosberg (1981) and later by Osman *et al.* (1990, 1992) with both *Botrylloides* and *Styela* present. Likewise we observed the almost complete dominance by the colonial bryozoans *Schizoporella errata* and *Bugula turrita* on the pilings of the Marine Biological Laboratory (MBL) water intake pier in 1987-1988 (Osman *et al.* 1990, 1992) that matched similar patterns observed in the early 1970's (Osman, pers. obs.). This site was < 1 km from the Eel Pond site by water (< 100 m by land), yet the only ascidians found in a 1988 survey of the pier were a few *Styela* and 1 large *Botrylloides* colony. Similarly, in eastern Long Island Sound we observed complete ascidian dominance on substrates at an Avery Point, CT breakwater site and only a few *Styela* and *Botrylloides* were found at the bryozoan-dominated Pine Island site < 1 km away (Osman *et al.* 1992, Osman and Whitlatch 1995a).

Secondly, although epifaunal species dominance differed between sites, larvae of all species were found to settle at both sites and adults transplanted between sites were able to survive and reproduce. In particular, survivorship of adult *Botrylloides* and *Styela* transplanted from Eel Pond to the bryozoan-dominated MBL pier suffered little mortality and showed no significant difference between treatments open and caged from large predators (Osman *et al.* 1990). Also, juvenile *Botrylloides* colonies transplanted from Eel Pond to the MBL pier actually grew significantly faster than control colonies in Eel Pond (Osman *et al.* 1992).

Thirdly, even though larvae of all species settled at all sites, recruitment of all species of ascidians was almost completely eliminated at the bryozoan-dominated sites. Observations (Osman *et al.* 1990) and subsequent experiments (Osman *et al.* 1992, Osman and Whitlatch 1995a) indicated that this primarily resulted from predation on newly-settled ascidians by the tiny snails *Mitrella lunata* and *Anachis lafresnayi* and possibly other small predators. Both species of gastropods were found at the bryozoan-dominated sites but not at the ascidian-dominated sites.

Fourthly, experiments also suggested that although *Mitrella* and *Anachis* preyed on *Botrylloides* and *Styela* as well as native species; this predation often had no significant measurable effect on the introduced species (Osman and Whitlatch 1995a).

Finally, a variety of experiments suggested that the native sessile community had little effect on the ability of *Botrylloides* or *Styela* to settle and recruit onto substrates (Osman and Whitlatch 1995b,c, Whitlatch *et al.* 1995).

Collectively, these results suggest that ascidians may be prevented from inhabiting sites where predators, particularly small micro-predators are present. The data also indicate that there may be some differences between native and introduced ascidians in their vulnerability to these predators which could influence their eventual ability to expand within a region. Our present research examines this possibility in greater detail.

METHODS

Experiments that were conducted in 1989 through 1992 (Osman *et al.* 1992, Osman and Whitlatch 1995) examined the effects of single individuals of the predators *Mitrella lunata* or *Anachis lafresnayi* on recruitment of sessile species. These experiments were conducted at the Avery Point breakwater (Figure 1) using paired surfaces of 18 cm^2 panels with one surface exposed to a predatory snail and the other surface acting as a control. In these experiments the recruitment of the colonial ascidians *Botryllus schlosseri* and *Diplosoma macdonaldi* was consistently reduced and usually eliminated in the presence of either species of predator. Companion experiments in which the densities of the solitary ascidians *Ciona intestinalis*, *Molgula manhattenis*, and *Styela clava* were manipulated demonstrated that

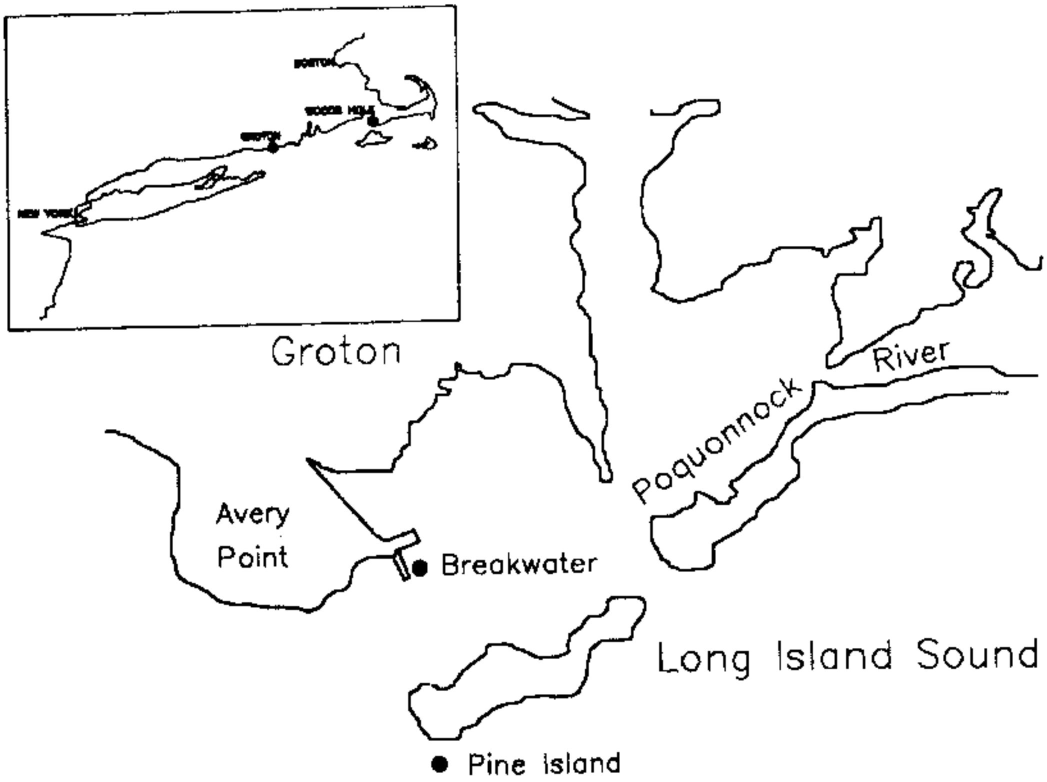

FIGURE 1. Map of the study area showing the location of the Breakwater and Pine Island sites.

Mitrella could eliminate recruits of these solitary species at densities well-beyond those observed in the field. However, although experiments with *Botrylloides diegensis* indicated reductions of its recruitment in the presence of these predators, differences between treatment and control surfaces were generally not significant, suggesting that these predators had little effect on this introduced species.

Although the results of these experiments are clear, they did not test whether this control of recruitment operates in the field under natural densities of predators. They also did not examine the role of other predators, including recruits, juveniles, and adults of larger invertebrate predators such as the crab *Libinia emarginata* or the seastar *Asterias forbesi* or by benthic-feeding fish such as the cunner *Tautogolabrus adspersus*. To address these questions we conducted a series of experiments between 1992 and 1994 at a field site near Pine Island < 1 km from the Avery Point breakwater (Figure 1). These experiments were conducted using artificial pilings that were 75 cm tall, 28 cm diameter PVC pipe secured upright to weighted frames to mimic both pilings and natural boulders. In a pilot study these pilings and substrates attached to them accumulated in 3-12 mo an epifaunal community indistinguishable from adjacent boulders. In each experiment 100 cm^2 panels attached to replicate pilings were used as sampling units. In most experiments 4 piling treatments were used with 5 pilings/treatment and 1-4 panels/piling. Treatments were:

1) open pilings, exposed to all predator guilds,

2) caged (1 cm^2 mesh) pilings which excluded all but the snails *Mitrella* and *Anachis* and other micro-predators (extensive tests for potential cage artifacts were negative),

3) screened (1 mm^2 mesh) pilings which excluded all predators, and

4) partially screened pilings to control for artifactual environmental changes (e.g. reduced flow) associated with screening the pilings.

Each experiment was conducted with 1 of 3 life-stages of an epifaunal species: 1-3 day-old recruits, 2-3 wk-old juveniles, or adults. Initially, clean panels were exposed to larvae of the chosen species in the laboratory or the field. After exposure panels were hung beneath a raft at the Avery Point breakwater site until individuals or colonies had reached the proper life-stage. During this time the panels were 'gardened' periodically to remove all other species. Prior to being used in an experiments, the panels were cleaned of all other species, counted, photographed, and the haphazardly assigned to treatments. In each experiment panels were exposed for 3-6 d. and then retrieved and photographed. Estimates of mortality and/or growth were made by comparing the initial and final photographs using computer-assisted image analysis. For the introduced species experiments were conducted with all 3 life-stages of *Botrylloides*, the recruit and juvenile life-stages of *Styela* and the recruit stage of *Ascidiella aspersa*. Experiments were also conducted with the native ascidians *Botryllus*, *Ciona*, and *Molgula*, the bryozoans *Bugula turrita*, *Schizoporella errata*, and *Cryptosula pallasiana*, and the mussel *Mytilus edulis*, but these will not be presented. Also, for those species in which recruits only survived in the screened treatment at the exposed site, panels with recruits were exposed with no caging on racks suspended 3-4 m above the bottom (no predators) to test for any effects on survival or growth resulting from caging.

RESULTS

The results of the field experiments using artificial pilings agreed strongly with the small cage experiments conducted previously (Osman *et al.* 1992, Osman and Whitlatch 1995). All ascidians suffered significant mortality from predation at 1 or more life stages at the Pine Island site where predators were abundant. Although predator abundances fluctuated throughout the summer, they remained fairly high. For example, during the summer of 1994 mean *Mitrella* abundances on open pilings ranged from 26 to 423 $piling^{-1}$ with a mean of 169 $piling^{-1}$ and mean *Anachis* abundances varied from 3 to 20 $piling^{-1}$ with a mean of 10 $piling^{-1}$. Larger invertebrate predators such as the seastar *Asterias forbesi* and the spider crab *Libinia emarginata* as well as know fish predators such as the cunner *Tautogolabrus adspersus* were also abundant at this site. Background recruitment data collected at the site showed that although all ascidian species could occasionally recruit at the site, their recruitment was extremely low and sporadic.

Botrylloides Experiments

An experiment conducted in 1993 with newly-recruited *Botrylloides* and *Botryllus* demonstrated the difference between the native ascidian and introduced species in their vulnerability to predators. Although *Botryllus* suffered high mortalities in all treatments except the screened treatment which kept out all predators, *Botrylloides* only experienced high mortality in the open treatment (Figure 2). This suggests that *Botrylloides* recruits were only preyed on by larger invertebrates or fish that were excluded in the other treatments. *Botryllus*, on the other hand was clearly vulnerable to the micro-predators that were only excluded from the screened treatment.

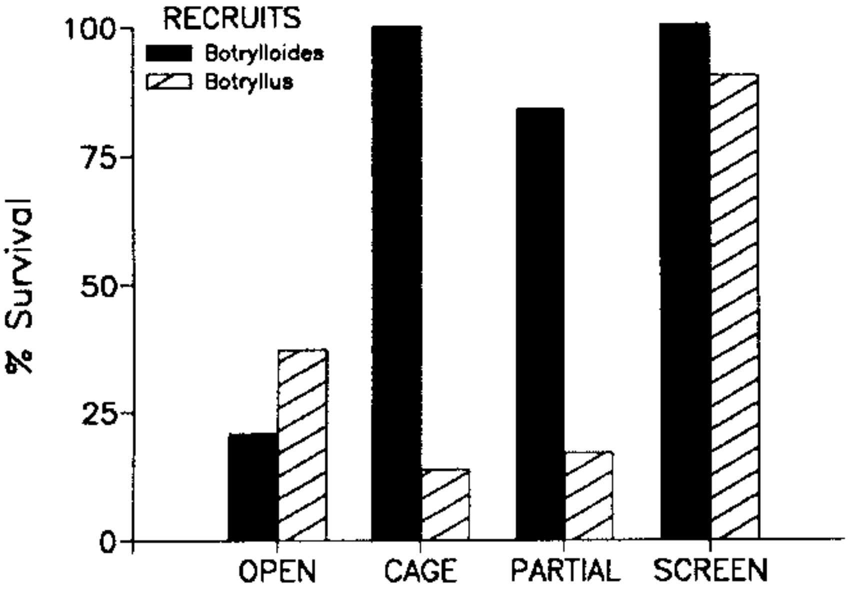

FIGURE 2. Mean survival of new 1-3 day-old recruits of the colonial ascidians Botrylloides diegensis *and* Botryllus schlosseri *on panels placed on experimental pilings at Pine Island. Treatments were open pilings, caged pilings to prevent predation by fish and large invertebrates, screened pilings to exclude all predators, and partially screened pilings as a control for any alteration of the physical environment resulting from screening.*

This trend continued with 1994 experiments with 1-3 week-old juvenile colonies of these species. While *Botryllus* suffered high mortality in all but the screened treatment, *Botrylloides* suffered almost no mortality in any of the treatments (Figure 3).

Finally, in experiments conducted in 1993 with 3-4 week-old larger juvenile and adult colonies of both species, there was little difference between the two species in their change in abundance during the experiments. Both species showed small losses in colony size in open treatments while colonies in cages grew by approximately 10% in the 5 days they were exposed in the field (Figure 4).

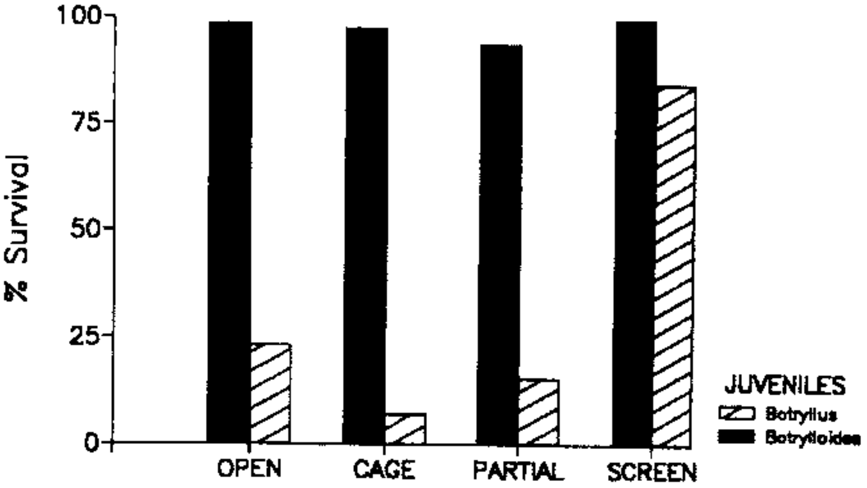

FIGURE 3. *Mean survival of 1-3 week-old juveniles of the colonial ascidians* Botrylloides diegensis *and* Botryllus schlosseri *on panels placed on experimental pilings at Pine Island. Treatments are the same as in Figure 2.*

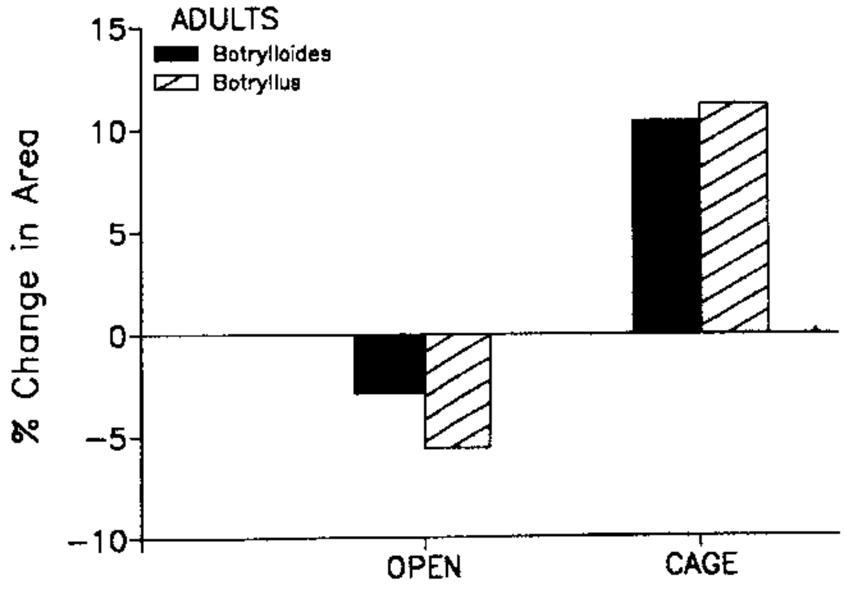

FIGURE 4. *Mean growth (% change in size) of colonies of the ascidians* Botrylloides diegensis *and* Botryllus schlosseri *on panels placed on experimental pilings at Pine Island. Treatments are the same as in Figure 2 with the exception that screened and partially screened treatments were not used.*

Styela Experiments

An experiment with *Styela* recruits was conducted in 1993. The recruits were 1-5 days old and exposed at Pine Island for three days. In Figure 5, the results of this experiment are contrasted with a similar experiment conducted in 1994 with *Ascidiella* and *Ciona*. *Styela*, as with the other two species of solitary ascidians suffered 100% mortality on open pilings and fairly high mortalities in all treatments except the screened pilings. The data suggest that as with other species of ascidian recruits, mortality from predation by small micro-predators was very high. Again, these results agree with the small cage experiments in which predation by *Mitrella* resulted in almost complete mortality of *Styela* (Osman and Whitlatch 1995a).

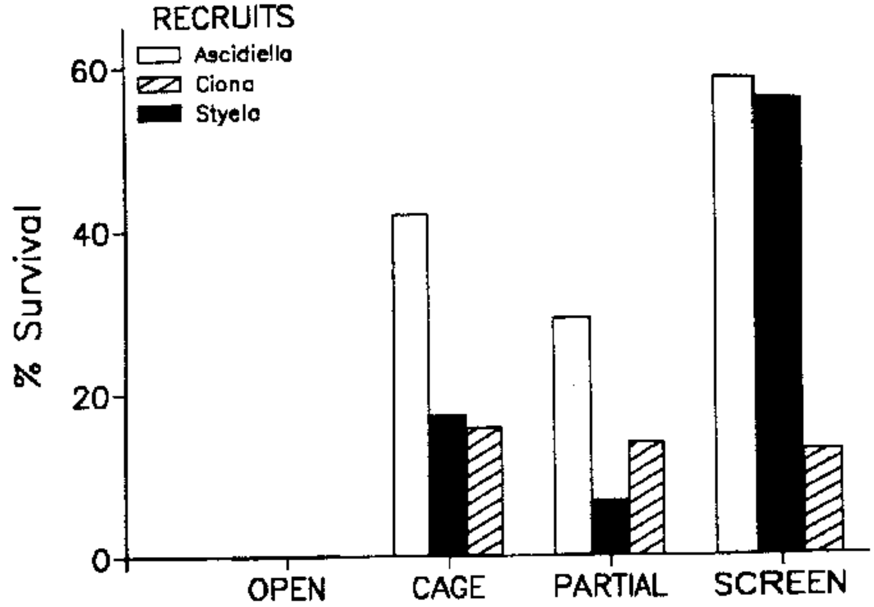

FIGURE 5. Mean survival of new recruits of the solitary ascidians Ascidiella aspersa, Ciona intestinalis, *and* Styela clava *on panels placed on experimental pilings at Pine Island. Treatments are the same as in Figure 2.*

In 1993 an experiment was also conducted with 2-4 week-old juvenile *Styela*. Because individual ascidians could not be reliably distinguished in the video-photographs taken of each replicate panel, the change of *Styela* abundance in this experiment was measured as a change in the percentage of the panel surface covered by all individuals on a panel. These data are contrasted with mortality data for *Ciona* and *Molgula* in Figure 6. It is clear that juveniles of all 3 species continued to suffer 100% mortality when exposed on open pilings. However, greater than 80% of *Ciona* and *Molgula* survived in the screened treatment and the area covered by the *Styela* increased by more than 30%. Values for the caged and partially screened treatments were intermediate (*Styela* and *Molgula*) or equally as high (*Ciona*). Thus it would appear that while mortality may be reduced by screening out the small micro-predators, the major influence on the mortality of these juvenile ascidians were the fish and possibly larger benthic predators excluded by any form of caging.

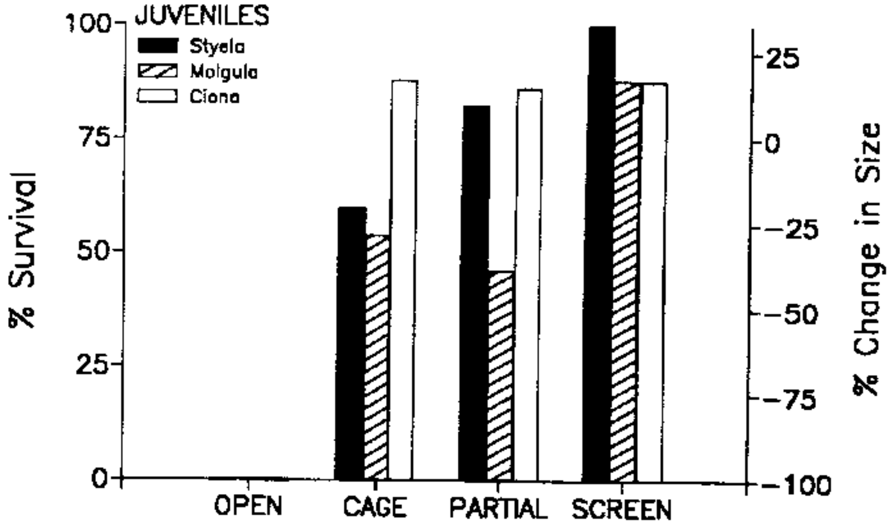

FIGURE 6. Mean survival of juveniles of the solitary ascidians Molgula manhattensis *and* Ciona intestinalis *contrasted with the % change in size of juvenile* Styela clava *on panels placed on experimental pilings at Pine Island. Treatments are the same as in Figure 2.*

Ascidiella Experiment

A recruitment experiment was conducted with *Ascidiella* in 1994. An identical experiment was conducted with *Ciona* at the same time. The results of these two experiments are contrasted with results for the *Styela* experiment discussed above (Figure 5). Clearly *Ascidiella* recruits also suffered mortality from both large and micro-predators.

DISCUSSION

The results of the field studies conducted in 1993 and 1994 show that the processes that were observed in previously conducted small cage experiments can have severe effects on the ability of ascidians, both native and introduced, to recruit successfully. Small micro-predators, such as the gastropods *Mitrella lunata* and *Anachis lafresnayi* can clearly eliminate ascidian recruitment. Furthermore, if solitary ascidians escape this 'micro-predation filter', they also can suffer severe mortality as juveniles from larger predators such as the cunner. Thus, in this sense the three species of introduced ascidians do not seem to differ from native species in that their local distributions are likely to be controlled by predators. If the predators are present, recruitment can be greatly limited and, for some species, juvenile mortality can be equally as high.

However, the experiments also indicate that the severity of predation on at least *Botrylloides* is much less than that of the native colonial ascidian *Botryllus*. Although we have observed some mortality of *Botrylloides* recruits from predation, the greatest mortality of *Botrylloides* recruits was seen only in the open treatments (Figure 2). Survival in the caged and partially screened treatments was high suggesting that larger predators such as the cunner were responsible for most *Botrylloides* mortality. In addition, for *Botrylloides* juveniles older than 1 week little or no predation related mortality was observed (Figure 3) and this contrasted with still high mortalities for *Botryllus* at this age. Finally, only when *Botryllus* colonies reached an age of 3-4 weeks did they exhibit the same reduction in mortality as *Botrylloides* (Figure 4).

There is some suggestion that *Styela* and *Ascidiella* mortalities at the field site may be lower than the native *Ciona* and *Molgula*. Recruits of both introduced species exhibited higher survival than *Ciona* recruits in all treatments (Figure 5) and juvenile *Styela* suffered lower mortalities in caged and partially screened treatment than *Molgula*. These differences could result from reduced mortality from micro-predators but the differences are not as striking as those between *Botrylloides* and *Botryllus*. Also, newly-settled *Ciona* are often weakly attached to the substrate which may contribute to their high losses in all treatments at the field site (Figure 5). *Molgula* also is less firmly attached than either of the introduced species, making it easier to be removed by predators or water currents.

Thus, overall the local distributions of the three species of introduced ascidians appear to controlled by the same environmental parameters as native species. Their abundance is strongly influenced by the presence of both large and small predators. However, they may escape the high mortalities resulting from predation more quickly than native species. This was indicated by a series of colonization experiments conducted in 1994 (Osman and Whitlatch, in prep.). In these experiments panels were exposed at the ascidian-dominated breakwater site for 1,2,3, and 4 weeks and then transplanted to the exposed site. For the 1-week series, mortalities of all ascidians were extremely high and a native bryozoan community developed. Panels transplanted after 2 weeks at the breakwater site (older and larger individuals) became dominated by bryozoans and *Botrylloides*. *Botryllus* only became abundant on panels transplanted after 3 and 4 weeks and solitary ascidians (*Molgula*, *Ciona*, or *Ascidiella*) were only found on caged substrates.

If local distributions of the three introduced species are controlled by interactions with the native fauna, then it can be asked what are the features common to all three species that have enabled them to both successfully invade and rapidly spread throughout the New England coastline.

First, all three species have limited larval dispersal capabilities. Most larvae released from an individual or colony likely settle within a short distance of the parent (Grosberg 1987, Davis and Butler 1989, Stoner 1990). This can allow local populations to rapidly increase in size, forming a stable foothold on an area. Since many of these areas are in or near harbors and marinas, boats may contribute to the long-range transport of these species with new localities quickly colonized by the local recruitment of offspring of founder individuals.

Secondly, recruitment of these species is not strongly inhibited by native sessile species (Osman and Whitlatch 1995a,b, Whitlatch *et al.* 1995). We have found little indication that predation on larvae or competition of established residents can significantly reduce the recruitment of these species. In addition, limited competition data indicate that these ascidians, particularly colonial species such as *Botrylloides*, can compete successfully for available substrate space.

Thirdly, they appear to be either equally or less vulnerable to predation than similar native species. Native predators, both large and small, do not limit their distribution any more than they limit the distribution of native species. In fact, given the reduced effect of predators on *Botrylloides* and possibly *Styela* and *Ascidiella*, we expect that these species could invade habitats not currently utilized by native ascidians. We thus expect the range of these species to expand both geographically and in terms of the habitats they occupy. However, other than shifting the relative abundances within the community we see no adverse effects resulting from their presence. As we have argued previously (Osman and Whitlatch 1978), communities may have an almost unlimited capacity to absorb new species.

ACKNOWLEDGEMENTS

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Sea Lamprey Management on Lake Champlain

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A substantial body of information collected on Lake Champlain indicates that the sea lamprey is constraining the coldwater and some warmwater fisheries. The negative impacts of sea lamprey parasitism have been clearly documented in the Great Lakes, where sea lamprey control programs have been in effect for more than 30 years. Surveys conducted on Lake Champlain showed sea lamprey larvae were abundant in 12 tributaries and five delta areas. In order to effect a rapid and dramatic reduction in parasitic phase sea lampreys in Lake Champlain, an eight year experimental sea lamprey control program utilizing lampricides was implemented on 12 Lake Champlain streams and five delta areas during the period 1990-92. In order to achieve maximum practical short-term reduction of sea lampreys, two applications of chemical lampricides to each stream or delta will be made over the eight-year period. Agencies involved in the program include the New York Department of Environmental Conservation, the Vermont Department of Fish and Wildlife, and the U.S. Fish and Wildlife Service. Assessments associated with the sea lamprey control project are being done to provide information for determining the desirability of continuing control long term. Assessment by the U.S. Fish and Wildlife Service include monitoring changes in sea lamprey abundance and the analysis of lamprey attack data. Abundance of sea lampreys in Lake Champlain peaked during the late 1980's and then declined dramatically in 1992 following the first round of control. The abundance of sea lampreys since 1992 has remained at less than 40 percent of the level recorded during the peak years of 1988-91. Initiation of the second round of sea lamprey control was begun in 1994 and it is anticipated that substantial reductions in the sea lamprey population will result from these efforts.

Aquatic Policy

Northeast Conference on Non-Indigenous Aquatic Nuisance Species

C.4

U.S. Fish and Wildlife Service: National and Regional Responses to Non-Indigenous Aquatic Species

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The invasion and spread of non-indigenous species have threatened and changed natural ecosystems for centuries. Non-indigenous species include any species or other viable biological material that enters an ecosystem beyond its historic, native range. Recent increases and advances in transport technology and human movement have accelerated the rate at which species are dispersed beyond their native range. Non-indigenous species introductions have been, and continue to be, a source of socio-economic benefits and costs to many sectors of our society.

NATIONAL RESPONSE

In 1990, spurred by the introduction of zebra mussels into the Great Lakes in 1986 and the associated economic and ecological impacts of that invasion, Congress enacted the Nonindigenous Aquatic Nuisance Prevention and Control Act, PL 101-646 ('Act'). The purposes of the Act are:

1) to prevent unintentional introduction and dispersal of non-indigenous species into waters of the U.S. through ballast water management and other requirements;
2) to coordinate federally conducted, funded or authorized research, prevention control, information dissemination and other activities regarding the zebra mussel and other aquatic nuisance species;
3) to develop and carry out environmentally sound control methods to prevent, monitor, and control unintentional introductions of non-indigenous species from pathways other than ballast water exchange;
4) to understand and minimize economic and ecological impacts of non-indigenous aquatic nuisance species that become established, including the zebra mussel; and,
5) to establish a program of research and technology development and assistance to States in the management and removal of zebra mussels.

Under the Act, non-indigenous aquatic species introduced into a system can be declared a nuisance, as defined by law, warranting the implementation of control programs that minimize the risk of harm to the environment and to the public health and welfare. An aquatic nuisance species, as defined in the Act, refers to "a non-indigenous species that threatens the diversity or abundance of indigenous species or the ecological stability of infested waters, or commercial, agricultural, aquacultural, or recreational activities dependent on such waters".

An Aquatic Nuisance Species Task Force (Task Force), co-chaired by the U.S. Fish and Wildlife Service (Service) and the National Oceanic and Atmospheric Administration, was established to coordinate federal efforts related to non-indigenous aquatic species. The Task Force consists of representatives from seven federal agencies including the Environmental Protection Agency, Coast Guard, Army Corps of Engineers, Animal and Plant Health Inspection Service, and the Department of State. Eight ex-officio members were appointed by the co-chairs to represent non-Federal governmental entities.

Despite funding levels below what is authorized in the Act, the Task Force has made significant progress towards the prevention and control of non-indigenous species introductions. In May 1993, federal regulations were enacted to prevent continued ballast introductions in the Great Lakes from trans-oceanic shipping. Ships destined for U.S. ports entering the Great Lakes from outside the Exclusive Economic Zone (EEZ) (200 mile limit) are required to exchange their ballast on the high seas prior to entering the EEZ. Also, as of December 30, 1994, ships entering the Hudson River north of the George Washington Bridge from outside the EEZ are subject to these ballast water regulations as well. Recognizing the significance of the safety risks associated with ballast exchange on the high seas and the potential for incomplete ballast exchange (unpumpable water and sediments), the Task Force supports investigations regarding other ballast water control alternatives.

The Task Force is coordinating Biological Studies in the San Francisco Bay, Chesapeake Bay, and Florida to determine the threat that aquatic nuisance species pose to the ecological characteristics and economic uses of these waters. Both the San Francisco Bay and the Florida studies are near completion. The Chesapeake Bay study was recently initiated. These areas were selected based on their vulnerability to potential introductions of aquatic nuisance species.

The Act mandated the Task Force to develop and implement a national program for U.S. waters to: prevent the introduction and dispersal of aquatic nuisance species; monitor, control, and study these species; and, disseminate related information. In fulfillment of this charge, the *Aquatic Nuisance Species Program* identifies goals, priorities, and approaches for aquatic nuisance species activities conducted or funded by the federal government; describes specific prevention, detection and monitoring, control, research, education, and other activities; and ensures coordination with other governmental and non-governmental organizations.

In March 1994, the Task Force completed a report to Congress titled *Findings, Conclusions, and Recommendations of the Intentional Introductions Policy Review (Review).* The *Review* was conducted by the Task Force in cooperation with other regional, state, and local agencies and industries to identify and evaluate approaches to reduce the risk of adverse consequences associated with intentional introductions.

In July 1994, the Task Force completed a research protocol, titled *A Protocol for Evaluating Research Proposals Concerning Nonindigenous Aquatic Nuisance Species*. This activity was undertaken to ensure that research activities funded in whole or in part by the Act do not result in further introductions or dispersal of such species. Although only projects funded by the Act must comply with the protocols, the Task Force encourages other agencies funding or conducting research to comply as well.

The development of State aquatic nuisance species management plans is encouraged by the Act, through the authorization of State grants for the implementation of such plans. The Governor of each state may submit a comprehensive management plan and a public facility management plan to the Task Force for approval and funding. As defined in the Act, comprehensive management plans identify activities within the state for which technical and financial assistance is needed to eliminate or reduce the environmental, public health, and safety risks associated with aquatic nuisance species. Public facility management plans are limited solely to identifying public facilities within the state for which such assistance is needed to reduce infestations of zebra mussels. Any plan submitted must identify management strategies to minimize infestations of aquatic nuisance species, the need for federal activities and how these activities will be coordinated for prevention and control of targeted species, and a schedule for implementation and annual objectives.

A *Nonindigenous Aquatic Species Comprehensive Management Plan* was submitted to the Task Force by the state of New York and approved in March 1994. New York State has taken the lead in non-indigenous aquatic species issues, as the first state to submit a plan to the Task Force. Funding for implementation of recommended activities was allocated by the Task Force in 1995. It is expected that New York State's plan will serve as a prototype for other states as they progress towards completing and initiating their own States' plans.

REGIONAL RESPONSE

As exemplified by the State of New York's pro-active approach to the management of non-indigenous aquatic species, the Northeast Region (Region 5) of the U.S. Fish and Wildlife Service has established itself as a leader in education and coordination for the prevention and control of non-indigenous species introductions. Region 5 includes the states of Maine, New Hampshire, Vermont, New York, Massachusetts, Rhode Island, Connecticut, New Jersey, Pennsylvania, Maryland, Delaware, Virginia, West Virginia, and the District of Columbia. A non-indigenous species coordinator was designated to the Region in 1992 (stationed at the Lower Great Lakes Fishery Resources Office, Amherst, New York) to assist in carrying out the requirements of both the Nonindigenous Aquatic Nuisance Prevention and Control Act and the Great Lakes Fish and Wildlife Restoration Act of 1990, PL 101-646. In 1994, recognizing the national scope of this issue, the Service designated non-indigenous species coordinators in each region to facilitate communication within and between the regions regarding non-indigenous species issues and concerns.

In 1992, federal non-indigenous species activities within Region 5 were limited to issues targeting the zebra mussel, particularly emphasizing waters within the Great Lakes basin. The coordinator developed a *Zebra Mussel Program* providing guidelines to direct northeast regional zebra mussel activities. Program goals, developed in compliance with the Act, included coordinating and standardizing zebra mussel monitoring and response programs, providing technical assistance to areas vulnerable to zebra mussel infestation, and promoting education and early detection monitoring.

Accomplishments that year included the development and distribution of zebra mussel monitoring guidelines, standard reporting sheets, and sampling equipment to a number of monitors in high risk areas. Confirmed sightings were and continue to be coordinated with the National Biological Service's Southeastern Biological Science Center, Gainesville, Florida, using Geographic Information System mapping and database. A Zebra Mussel Reference Collection was also initiated in cooperation with the Academy of Natural Sciences in Philadelphia, Pennsylvania to document and maintain physical records of the zebra mussel spread.

By 1993, the need to expand activities beyond zebra mussels and the Great Lakes was evident. Previous activities were used as a foundation to develop the newly named *Exotic Species Program (Program)*. The *Program* is consistent with the mandates of the Act as well as the goals of the national *Aquatic Nuisance Species Program*, including monitoring, research, education, technical assistance and coordination to prevent and control the introduction and dispersal of non-indigenous aquatic species that are or may become nuisance species. Effective monitoring programs foster early detection of non-indigenous species introductions and range expansions, evaluation of control strategies already implemented, and the determination of impacts on indigenous populations through the collection of baseline data. Research is a critical factor contributing to the development of effective prevention strategies and control technology. Education is one of the most effective weapons against future introductions and range expansions of aquatic nuisance species. It is anticipated that through effective education, society will make informed decisions, fully understanding the consequences, good or bad, of any decision. The expanding scope of non-indigenous species issues and concerns has emphasized the need for and importance of effective coordination and technical assistance. Efficient and accurate information exchange between resource agencies, researchers, private and public organizations is necessary to avoid duplication of effort and promote an effective and cohesive approach to prevention and control.

Since the *Program* was expanded, a number of new activities have been initiated and new approaches have been explored. To review all of these activities would be discursive, however, the invasion of the ruffe, a small Eurasian percid fish, into the Great Lakes and the activities that followed its recognition as a threat to the fishery resources provide an example of how the federal government responded and the *Program* can be implemented.

The ruffe, (*Gymnocephalus cernuus*), is believed to have been introduced into the Duluth/ Superior Harbor in western Lake Superior in the early 1980's, most likely through ballast water discharged from trans-oceanic shipping. Since it was first identified by the Wisconsin Department of Natural Resources in 1987, populations have increased sharply and their distribution has spread along the southwestern shoreline of Lake Superior (Pratt *et al.* 1992). In 1994, surveys revealed the greatest annual range expansion observed so far, with ruffe being found in the Ontonagon River, Michigan, approximately 180 shoreline miles from its origin in Duluth, Minnesota (T. Busiahn, pers. comm.). Population investigations conducted in Duluth, Minnesota since 1989 have shown increases in ruffe populations and declines in native species such as yellow perch, spottail shiners, emerald shiners, and trout-perch (Selgeby 1994). Notably, since 1993, ruffe have been more abundant in trawl surveys conducted in Duluth, Minnesota than all other species combined. This trend of increasing abundance and dominance of ruffe in the fishery community appears to be occurring in other areas of Lake Superior recently colonized (T. Busiahn, pers. comm.).

In April 1992, the Task Force declared the ruffe an aquatic nuisance species, as defined by law, warranting control. A Ruffe Control Committee was subsequently formed to develop, coordinate, and oversee implementation of a ruffe control program minimizing the risk of harm to the environment and the public health and welfare. By August, 1993 a draft *Ruffe Control Plan (Plan)* was developed. In 1994, as required by the Act, economic and ecological assessments were prepared examining implementation of *Plan* strategies and various alternatives. The overall goal of the *Plan* is to prevent or delay the spread of ruffe through the Great Lakes and inland waters by containing the species to western Lake Superior. The major components of the *Plan* include range reduction through chemical treatment, ballast water management, population investigations, surveillance, predator evaluation, and education. The proposed *Plan* is available for public comment. After the 60 day comment period ends in March 1995, the Ruffe Control Committee will address all comments and submit the *Plan* to the Task Force for approval.

If ruffe continue to spread naturally at the rate observed in 1994, colonization throughout the Great Lakes would be expected in the next ten to fifteen years. Of the five Great Lakes, Lake Erie has been identified as having the most appropriate habitat available for ruffe colonization based on the thermal requirements of ruffe. The thermal habitat utilized by ruffe is approximately the same as that used by walleye and yellow perch. This characteristic allows managers to estimate the amount of thermal habitat available for ruffe based on estimates determined for walleye and yellow perch. Of the estimated total 6.6 million hectares (16.3 million acres) suitable for walleye in the Great Lakes, approximately 58% , or 3.8 million hectares (9.5 million acres) is in Lake Erie (Edsall *et al.* 1993). The introduction of ruffe into Lake Erie potentially threatens indigenous species such as yellow perch (a recreationally and commercially important harvest species), as well as other forage species important to indigenous predator species. However, like the zebra mussel, the threat of the ruffe is not limited to the Great Lakes. Connected waterways, bait-bucket transfer, recreational and commercial boating, inter- and intra-lake ballast exchange expand the threat to most of the inland waters of the U.S. and parts of Canada.

In response to this threat, under the umbrella of the *Exotic Species Program*, Region 5 initiated a *Lower Great Lakes Ruffe Monitoring Program (LGLRMP)* in 1993 to provide the earliest possible warning of ruffe presence in the lower Great Lakes, securing the opportunity for appropriate management actions, where possible. The two main components of the *LGLRMP* include direct monitoring through field surveys and public monitoring and prevention through education. Consistent with the proposed *Ruffe Control Plan*, the survey targets sites likely to be colonized by newly established ruffe populations transported through inter-lake shipping. In 1993, four sites on Lake Erie, including Ashtabula and Conneaut, Ohio, Erie, Pennsylvania, and Buffalo, New York, and one on Lake Ontario, Rochester, New York were surveyed. In 1994, the *LGLRMP* survey was broadened to include three additional sites on Lake Erie, at Toledo, Sandusky, and Cleveland, Ohio. To date no ruffe have been found in the lower Great Lakes, however, samples collected in 1994 are still being analyzed.

In an effort to strengthen our monitoring capabilities and minimize the risk of introduction to the lower lakes and inland waters through bait-bucket transfer and boating, the education component of the *LGLRMP* focuses on increasing public awareness of the presence, distribution, and identification of ruffe, as well as appropriate action in the event that a potential candidate is caught. A ruffe identification poster, entitled, "WANTED: Dead or Alive" was developed and distributed throughout the lower lakes to resource agencies, public and private organizations, public access areas, marinas, and bait and tackle shops. Assistance was provided to the Minnesota Sea Grant Extension Program to develop and distribute a wallet-sized ruffe identification card, "Ruffe Watch".

Presentations, workshops, and news releases provide opportunities to reach special interest groups as well as a broader audience. Most recently, public meetings were held to announce the availability of the *Ruffe Control Plan* for public comment. Three meetings were held in the Great Lakes basin to provide an opportunity to present the *Plan* to the public, as well as for the public to verbally express their concerns and opinions. One of these meetings was held in Buffalo, New York, coordinated through the *Exotic Species Program*, so that the concerns of the lower lakes would be recorded.

Activities within the lower lakes basin addressing the introduction of ruffe into the Great Lakes provide an apt example of how the *Exotic Species Program* of the Northeast region can be and has been implemented to prevent further spread of a targeted aquatic nuisance species. As the regional *Program* evolves with the growing scope of this issue and priorities are assigned, the main components of the *Program* should remain consistent. Monitoring, research, education, technical assistance, and coordination have been, and will continue to be, the basic strategies used to prevent and control the introduction and dispersal of non-indigenous aquatic species in the Northeast Region of the U.S. Fish and Wildlife Service.

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Development and Implementation of a Regional Policy on Non-indigenous Aquatic Species for the Chesapeake Basin

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ABSTRACT

The discovery of zebra mussel veligers in the upper Susquehanna River, the major tributary to Chesapeake Bay, the increased use of triploid grass carp in some states of the Chesapeake basin and the initiation of *in situ* experiments with the non-indigenous oyster *Crassostrea gigas* were major factors stimulating the development of a basin-wide policy for prevention and control of non-indigenous aquatic species. We present the policy developed by the Exotic Species Workgroup of the Chesapeake Bay Programs' Living Resources Subcommittee in response to the potential environmental threat posed by non-indigenous aquatic species. Workgroup members include scientists, policy staff, and resource managers from the Chesapeake Bay Program jurisdictions (Maryland, Pennsylvania, Virginia and the District of Columbia) with representation from the non-signatory basin states (Delaware, New York and West Virginia).

The "Chesapeake Bay Policy for the Introduction of Non-Indigenous Aquatic Species" was approved by the policy advisors to the Jurisdictional leaders and forwarded to the Jurisdictions for signature on 2 December 1993. This regional policy was adopted and is now being used as a guide for intentional and unintentional introductions. With the recent signatures of the Governors of Delaware, and West Virginia, and the anticipated adoption by New York, the policy covers all of the Chesapeake basin.

This policy includes three important provisions. First, species approved by individual jurisdictions at the time of adoption for aquaculture or stocking are "grandfathered" by the policy

and their introduction can continue as part of jurisdictional fisheries management. Other species will be considered "first-time" introductions; specifically, first-time introductions include: a) species that are non-indigenous and not naturalized, b) species that a jurisdiction has not previously permitted or c) "changes in scope" that include changes in stocking rates and locations, or culture methods for previously approved species that might significantly increase risk of escapement. A second provision requires that applications for first-time introductions into a jurisdiction will be submitted to multi-jurisdictional review by an *ad hoc* Technical Review Panel. Third, all jurisdictions agreed to participate in development of an Implementation Plan expected to be completed by the Exotic Species Workgroup by 1 April 1995 that specifies protocols for introduction by different pathways (aquaculture, fisheries management, biological controls, research and ballast water discharge) prevention, education and control.

INTRODUCTION

The recent Report of the Office of Technology Assessment "Harmful Non-Indigenous Species in the United States" observes that conflicts arise between States regarding introduction of Non-indigenous aquatic species because of "differing ecological, economic and policy contexts". The decision of an individual jurisdiction to permit introduction of a non-indigenous aquatic species may represent a carefully considered balance between economic goals and environmental protection. However, in a watershed shared by a number of jurisdictions the environmental risks apply to all, while the economic benefit may not. Therefore, the most compelling reason to work toward the development of Regional Policy for aquatic introductions is that watersheds are defined by geographic and ecological boundaries not jurisdictional lines. Although individual jurisdictions are likely to agree that policy mechanisms to reduce conflict are desirable, their success is entirely dependant on voluntary support and a spirit of compromise.

A regional approach to the issue of non-indigenous aquatic species in the Chesapeake had been addressed as follows by the Chesapeake Bay Commission: "It is the Policy of the Chesapeake Bay Commission to oppose the introduction of non-native species into the Chesapeake Bay watershed for any reason unless comprehensive environmental and economic impact studies are conducted and thoroughly evaluated in order to ensure that risks associated with the introduction are minimized". Although the Chesapeake Bay Commission provided a strong and clear position, the need for more comprehensive policy development was emphasized by several decisions to allow introductions that conflicted with other jurisdictions. For example, in 1992 Virginia approved an experimental introduction of the Japanese oyster *Crassostrea gigas* to evaluate resistance to the oyster diseases MSX and Dermo. These diseases were responsible, in part, for the decline of the native oyster *Crassostrea virginica*. Maryland resisted the introduction over concern that the Japanese oyster might compete effectively against the native *C. virginica* if reproduction occurred. Conflict arose again when the Pennsylvania Fish and Boat Commission approved the introduction of triploid grass carp beginning in 1994. With this decision, Maryland became the only state in the Chesapeake basin that did not permit the use of triploid grass carp to control aquatic vegetation . Maryland's concern was that grass carp could be released and damage the beds of submerged aquatic vegetation that were in recovery after years of effort to restore the resource in decline since the 1970's.

Decisions in favor of intentional introduction of the Japanese oyster and grass carp led to divisiveness among jurisdictions. However, the threat of zebra mussels, an unintentional introduction into the Great Lakes from ballast water discharge, created an atmosphere of common concern that contributed to the successful development of the policy.

Nationwide, most of the responsibility for the regulation of introduced species lies with the states. The role of the Federal government has been to support states when regulations have been violated through the Lacey Act and its Amendments of 1981. The emphasis in the Lacey Act is to support states in the prevention of intentional introductions. Further Federal support was the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, a proactive measure to reduce the risks of unintentional introductions primarily in response to the zebra mussel invasion of the Great Lakes. The desire on the part of states to assume the lead role in regulating the introduction of non-indigenous aquatic species is evident in the fact that most states have adopted regulations to control introductions (Palmer 1991). However, there is considerable variability in enforcement and management among the states (Hocutt 1984). For example, Palmer (1991) developed regulatory scores to rank states according to how conservative and comprehensive their management programs for aquatic nonindigenous species were. Factors considered included the use of species lists (approved or disapproved), permit requirements for importation, aquaculture and fish stocking in public or private waters. High scores represent the most conservative approach. Nationwide the scores ranged from 8.50 for Montana to 0.50 for New Jersey. In the Chesapeake basin (which includes Delaware, Maryland, New York, Pennsylvania, Virginia , West Virginia and Washington, D.C.), scores ranged from 5.67 for Maryland to 1.41 for Delaware. The variability in ranking of states that share the same watershed further underscores the need for regional policy development.

The most effective regional policy should be a product from the crucible of discussion of policies and management approaches of the concerned jurisdictions. Models have been developed for evaluation of a non-indigenous species for introduction to serve as guides for state resource managers. An early set of "minimal" steps were suggested by Courtenay and Robins (1973) that included justification of the need for an introduction, an evaluation of candidate species, assessment of risk/benefit and an opportunity for public review. These guidelines were adopted by the American Fisheries Society in 1972 and revised recently (Kohler and Courtenay, 1986). Recently a model State code for evaluation of proposals for introduction of aquatic non-indigenous species was published by the Aquatic Nuisance Species Task Force (1994).

The following is a summary of the "Chesapeake Bay Policy for the Introduction of Non-Indigenous Aquatic Species". The goals of the Policy were to: a) provide objective technical reviews of proposed non-indigenous aquatic species to the permitting decision-makers, before an introduction, to identify potential nuisance species, b) create a mechanism for sharing information among the Bay jurisdictions regarding species being considered by other Bay jurisdictions, and c) not unduly lengthen or burden the exiting permitting processes within the signatory states.

A case study that successfully tested the efficacy of the policy review process in regional decision making.

THE POLICY

Exotic Species Workgroup

In early 1992, the Living Resources Subcommittee of the Chesapeake Bay Program established the Exotic Species Workgroup. The mission of this workgroup is to coordinate regional information and develop a strategy for dealing with the introduction of non-indigenous aquatic species into the Chesapeake Bay basin. A major goal of the Exotic Species Workgroup is to ensure that the activities of state and federal signatories to the 1987 Chesapeake Bay Agreement and other Bay basin states are directed towards the prudent control of non-indigenous species introductions. This goal is consistent with the goal of the 1987 Chesapeake Bay Agreement: "provide for the restoration and protection of the living resources, their habitats and ecological relationships".

Scope of the Policy

For the purpose of the policy, "introductions" refers to a first-time introduction of a non-indigenous, non-naturalized aquatic species. A first-time introduction occurs when such a species is intentionally or unintentionally moved by human activities to a geographic region where it did not previously exist. Introductions do not include natural migrations, range extensions or supplemental stocking and restoration programs. An introduction may be considered "first time" if : 1) the species is not indigenous or naturalized, 2) the jurisdiction has not previously promulgated rules, regulations or otherwise issued a permit allowing the introduction of that aquatic species into an unconfined system.

The key feature of the policy is to provide a framework for making decisions about the **intentional introduction** of non-indigenous aquatic species. Signatories to the policy have agreed that all intentional introductions of non-indigenous aquatic species, defined in accordance with the federal guidelines, into any aquatic environment of the Chesapeake Bay and associated tributaries will be submitted for review and approval by the appropriate agency(ies) of the jurisdiction and an *ad hoc* review panel prior to the introduction taking place. The process of approval of the introduction, and information-sharing between managers and technical personnel is shown in Figure 1.

Furthermore, signatory jurisdictions agreed to reduce the risk of introducing undesirable organisms **unintentionally** by use of the following guidelines:

* Educate their citizens on preventive measures, identification of non-indigenous species, and the proper use of control measures.

* Develop regulations to eliminate or drastically reduce the dangers associated with ballast water discharge.

* Develop and implement monitoring programs which include participation by the public.

* Develop control measures acceptable to all jurisdictions in the Bay watershed.

- To notify jurisdictions, via the Exotic Species Workgroup, of any organisms, dispersal, or practices that present risk.

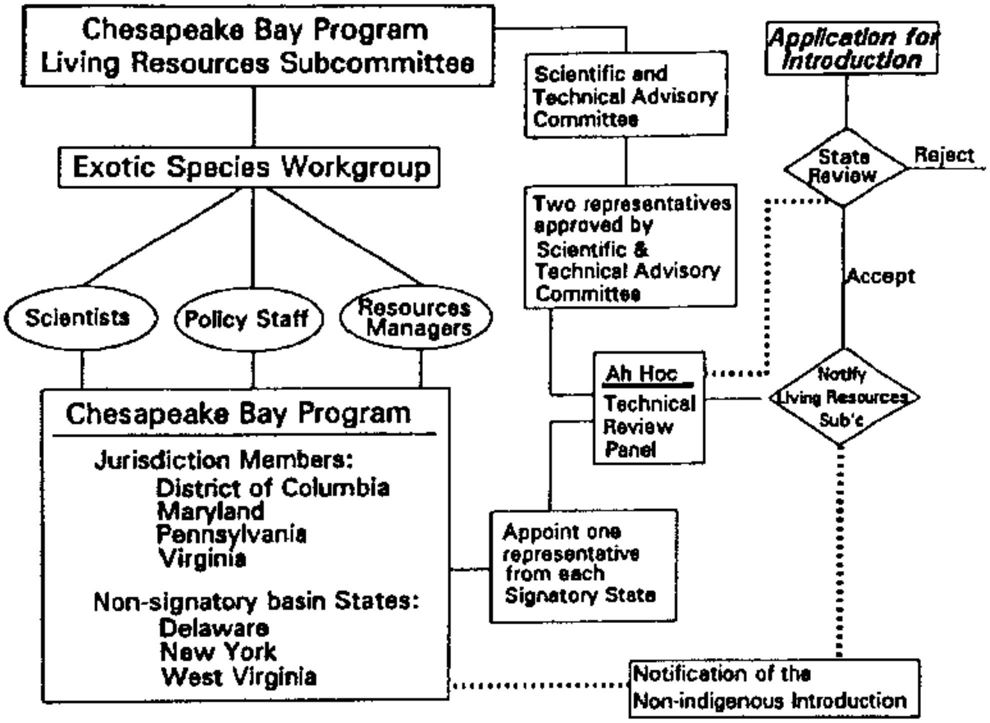

Figure 1. *Flow chart illustrating the Ad Hoc Technical Review Process. Dashed lines indicate procedure following technical review.*

IMPLEMENTATION OF THE POLICY

An implementation plan that establishes time lines and assigns tasks associated with the policy is nearly completed. The implementation plan contains procedures for: 1) listing approved species for aquaculture, 2) listing and assessing risks of activities involving transport of species through and within the Chesapeake basin and recommendations for reducing risks associated with transport activities, 3) listing and assessing risks associated with research activities and recommendations for lowering risks associated with research, 4) incorporating monitoring activities for aquatic nuisance species within existing monitoring programs, 5) facilitating communication among the jurisdictions concerning species of concern including monitoring and control methods, and 6) increasing educational effort and enhancing current activities through the creation of an education coordinator to serve the Chesapeake basin.

GRASS CARP AND LAKE ANNA, VIRGINIA: TESTING THE *AD HOC* PROCESS

The first *ad hoc* panel convened on 29 April 1994 to consider a proposal submitted by Virginia Power to stock 6300 triploid grass carp in the *Hydrilla* infested cooling lagoons of Virginia Power at Lake Anna. The panel was chaired by Dr. Carl Sinderman with the assistance of Fred Kern. Maryland, Pennsylvania, Virginia and Washington, D.C. were represented in the process by A. Heft, A. Shiels, J. Kaufmann and J. Siemien, respectively. Additional technical expertise was provided by Dr. P. Jacobsen (modeling and risk assessment), R. Ivarie (USFWS grass carp certification procedure), and Dr. C. Kohler (review and decision model).

Critical areas of concern were risks of reproduction, migration through saline waters to other parts of the Chesapeake basin, and ecosystem impacts. Although triploid grass carp have been used for aquatic weed management in Virginia impoundments since 1984, the proposed stocking of 6300 was an increased stocking rate and therefore was considered a "change-in-scope" as defined in the policy. The panel procedure included extensive discussion of the proposal, its merits and concerns, followed by application of the decision-making model of Kohler and Stanley (1984). The model results demonstrated that benefits outweighed risks and the panel concluded there was "no overriding reason to advise against" the proposal. This conclusion was based on a) the agreement of USFWS to certify triploidy for each of the 6300 fish rather than a sample as in their normal procedure b) monitoring would be employed to evaluate post introduction movements and c) this stocking represented a single event.

SUMMARY

A policy to address regional concerns about the introduction of non-indigenous aquatic species was developed by the signatory states of the Chesapeake Bay Program and adopted in December 1993. Non-signatory states within the Chesapeake basin have become signatories (Delaware, West Virginia) and with adoption by New York, the entire Chesapeake basin will be represented. A critical feature of the policy, the agreement to submit "first time" introductions or changes in practice to an interjurisdictional *ad hoc* technical review, was tested in response to a proposal by Virginia Power to stock 6300 triploid grass carp in a cooling lagoon at Lake Anna, Virginia. The results of the panel deliberations demonstrate that potentially divisive proposals for introduction can be resolved on a regional basis.

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The Exotic Pest Plant Council: Dealing with Biological Pollution

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Native species are losing ground (literally) in the natural areas of the United States. When species with narrow ecological requirements are out-competed by invasive exotic plants, the effect is perhaps as destructive as bulldozing and paving. Within the "developed" areas, invasive exotic plants are also a costly problem; over one million acres in Florida are infested with Brazilian pepper, now out-pacing Melaleuca in its spread. Millions are spent controlling trees within private and public lands and along road, canal, and powerline easements. Over $100 million per year is spent annually on aquatic weeds alone in the United States. There are risks associated with these vast stands of invasive exotics as well, including fire hazards (as with the Eucalyptus trees in the Berkeley, California fires), public health hazards (respiratory difficulties caused by Melaleuca), and public safety hazards (Australian pine falling across roads during Hurricane Andrew). There is now an increased awareness and organized approach toward identification, control, and prevention of this serious environmental problem.

The Exotic Pest Plant Council (EPPC), founded in Florida in 1984, has become a national, non-profit organization that addresses the causes of "biological pollution". It grew from the need for communication on effective means of control and management of the approximate 925 pest-plants then in Florida. Besides the Sunshine State, chapters have been formed in California, the Pacific Northwest (encompassing Oregon and Washington), and Tennessee. Members include federal, state, and local businesses, and individuals with a concern for the nation's fragile, native ecosystems.

The purpose of the Exotic Pest Plant Council is to:

1) educate the public about the problem associated with invasive exotic plants;
2) secure funding for the development of integrated management strategies that will lead to long-term management of current invasive exotic plants; and
3) develop other methods to prevent the spread of invasive exotic plants throughout the United States.

Why has it taken so long to recognize the problem? The answer to this question is partly an answer to the origin of these plants. Human migration has always included the movement of plants useful to people, and the advent of new transportation methods simply allowed more movement of more species, in larger quantities, across greater distances, and with some unexpected hitchhikers. Intentional introductions include most of our food staples, but these plants are often very exacting in their needs, having been selected over time for traits which are useful to the farmer, but harmful to the species' competitiveness. Few if any of these plants ever become pests.

In contrast, forage grasses, fast-growing crop trees, and newly-introduced ornamental plants are often little modified from their typical wild species, and have characteristics which should ring an ecological alarm bell. There is a profile of the invasive exotic plant which is beginning to appear as more species show their aggressive tendencies.

The following questions should be used to screen out species with a combination of dangerous traits:

1) Is the plant adaptable to a wide range of soil, temperature, and moisture conditions? Is it tolerant of fire?
2) What is the reproductive manner of the plant? Does it exhibit rapid growth, early flowering and fruiting? Does it produce large numbers of lightweight seeds or brightly colored fruits? Do the fruits contain large numbers of viable seeds?
3) Does the plant re-sprout with ease when it is cut or injured, and does it propagate readily from cuttings, root pieces, or tubers?
4) Is the plant far from its original home and therefore far from the predators (diseases, invertebrates, etc.) that co-evolved with, and kept the plant in check?

The behavior of exotic plants in a manicured landscape is not indicative of the danger and judgements on the "escape potential" of plants in such situations are meaningless. In fact many invasive exotic plants have come to light only because of the observations of botanists, land managers, and others involved in direct contact with uncultivated lands which are assumed to suffer minimum human disturbance. When dense thickets of non-native species are found in wilderness areas, it's disappointing. When seedlings are found of that same plan spreading in all directions from the source plants, it becomes a greater concern. Finally, wher after freeze and fire, the non-native plant seems to dominate a site where there once was a wide diversity of native species, both animal and plant, the phrase "biological desert" strikes home.

Today, there are numerous invasive exotic plants that are present in New England, an are causing serious environmental damage: *Lythrum salicaria* (Purple loosestrife), *Trapa natans* (Water chestnut), and *Myriophyllum spicatum* (Eurasian watermilfoil) are a few that have been recognized as nuisances. According to a 1993 report entitled "Harmful Non-Indigenous Species in the United States" prepared by the U.S. Congress, Office of Technology Assessment, New England has approximately 821 non-indigenous plants (29%).

Already, agencies like the Vermont Department of Environmental Conservation (VTDEC), while grossly under-funded, have been active in the management of several of these species, as well as research associated with biological control organisms. A substantial effort by the VTDEC staff has been made to identify other potential invasive plants of the region as well; for instance, Hydrilla *(Hydrilla verticillata)* has already been recognized as having great potential for becoming an ecological nightmare to the New England area.

The concern over invasive exotic plants has truly become national in scope, and to address that concern, members from the various pest plant councils recently met to discuss the formation of the National Association of Exotic Pest Plant Councils (NAEPPC). This organization will facilitate coordination between the councils on issues national in scope. Ms. Faith Campbell, formerly of the National Resources Defense Council, has agreed to represent the national organization in Washington D.C.

I encourage the New England area to strongly consider the establishment of a regional exotic pest plant chapter. In view of the regional scope of exotic pest plants in New England's natural areas, I feel that the formation of this chapter is a logical step to address the issues in this area. On behalf of the Florida EPPC and our Washington, D.C. support, I offer my services and encourage you to join us.

Power of the People to Advance Solutions: COLAM's struggle to control Eurasian Watermilfoil

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Eurasian Watermilfoil is an aggressive, noxious, aquatic weed that is alien to North America. It robs lake users of recreational and scenic enjoyment of their lakes. It displaces wildlife by destroying natural habitats. It destroys entire lake ecosystems. It pushes property values downward until lake-side homes are virtually unsalable. Because it has no natural predators powerful enough to keep it in check, milfoil raises havoc nearly everywhere it takes root, and this will continue unless someone can intervene to stop it.

Milfoil is no small problem in New York State -- a State with 7200 lakes and ponds. More than 42 of the State's 62 counties are now infested with Eurasian Watermilfoil.

The Coalition of Lakes Against Milfoil, COLAM, was founded in 1991 by a group of New York State residents, property owners, and lake association members. The very first goal of COLAM was to educate people about the problems associated with Eurasian Watermilfoil and possible controls to deal with these problems. Officials in New York State's government agencies thought of milfoil as a localized problem. Because of this misconception, they saw no need for a coordinated state-wide program to deal with the milfoil issue, and because of this lack of leadership, a major stumbling block was presented to anyone interested in trying to stop the milfoil infestation.

COLAM began as a regional association and quickly grew to a state-wide organization. Citizens and lake associations came into COLAM because they were frustrated with their own efforts to deal with the milfoil problem. There was a lack of information on this aquatic weed. There was no place to turn to get information on permitting requirements, and there was no funding available to help deal with this problem. People were tired of hearing that cleaning up their own septic systems and controlling runoff would effectively solve the milfoil problem. While sound environmental advice, these measures alone would not control the invasion of milfoil in their lakes. And because of the lack of knowledge about Eurasian Watermilfoil, even the New York State Department of Environmental Conservation experts had difficulty correctly identifying

Lake George had been in the news a lot because of their milfoil problem. So, it seemed that the Lake George Association was the logical place to begin. After the initial set-up meeting, held at the Lake George Association office, goals were set, officials elected, committees formed, and the process of educating ourselves and the public about milfoil began. Members of COLAM agreed that we needed a coordinated plan. Our main goal was to develop and institute a state-wide aquatic plant management program to deal with the problem of milfoil in our lakes. The state-wide program was to address three issues: 1) simplifying the permitting process, 2) registering adequate and modern control techniques, 3) obtaining State funding.

By organizing COLAM as a state-wide organization, we were able to draw on the special skills and expertise of persons from a much larger area. The abilities of those individuals and their desire to work together as a team has made COLAM what it is today. As an organized group, COLAM has had positive effects. It now has a voice in State policy and future State programs, and it has moved forward toward solutions to the milfoil problem.

But, in the beginning, members of COLAM needed to get the facts about Eurasian Watermilfoil. How wide spread was the problem? Was it localized, as the DEC had indicated? What, in fact, is milfoil? How does it effect our lakes, the ecosystem, the economy and property values, human safety? What kinds of techniques were available nation-wide or within New York State to effectively control milfoil? What had other States done about their milfoil infestations? How much was it going to cost to control milfoil, and how much money was being spent in legislative grants and local programs on this problem? After several months of asking questions, reading the literature and talking to the experts, a Facts Sheet was compiled. With the addition of a map from the RPI Freshwater Institute and COLAM's recommendations to the State, we had our documented facts and an effective educational booklet.

After this, a questionnaire was prepared and sent out to lake associations throughout New York State. This was done to help us better understand the problems milfoil was causing. Results from this survey helped us better pinpoint the areas and degrees of infestation. We also gained knowledge on techniques used to help control milfoil growth, successes and failures in acquiring funding, and the degree of public awareness about milfoil.

The next step was to educate the lake associations, government officials and legislators. Posters and pamphlets were designed and distributed. COLAM regards education as the most cost effective means available to control the spread of Eurasian Watermilfoil and other non-indigenous aquatic species in our lakes and ponds.

In the Spring of 1992, with the Facts Sheet and gathered information in hand, a grass roots lobbying effort was started. To further emphasize the need for a state-wide exotics aquatic program, meetings were arranged with the State Senate and the Assembly's Environmental Committee members. COLAM also promoted the need for the registration of the chemical herbicide Fluridone or SONAR as a modern, safe, cost effective and practical technique for milfoil control. In August of 1992, public hearings on the change of rules and regulations for pesticide use in New York State were held. SONAR was a major topic at these hearings.

In 1993 COLAM's membership doubled and so did the move forward to develop a statewide program for the control of milfoil. This increased interest and support gave us the opportunity to organize a two-day conference for anyone interested in the management of milfoil.

This conference, entitled "Milfoil Management in Northeastern Lakes," marked a milestone for COLAM. It was a milestone because it made very real and tangible the goals and objectives that COLAM had worked so hard for. The purposes of the conference were twofold.

First, the conference was for the educational benefit of everyone concerned about the management of Eurasian Watermilfoil in their lakes. Speakers in the program talked about what milfoil is and what it can do to a lake, and they also discussed proven milfoil management strategies and currently available and future techniques for managing milfoil. That is, people talked of legitimate solutions to the milfoil problem. The educational aspects and the dissemination of information is a major goal of COLAM, and this was achieved at this conference.

The second purpose of the conference was the establishment of a community. The conference was designed to promote interaction between riparian property owners and lake business owners, recreational lake users, state regulators, professional lake managers, weed control specialists, and industry. The forming of a community that had come together to share information on the common issue of Eurasian Watermilfoil was the most important aspect of this conference, and the most substantial element in COLAM's desires to effectively make solutions for this problem. Only by developing public awareness and public concern can we achieve the goal of milfoil control in our lakes. This conference gave a place and a time and a reason for this community to come together. This was a very important event in COLAM's history and growth.

The participants at the conference were crucial to the development of the community. For instance, there was Dr. Douglas Pullman, president of A-Quest Corporation, aquatic and wetlands vegetation management consultants. Dr. Pullman was instrumental in creating and organizing this conference. He seems to know everybody in and everything about the management of lakes, and he is a leading expert on milfoil and its management. Dr. Pullman gave the opening lecture on milfoil and its impacts on our lakes. He also led the "Aquatic Vegetation Workshop." He also moderated the "open forum" at the end of the conference. There was also Dr. John Troth, an aquatic biologist for DowElanco, Technical Services. Dr. Troth is heading the development and promotion of a new aquatic herbicide, Triclopyr or GARLAN 3A. He spoke of the great potential this herbicide could have for the management of milfoil in the future. And Gary Johnson, a DowElanco information specialist, is perhaps the world's leading authority on Fluridone or the herbicide SONAR. These scientist and industry persons were essential information givers at this conference. They are the network to the scientific and technological world that is necessary for information about aquatic vegetation and it's control.

There are other groups that are also essential to this community. For this conference, we invited members of the New York State Department of Environmental Conservation and also members of departments of environmental conservation from the States of Vermont, Connecticut, and Massachusetts. These are the State regulators that lake managers and aquatic vegetation control specialists have to go through to get permits and find out information on State policies and restrictions. This is an important group to include in the community because there has to be constructive communications between private riparian land owners and residents, with their desires to create and maintain a useful and aesthetic lake environment, and the government regulators, whose job it is to oversee and regulate private citizens' uses of water resources. These are the government overseers of our total environment, and they do this for our long-term good. Often, however, there is animosity between these groups. There is often frustration and anger because the goals of these groups do not fit together exactly. Some of these frustrations came out during the conference. But more importantly, the conference gave a forum to discuss these issues and talk about differing perspectives. Only by talking out differences can headway be made. This conference allowed for these types of meaningful, although sometimes tense, dialogues.

Perhaps the most important participants in this conference were the private citizens who came forward to share stories of their successes and failures with the milfoil problems. For instance, there is Pat Wulff. Pat is a retired nurse who lives on a lake in Minnesota. In 1988, she started reading articles in the newspapers about this stuff -- this Eurasian Watermilfoil and what it can do to lake property values and the environment. She got concerned and took action to fight to control this noxious weed that was infesting all of the lakes. She said at one point, "We have got to stop this. I have to talk to the Governor" (conference proceedings, COLAM Sept. 21 1993). Well, she did, and she talked to just about everyone else too. She rallied together individuals from lakes all over Minnesota; she talked to persons in the government at the local, state and federal levels; she made things happen. Because of Pat's efforts, the State of Minnesota passed laws to make it illegal to transport milfoil on boats and trailers. This was the first of its kind. Pat was also instrumental in forming and heading a state-wide "Exotics Committee" -- a politically active group composed of private citizens and State government representatives. This committee entered the political arena and put pressure on the State government for their cause. They actually got funding from the State, in 1993 one million dollars worth, to establish and maintain an "Exotic Species Program." This program funds and deals directly with aquatic vegetation problems such as milfoil. This was a success story. And in this conference session, called "Citizens Initiatives," private citizens came forward and told stories of their actual dealings in trying to manage milfoil in their lakes. Not all of the stories were of success, but every one was an inspiration of what people working together could do. This session, more than any other, melded this conference together and gave hope to the community.

The COLAM members worked many long hours to make this conference happen. This conference is a success story and an example of what people, working together, can accomplish.

In 1994 COLAM refined the proposed solution of a state-wide aquatics program. We worked together with State regulatory agencies and legislators to write a Bill for such a state-wide program. In this Bill we proposed to: 1) facilitate funding from the State for aquatic vegetation control projects to be designed and implemented locally or regionally, 2) simplify the permitting process for projects to control Eurasian Watermilfoil and other nuisance aquatic plants, 3) expedite approval of new control methods, especially those previously approved by the U.S. Environmental Protection Agency, including the herbicide Fluridone and biological mechanisms, and 4) establish COLAM as the clearinghouse for information on Eurasian Watermilfoil for lake users, property owners and lake associations, and as the source of information for lake managers, aquatic vegetation control experts, and as the contact for technical assistance from the New York State DEC.

Since our formation in 1991, COLAM has had many accomplishments and, unfortunately, many setbacks. Often, just as we were beginning to feel that we were making progress, unexpected things would surface and delay our progress. A good example of this is the battle we have had to get a modern control technique registered and useable in New York State. Specifically, the chemical herbicide SONAR. SONAR has been shown to work effectively to control milfoil in other States, and it is shown to have very limited effects on native aquatic plants, the fishery, and other living organisms in your lakes. It is a far less toxic herbicide than the others that are permitted currently for use in New York State. SONAR was finally registered in New York State in 1993, after much letter writing, calling and meeting with the DEC. However, use of the product was effectively stifled because of environmentalist rhetoric and imposed litigation. This obstacle was to be defeated by the writing of a generic environmental impact statement on SONAR and its effects on the environment. This long and intensive study was done for the State of New York by the then producer of SONAR, the DowElanco company. The process began Labor Day 1993 and only now, January 25, 1995, has the statement been finalized and published. The public, however, still awaits a "Statement of Findings" from the DEC that will effectively tell State regulators how to properly interpret this lengthy report. What is even more outrageous is that the basis of restriction information of this herbicide was taken from the outdated and no longer used Federal label. So, in effect, the herbicide can still not be used in the vast majority of New York's lakes because of an outdated and since overturned restriction on SONAR in potable water systems. As a result, ten years after the Lake George Association petitioned the State to register SONAR as a control for Eurasian Watermilfoil, there is still no practical registration technique available. Nevertheless, COLAM will keep working towards a reasonable solution to this standoff. We are working closely with the SePRO Corporation, the current producer of SONAR, to get the unreasonable restrictions amended by 1996.

Unfortunately, so much time and effort has been spent trying to get SONAR registered that COLAM has been perceived by many as a single-minded proponent of chemical controls. In fact, COLAM does not limit itself to this and we strongly hold that for every lake there will be different solutions, whether mechanical, biological, chemical or non-interference. We do, however, feel that access to all effective and safe controls should be available to citizens of New York State. COLAM has and will continue to educate themselves and others on future milfoil controls and solutions, especially the new possibilities of biological controls such as the milfoil weevil.

COLAM also continues to be involved in regional concerns over milfoil controls. The Adirondack Park Agency (APA) -- a State agency primarily responsible for managing development in the six million acres of public and private lands that make up the Adirondack Park -- has taken the stance that Eurasian Watermilfoil is a protected plant and therefore under their jurisdiction. This adds another complex layer of government regulations which has only resulted in more delays in any effort to control milfoil invasion. The permitting process within the Adirondack Park is so cumbersome that for a landowner to walk along her/his shoreline and pick (hand harvest) a single plant was illegal, without a permit which would have been so technical that it required assistance from an engineer. Through COLAM's efforts and education on the potential harmful effects of Eurasian Watermilfoil to the wetlands, a general aquatic plant hand harvest permit has been authorized, as of 1995, by the APA. However, the amount to which one is allowed to hand harvest their lakefront is dependent upon the water quality. In good water quality, up to 200 square feet can be harvested. In poor water quality, up to 800 square feet of shoreline may be harvested. This is somewhat ironic because milfoil is more invasive and grows faster in good, clear water than in poor. However, this permit is a start, and it is a sign of active communications between COLAM and State agencies.

There are many future goals for COLAM. We will continue to educate the public and government officials. The serious need for a state-wide aquatics program is at the top of the our agenda for this year, and we anticipate being able to work closely with DEC officials and other State agency personnel under the new administration of Governor George Pataki. We have also been asked to assist a lobbying effort in Washington D.C. to get Federal funding for control projects of non-indigenous aquatic species. And we will continue to be a clearinghouse for information and educational materials for lake associations, lake users, private citizens and government officials.

An important part of COLAM's success has been the people. Involved citizens and the organization of those citizens is crucial to any effective grass roots effort. The final section of this paper will describe the steps of COLAM's growth from a handful of interested persons to a well organized and active grass roots effort.

Many times we get caught up in our professional careers and daily lives and forget that we are all members of a society, and that we share many of the same concerns. Shared concerns are the focus of any coalition. In fact, a coalition is defined as, "a temporary alliance of factions,... brought together for some specific purpose" (Webster's New World Dictionary, D. Guralnik (ed.) 271:1976). There are steps to establishing and maintaining an effective coalition.

The first step is to call a meeting. There you will find out who the people are that care enough to work on the project. At that meeting make sure you define your idea of what the problem is. In our case, we were very interested in the milfoil problem. There were a number of lakes around Lake George by the late 1980's and early 1990's that had significant milfoil problem's. The weed started to show up on the surface of many lakes. In some places, property values had begun to drop, and this caught the attention of the business community. These factors developed a heightened awareness, and people were beginning to get worried about this weed.

In the beginning it is also important to find a central location for gathering. This is important because it is very likely that you are going to meet again. If you can start out with an accessible place to get together, it will encourage people to meet. Another part of having that meeting is to give people a chance to explain why they are there and to find out what their real goal is. Why did they get involved, and why are they worried about the milfoil at their lake? Milfoil is getting used as an example here, but you may have a totally different problem that you want to build a coalition around. A coalition could be formed around just about anything. We chose to focus on milfoil because we had seen so many other efforts fail. Some lake associations were trying to deal with too many problems at once. For instance, they had to deal with the control of septic systems and runoff problems, and poor fisheries, and they had to debate and decide about what horsepower for boats should be allowed. All kinds of things. So many things that the issue of milfoil could not be adequately addressed. So, we thought, "Let's start with milfoil. Solve that problem, and then move on to the next one." By focusing just on the milfoil problem we could concentrate on all of the issues that specifically dealt with milfoil and it's control.

Another step is to make sure that the meeting has some sort of structure. It only takes one person to develop that. For instance, give a certain amount of time for introducing each other and finding out who you are. Then somebody should get up and say, "O.K., let's move on. What is the specific problem at your lake? What is really keeping you from solving it?" It could have been that people came together because they were frustrated in dealing with our State government. For others, it could have been that they could not find any information about milfoil and what possible solutions were out there. There was no good source of information on milfoil in our State agencies or our counties. Others came together because they had gone through the process to try to make a solution and felt that they could not go it alone anymore. They wanted company and they wanted others to work with them to help them with their problem. From that, it led pretty easily into finding a goal wanted by everyone concerned. We held another meeting in a few weeks, and people traveled from one to one-and a half-hours to get there. They came from north and south of Lake George. The Lake George Association happens to have an office right off interstate 87. People can get right off the exit and get there easily. So, we decided to meet there regularly.

We refined the goal and decided that we wanted to start a state-wide milfoil control program in New York because we had nothing. It had a title on a piece of paper that gave all kinds of descriptions of things that you couldn't do without permits, but no program to solve the problem. Then we started to ask "What is that program going to be?" We have already alluded to the fact that we felt we needed to have some kind of information clearinghouse. We also needed to simplify the permitting structure so that we could do something besides watch this weed growing in our lakes. We also decided that we desperately needed funding. There was absolutely no funding except a few "pork-barrel" grants in the legislature, and those were very much limited to only a few lakes in the State. For the rest, even Lake George, there was no way to tap into that money. We wanted also to have some kind of access to technical expertise. We contacted research scientists who study the problem, and people who are actually in the business of solving the problems -- that is, aquatic plant managers and aquatic vegetation control specialists. In the beginning, we had no way to even find out who these people were in this country, much less in New York State. The State could not provide us with this very useful information.

We looked around and we defined what we were going to do. We had a room full of people, and we said, "Well Ralph, what will you do?" Ralph was a newspaper writer, and he said, "I can't go to the legislators without first putting together a facts sheet. I will do that if somebody will help me." Then we asked someone else, and she said, "We can't go to the legislators without at least getting meeting dates with them. I will set them up if several of you are willing to come to the meetings." We had another person who wanted to become a town supervisor. He knew the government systems reasonably well. He helped us learn how to interact with some of the local government officials to get them on our side so that when we went to the State we would have more influence. That was very important. We had a secretary who could type out our minutes or send out our meeting notices. And most of all we had our current president, Wendy Davis. Wendy sat there the first day and said, "I can't do anything. I am just a mother and a housewife." But, what would we have done without her? Wendy has just done everything. Whenever we asked her to do something she said, "Well, I really can't do that, but I will." And she did it well. Use the people you have. Develop their talents and encourage new talent.

The other thing that is really important is to keep up the momentum. There are many frustrations along the way, particularly when there are dealings with government agencies. You have to give yourself time to vent that frustration and move on. Just let it out and have your temper tantrum or whatever you need. Then say, "O.K., we all say this is a terrible problem - now what can we do about it." In letting people blow off a little steam, we are then often able to turn that energy into something positive.

All the while we kept on going back and refocusing, re-looking at our goals to see if we were still on target. Take each step along the way, and let them take as much time as they need to do it. That is basically all it is. Getting people together. Talking to people at cocktail parties, at your coffee breaks, at your school lunches, wherever you can get together. Find out if people are aware of the milfoil problem and whether they care enough to do something about it. Pretty soon, we had a whole network of lake associations throughout the State. But it is not just a matter of sending out a few newsletters and things. People also have to be willing to take action. For example, when hearings came up on milfoil registration people from COLAM attended. They went as far away as Rochester and New Paltz, and they stood up to make public statements. They were willing to say, "Citizens ought to decide what to do with this problem in their lake, and we would like government help on this." We are trying now to change that order in New York. Until recently, the citizens have not been involved in the development of policies of programs in New York State. In the past, decisions have just been handed down to us. But we have made a change, and now we are frequently contacted about what we would like to see happen. This is a real case. This is real progress.

If we can take care of our problems, if we follow these steps, then we can make a difference. Get people involved! Divide up the work! Encourage each other! And follow through!