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SUMMARY

The zebra mussel, *Dreissena polymorpha* is an aggressive, nonnative, aquatic organism that has rapidly invaded freshwater systems throughout the United States. This tiny black and white striped mollusc has caused extensive damage to the intake pipes of many facilities such as utilities, industries, and waterworks plants. Zebra mussels clog intake pipes, reducing flow, and even infiltrate interior plant structures, resulting in the failure of plant components. Zebra mussels have also impacted recreational water use by settling on piers, hulls, engine intakes, and moorings. Large colonies of zebra mussels are even responsible for sinking navigational buoys in the Great Lakes. Aside from impacting water-dependent users, zebra mussels have altered freshwater ecosystems by competing for food and space with our native mussels and benthic fish. After its introduction into the Great Lakes Basin in 1986, this mollusc has extended its range into most major river systems and smaller tributaries of North America. It has been estimated that the economic impact of zebra mussels for the next decade will exceed $5 billion for the Great Lakes region alone.

In July 1993, zebra mussels were sighted in the southern section of Lake Champlain. By 1994, zebra mussels had spread 78 miles north in Lake Champlain. This recent invasion into the New England region is cause for concern for all New England industries, aquaculture facilities, power plants, utilities, and boaters and anglers that utilize freshwater resources. Such concern has prompted many states to evaluate the potential for a zebra mussel invasion and sustained zebra mussel population. Many states have predicted invasion potential based on environmental conditions. Water quality parameters such as temperature, pH, and calcium concentration are critical factors that limit zebra mussel growth and reproduction. These factors have been utilized to predict zebra mussel invasions into freshwater systems by assessing whether a suitable habitat exists for zebra mussels. Invasion potential for Rhode Island fresh water was determined with similar criteria, but using calcium concentration (mg/L) as the primary determinant for zebra mussel habitat suitability and successful colonization potential.

For this report, the potential areas in Rhode Island that could experience a zebra mussel invasion were evaluated by habitat and boating activity. Calcium data reviewed for this report was provided by two water quality monitoring organizations, the University of Rhode Island Watershed Watch Program and the Citizens Bank River Rescue Program. The monitored waters were then evaluated to assess boating activity. Boating activity may act as the transport vector for zebra mussel introductions. Boating activity was determined by assessing both the boat-launch type and boating restrictions at the monitored locations. These two factors, zebra mussel survival and boat-launch type, were reviewed in 1992 and mapped by the Geographic Information System (GIS) by the Department of Natural Resource Sciences at the University of Rhode Island. The maps produced were used at identification workshops and seminars. The 1992 GIS map was updated for this report to incorporate 1993 and 1994 monitoring data.

A majority of the monitored waters in Rhode Island have very low calcium concentrations, making these locations unsuitable habitat for zebra mussels. In addition, the boating activity at monitored areas is limited to small carry-in boats that do not require a trailer. The limitation of larger boats and trailers by regulations or natural water depth may reduce the risk of introducing zebra mussels into Rhode Island. Of the 78 Rhode Island water bodies reviewed with respect to their calcium concentration, only 20 areas have potential habitat to support zebra mussels. Of these 20 areas, **Tiogue Lake** in Coventry may experience an invasion of zebra mussel through boating activity. Although **Slater Pond** in Pawtucket has suitable habitat and no restrictions on the boat launch, it should not experience a zebra mussel invasion because the water depth limits boating to paddleboats. The **Moshassuck** and **Ten Mile Rivers** are at low risk of introducing zebra mussels through boating because only small carry-in boating is possible. However, these rivers could support a zebra mussel population. On the other hand, the **Blackstone, Woonasquatucket** and **Pawtuxet Rivers** are at risk of introducing zebra mussels through boating activity within them or in their tributaries, but have marginal calcium concentrations, allowing for uncertain zebra mussel habitation.

As of June 1995, no zebra mussels had been sighted in Rhode Island freshwater systems. Nevertheless, the introduction of zebra mussels into Rhode Island waters within the next several years is likely. Thus, predicting which areas are at risk of becoming infested with zebra mussels is essential to developing monitoring, control, and management programs for both state and private industries in Rhode Island. Evaluating zebra mussel habitats and survival using calcium concentration can predict invasion areas, but reviewing these locations with respect to boating activity will provide a better assessment of invasion potential for Rhode Island fresh water.

INTRODUCTION

Historically, several nonnative aquatic plants and animals known as "exotics" have invaded North America. Some exotic introductions, such as the rainbow trout and water cress have been benign or even beneficial to mankind for agricultural or sport-fishing purposes, but a number of exotics are cause for concern, such as Eurasian water-milfoil, purple loosestrife and gypsy moths (Rosenfield and Mann, 1992). However, recent invasions into freshwater systems by exotic species have generated more than scientific curiosity and general interest; they are responsible for severe economic and ecological problems. Aquatic exotic species, especially invertebrates, have caused substantial damage to public water works, utility plants, and industries by invading, colonizing, and clogging the water intake pipes. The most notorious exotic introduction is the zebra mussel, *Dreissena polymorpha,* and its close relative the quagga mussel, *Dreissena bugensis.* These two mussel species are considered to represent the most expensive aquatic biological disaster ever recorded, costing $2.5 million in pest control with a projected cost of over $3.5 billion for the next decade (Tyson and Hoversten, 1994). Aside from being the most severe biofouling pest recorded in North America, zebra mussels have completely altered the ecology of the Great Lakes region by aggressively invading the benthic community and the ability to rapidly filter food from the water (Nalepa and Schloesser, 1992).

HOME RANGE OF ZEBRA MUSSELS

Zebra mussels are tiny black-and-white striped, D-shaped, bivalve molluscs that are native to western Asia (Figure 1). Information from fossil records indicates that zebra mussels originated in the partially saline drainage basins of the Aral, Caspian, Azov and Black seas (Karnaukhov and Karnaukhov, 1993). Due to glaciation, zebra mussels were restricted to these areas and the Volga River, where the mollusc was first described by Pallas in 1771 (Ramcharan et al, 1992). During the late 1700s, the construction of shipping canals and establishment of freshwater trade routes extended the range of zebra mussels into Northern European rivers and lakes. By 1830, zebra mussels had invaded rivers, lakes, and canals of The Netherlands and Britain (Smit et al, 1993). By the 1950s, zebra mussels had spread to the Mazurian lake land area of Poland, including the Great Mazurian Lakes, Jorka and the Krutynia river systems, comprising a total of 43 lakes (Stancykowska and Lewandowski, 1993). Presently, zebra mussels exist throughout most inland water systems in Europe. Although zebra mussels can extend their range by natural colonization, evidence suggests that human activity has greatly expedited the invasion process. By constructing canals, shipping routes, and inadvertently transporting mussels, humans have had a tremendous influence on the movement of zebra mussels throughout the world (Morton, 1993).

INVASION INTO NORTH AMERICA

In June 1988, zebra mussels were discovered in the Laurentian Great Lakes Basin in Lake St. Clair, Michigan . The shell size of the population discovered indicated that the mussels were at least two years old (Hebert et al, 1989). The actual invasion pathway of the zebra mussel into North America is not known.

However, scientists theorized that the mussels were accidentally introduced during the mid-1980s by European cargo ships discharging ballast water after trans-Atlantic crossings (O'Neill and MacNeill, 1991). Within just four years, zebra mussels have established successfully reproducing colonies throughout all the Great Lakes, and the St. Lawrence Seaway and many of its adjacent lakes. By 1992, zebra mussels were found as far north as the Wisconsin lakes and as far south as Arkansas in the Mississippi River and its tributaries. Other colonies of zebra mussels were discovered as far east as the Tennessee and Ohio rivers. By 1993, zebra mussels had extended into the Cayuga and Seneca lakes of the New York Finger Lake system and into the Susquehanna, Mohawk, and Hudson rivers. Zebra mussels were discovered in New Orleans and are expected to appear in the panhandle region of Florida. In July 1993, zebra mussels were also discovered for the first time in New England, in the southern portion of Lake Champlain (Lake Champlain Basin Program, 1993). The current range of the zebra mussel is displayed in Map 1.

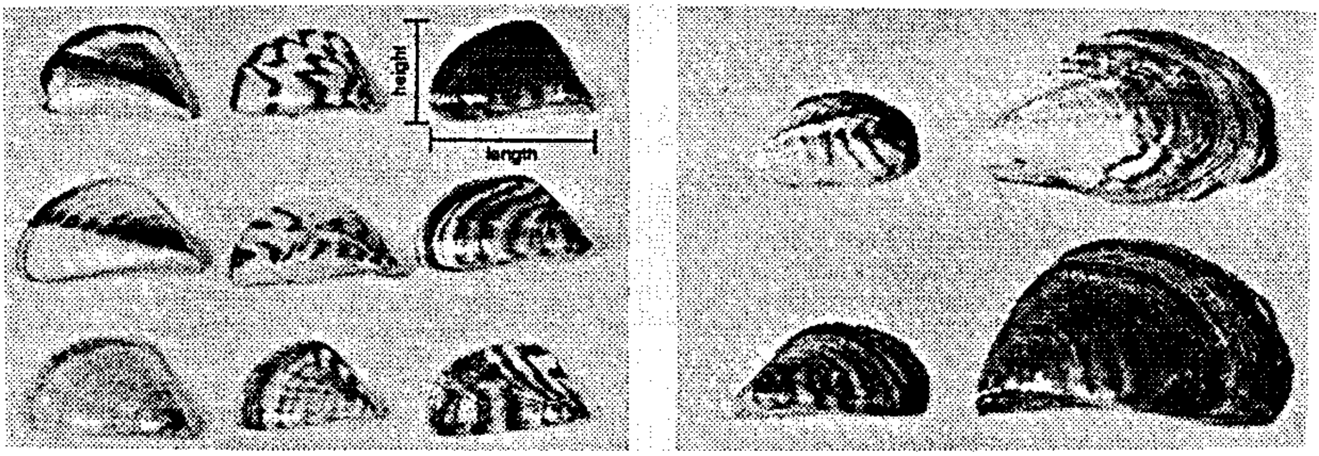

Figure 1. Comparison of Zebra and Quagga Mussels' Shapes and Sizes. (Marsden, J. E. 1992. Standard protocols for monitoring and sampling zebra mussels. Illinois Natural History Survey Biological Notes 138. page. 4.)

Most researchers believe that the zebra mussel will continue to extend its range throughout most freshwater systems in the United States, and Central and South America (Ramcharan et al., 1992). Because zebra mussels inhabit some saline estuaries in Europe, they are predicted to invade similar habitats in North America. The extent of an estuarine invasion is still uncertain because of the variable salt tolerances of zebra mussels,— 0.5 to 12.3 parts per thousand (ppt) salinity (Strayer and Smith, 1993).

IMPACT OF ZEBRA MUSSELS

Zebra mussels are infamous biofouling organisms that will settle and create large colonies on any surface — rocks, metal, rubber, glass, and cloth. They will even attach to aquatic plants, rocks, floating debris, crayfish, and other bivalves. Zebra mussels have the ability to colonize surfaces in high densities. This ability, coupled with a rapid growth rate, produces encrusting layers ranging from 5 - 8 cm thick (Kovalak et al, 1993). As a result, zebra mussels have impacted facilities that use raw surface water, such as utility plants, factories, water treatment plants, agricultural and golf course irrigation systems. These facilities have experienced severe problems due to zebra mussels clogging intake pipes.

Zebra mussels not only clog intake pipes and reduce flow, but can also infiltrate the interior plant structures, causing obstructions that lead to the failure of vital plant components. Furthermore, water treatment plants must also retreat drinking water before releasing it into the public supply due to an off taste produced by decaying shellfish inside the plant (O'Neill and MacNeil, 1992). Between 1989 and 1991, the Monroe, Michigan, waterworks plant experienced several water outages due to zebra mussel infestation. Zebra mussel densities inside intake pipes and screenhouses were 700,000 to 800,000 mussels per square meter (LePage, 1993). The plant was forced to shut down, leaving 45,000 residents of Monroe without water.

The estimated cost of treating the initial infestation was over $300,950, with a long- term cost of about $50,000 per year to implement chlorine treatment (LePage, 1993). Zebra mussel infestations have also had a major impact on recreational water users. Boat and marina owners have had to remove large mussel colonies from piers, hulls, engine intakes, moorings and navigational buoys. Tourism to the Great Lakes beaches has suffered due to the large volume of sharp shells and stench from decaying mussels. New York Sea Grant has estimated that the economic impacts of zebra mussels will exceed $5 billion just in the Great Lakes (New York Sea Grant, 1992).

ZEBRA MUSSEL BIOLOGY

The zebra mussel has been a successful invader because of its life cycle, biology, and habitat preference. Zebra mussels are very small, averaging 2.3 to 2.5 cm in length, with a maximum size of 5 cm (Claudi and Mackie, 1994) (Figure 1). Zebra mussels grow in dense clusters of numerous individuals that firmly attach to surfaces by strong adhesive threads called byssal fibers. Mussel densities along the shallow embayments of Lake Erie were reported to exceed 30,000 individuals per square meter (Griffiths et al., 1991). A single female zebra mussel can release up to 108 eggs within the two years of its life, and averages about 300,000 - 400,000 eggs during one spawning event. Zebra mussels experience an annual reproduction cycle that is triggered when water temperatures exceed 12 C (54 F). Although zebra mussels usually spawn annually, some females may spawn multiple times throughout the year (Neumann et al., 1993). Within days, a free-swimming planktonic larva called a veliger develops. The microscopic veligers are transported by water currents or inadvertently by humans. The larval life cycle usually takes 4 weeks to complete, at which time the swimming veliger will settle on a hard surface (Fraleigh et al., 1993; Claudi and Mackie, 1994). It is during the larval stages that zebra mussels can infiltrate water intake pipes virtually undetected, eventually settling to develop into adults.

ECOLOGICAL IMPACT OF ZEBRA MUSSELS

Zebra mussels are filter feeders. Phytoplankton and detritus particles are major food sources for the zebra mussel. An average adult zebra mussel can filter over 1 to 2 liters of water per day (O'Neill and MacNeil, 1992). The collective filtering from large numbers of zebra mussels is responsible for the increase in water transparency and decrease in chlorophyll a (pigment associated with phytoplankton abundance) in western Lake Erie (Leach, 1993). This capacity to filter large volumes of water may have a long-term ecological impact on zooplankton, benthic fish communities, and native freshwater mussels (unionids).

The unionids of North America are the most biologically diverse group of freshwater bivalves, with over 50 known species, many of which inhabit sensitive or endangered habitat areas (Baker, 1928; Stern, 1990). Native mussels may become more endangered because of the aggressive infestation pattern of the zebra mussels. Zebra mussels not only compete for food and space with unionid mussels, but also settle on the shell. Dense clusters of zebra mussels hinder the locomotion, feeding, and growth of unionids to the point that death can result. In 1993, large numbers of native unionids, alive and dead, were found covered with dense zebra mussel colonies in Lake Erie (LePage, 1993).

There are a number of zebra mussel predators. Diving ducks and crayfish are known to prey on adult and larval mussels. There are several predatory fish found in eastern North America that also may be able to control zebra mussels (Snyder et al., 1991). These fish are considered to be potential predators because their teeth enable them to crush mussel shells. The most effective predators are from the sunfish, sucker, sturgeon, drum, and carp fish families (French, 1993). Nevertheless, it is unlikely that natural predation alone will make a significant impact on the zebra mussel population within infested waters in the short term, or that it will even contain their spread to non-infested waters.

INVASION POTENTIAL

ZEBRA MUSSEL HABITAT

Environmental parameters are critical determinants of whether or not zebra mussels can survive, grow, and reproduce in freshwater systems. These parameters have been used to predict zebra mussel invasion areas. The most important factors are calcium concentration, temperature, and pH. Other factors, such as dissolved oxygen, nutrient levels, turbidity, and phosphorus concentration, may also affect zebra mussel colonization, but are considered less important (Claudi and Mackie, 1994).

Calcium concentration is the most critical variable affecting zebra mussel colonization. Calcium is necessary for shell production in all bivalves. If calcium concentrations are low, it is likely that zebra mussels will not survive regardless of other environmental factors, including temperature and pH. Low calcium levels prevent molluscs from surviving in some North American and European freshwater systems (Ramcharan et al. 1992). Measurements such as calcium hardness, alkalinity, and conductivity can all be utilized as estimates of calcium concentrations in fresh water. Of these methods, total calcium concentration has been the most common parameter used to determine survival and infestation potential in fresh water. Claudi and Mackie (1994) have summarized zebra mussel survivorship and performance based on the various ways calcium concentration is reported (Table 1.).

Although considered to be a critical parameter, temperature has not proven to be a limiting factor to zebra mussel invasions in North America. Evidence includes the invasion of zebra mussels into warmer climates, such as the lower Mississippi River in New Orleans. Furthermore, in European lakes, zebra mussels were able to tolerate a wide range of temperatures. European adult mussels survived in temperatures above freezing and tolerated maximum temperatures exceeding 25 C, but prefer temperatures ranging from 10 - 16 C (Strayer, 1991). Zebra mussels can tolerate the year-around temperature regime found in most of North America and New England.

Another major factor influencing invasion potential is human activity. It has been estimated that there are 43 possible vector mechanisms that can transport zebra mussels; all but 3 are human related (O'Neill, New York Sea Grant, com. 1994). Although the transport of zebra mussels can occur naturally, boating activity can facilitate the spread of zebra mussels to non-infested waters. Zebra mussels may be inadvertently transported by trailer, boat hull, motor, bait, bilge water, and fishing equipment. Zebra mussels are often transported by the aquatic vegetation that clings to trailers after a boat is launched or removed from infested waters (Johnson and Carlton, 1993).

In assessing the invasion likelihood for Rhode Island, we considered the inadvertent transportation of mussels through boating and trailer access. Access to a water body can be defined by categorizing the type of boat launches available to the boater. The launch type directly influences boating by limiting boat trailer boat accessibility. A concurrent variable that affects boat activity and influences invasion potential is boating limitations. Boating limitations are defined as restrictions placed on fishing or boating at a particular water body. The most common restriction to boating in Rhode Island fresh water is engine size. Larger boats, trailers, and motors may be excluded from certain waters even when there is an accessible boat launch.

Table 1. Approximate growth performance Of zebra mussels in relation to various methods of measuring calcium concentration from Claudi and Mackie. 1994.

Criteria	***No Survival***	***Poor Growth***	***Moderate Growth***	***Good Growth***	***Best***
Calcium (mg/L)	5 - 6	10 - 11	25 - 26	35 - >35	+35
Alkalinity ($CaC0_{3}$/L)	0 - 17	18 - 35	36 - 87	88 - 122	>122
Total Hardness (mg$CaCO_3$/)	0 - 22	23 - 41	43 - 90	91 - 125	>125
Conductivity (uSiemens)	0 - 21	22 - 36	37 - 82	83 - 110	>110
pH	0 - 6.8	6.9 - 7.4	7.5 - 7.8	7.9 - 8.0	>8.0
Temperature (C)	<- 2 or >40	0-8 or 28-30	9-12 or 28-30	13-17 or 21-24	18-20

OBJECTIVE OF THIS STUDY

As of June 1995, no zebra mussels had been sighted in Rhode Island. However, given the zebra mussel's ability to adapt to a variety of North American habitats, its introduction into Rhode Island waters within the next several years is likely. Thus, predicting which freshwater locations are at risk of becoming infested is critical to developing monitoring, control, and management programs for both state and private industries in Rhode Island. This study determines some of the water bodies in Rhode Island with the potential to experience zebra mussel invasions. This assessment is based on water-chemistry characteristics and boating activity. Data from Rhode Island monitored waters were reviewed using calcium as the limiting variable. This report is intended to complement previous reports predicting the potential for zebra mussel invasion of Connecticut (Murry et al., 1993) and Massachusetts (Smith, 1993).

In addition, this report examines boating activity as the vector that increases the range of a zebra mussel invasion. Boating activity of monitored waters was analyzed for launch type and boating restrictions. Assessing these locations by boating activity may provide a better sense of the short-term invasion potential for Rhode Island lakes, ponds, rivers and reservoirs.

MATERIALS

MONITORING DATA

The calcium data utilized for this review was obtained from the 1994 University of Rhode Island Watershed Watch Program's annual report. This volunteer monitoring group has been in existence since 1988 and has compiled valuable water chemistry information from over 60 lakes and ponds in Rhode Island (Watershed Watch 1994 Report). A second volunteer monitoring program, the Citizen's Bank River Rescue, provided calcium concentration data for five Rhode Island rivers: the Blackstone, Woonasquatucket, Moshassuck, Pawtuxet and Ten Mile rivers. River Rescue is a volunteer monitoring group which targets data collection and clean-up of Rhode Island rivers. This report utilized the average calcium concentration (mg/L) collected in 1993. The monitored areas can be seen in Appendix A.1 and A.2.

Additional information about Rhode Island water supplies and reservoirs was provided by the Department of Environmental Management Division of Water Resources, the Rhode Island Department of Public Health, and Providence Water Supply Board via verbal communication and summary reports. Information on boating usage was supplied through the Department of Environmental Management Fish and Wildlife Division's, *Angler's Guide to Public Freshwater Access in Rhode Island* (Guthrie and Stolgitis, 1994). Boating and fishing information was also obtained through an informal survey of the Rhode Island Bass Anglers Sportsman Society .

METHODS

ANALYSIS PROCEDURES

I. Zebra Mussel Habitat for Rhode Island Waters

In an attempt to determine potential zebra mussel habitats, Rhode Island lakes, ponds, rivers, and reservoirs were reviewed using calcium data. Calcium concentrations for Rhode Island waters were examined according the invasion criteria in Table 2.

Table 2. Zebra mussel invasion and growth potential for Rhode Island waters in relation to calcium concentration

Calcium (mg/L)	Zebra Mussel Performance
+ 35	Very good growth
25 - 35	Moderate to good growth
10 - 24	Poor to moderate growth
7 - 9	Low survival
0 - 6	No survival

II. Boating Activity

The invasion potential of zebra mussels was also based on the boating activity in monitored Rhode Island waters. Boating activity was determined by reviewing two components, launch type and boating limitations (restrictions). The first component, launch type, was divided into five categories listed in the Department of Environmental Management's, *Angler's Guide to Public Freshwater Access in Rhode Island* (Guthrie and Stolgitis, 1994). In this analysis, boat launches that were defined as boat launch, gravel boat launch, and slab boat launch allow for the launching of larger trailers and boats (The launch categories are defined below in Table 3.). As a result, these areas are at high risk of introducing zebra mussels or other aquatic exotic organisms from the trailer, boat, and motor. From those areas listed as cartop or shore access generally only small boats can be launched. Small boats, such as rowboats, canoes, kayaks, and john-boats have a lesser risk of introducing zebra mussels because trailering may not be necessary. Additional information on boating access was provided by the water quality monitors themselves and the Rhode Island Bass Anglers Sportsman's Society.

Table 3. Rhode Island launch types

Categories
1. Boat Launch (includes Private Boat Launch)
2. Slab Boat Launch (concrete)
3. Gravel Boat Launch
4. Cartop Boat Launch
5. Shore Access (no launch access)
6. Boating Prohibited

In addition to classification of the launch type, a review of the boating limitations was also conducted. Boating limitations referred to the restrictions placed on the pond or lake by the Department of Environmental Management, local town government, or private owners. Restrictions at a water body are very important because they directly affect the boating activity allowed at a particular area. For example, some ponds have boat launches, but boats are limited to a maximum 10 hp motor.

III. Geographic Information System (GIS)

Invasion potential for Rhode Island waters was delineated in 1992 by mapping boat-launch type and calcium concentrations using the Geographic Information System (GIS), with the assistance from the Department of Natural Resource Science at the University of Rhode Island. A calcium concentration color gradient and a launch-type code show potential zebra mussel survival, growth, and transportation at those monitored waters. The 1992 GIS map was updated for this report in order to incorporate current monitoring data collected in 1993 and 1994. The revised analysis can be seen in Maps 2 and 3.

RESULTS

I. Zebra Mussel Habitats in Rhode Island

Of the 78 monitored lakes, ponds, reservoirs and rivers in Rhode Island, 58 areas are uninhabitable to zebra mussels because of very low calcium concentrations. These areas were given a "No survival" rating. The remaining 20 waters received ratings ranging from "Low survival " to "Very good growth" as seen in Table 4. These areas could potentially support a population of zebra mussels and are likely to become successful invasion areas if zebra mussels are transported into them. The results of this analysis can be seen in Appendices B.1 and B.2, and Map 2.

Table 4. Potential zebra mussel habitats in Rhode Island lakes, ponds, reservoirs and rivers with respect to calcium (mg/L)

Name	Calcium (mg/L)	Zebra Mussel Survival
Barney Pond	20.4	Poor to moderate growth
Belleville Pond - Lower	7.6	Low survival
Belleville Pond - Upper	7.5	Low survival
Brickyard Pond	21.7	Poor to moderate growth
Handy Pond	22.8	Poor to moderate growth
Mishnock Lake	10.2	Poor to moderate growth
Moshassuck River	13.8 - 16.5	Poor to moderate growth
Olney Pond	9.5	Low survival
Pleasure Pond	16.7	Poor to moderate growth
Prince's Pond	53.7	Very good growth
Regulating Reservoir	7.0	Low survival
Roosevelt Pond	19.1	Poor to moderate growth
Scituate Reservoir	7.1	Low survival
Scott Pond	7.1	Low survival
Secret Lake	10.6	Poor to moderate growth
Silver Spring Lake	7.6	Low survival
Slater Pond	8.6	Low survival
Ten Mile River	15	Poor to moderate growth
Tiogue Lake	9.1	Low survival
Wenscott Reservoir	8.8	Low survival

II. Boating Activity

Boating activity with respect to launch type was reviewed for the 78 monitored locations. Fifty-two areas had defined launch types (cartop, gravel, slab, private or public boat launch), ten locations had shore access only, seven areas did not allow boating, and ten sites had unknown boating activity. Because the boat trailer itself is the transport mechanism, those areas defined as having a cartop launch or shore access should not experience an introduction of zebra mussel by trailers. Locations such as Barney, Belleville, Brickyard, Carr, Georgiaville, Handy, Long, Meadowbrook, Mishnock, Prince's, Scott , and Spring Grove ponds, Slack's reservoir, and Secret and Silver lakes all have boating that is limited to canoes, paddleboats, rowboats and kayaks. Areas determined to have no boating were Deep Pond and Barden, Moswanicut, Regulating, Scituate,and Westconnaug reservoirs.

The remaining 40 areas with launch types defined as gravel, slab, private or public boat launch are areas where larger boats may be launched. However, a review of the boating restrictions at these launches, indicates that only 20 areas are potential introduction sites for zebra mussels. These areas are listed in Table 5. A majority of these launch sites are privately owned or have no boating restrictions to prevent the launching of larger trailers. The areas that boating activity could not be defined and which are also considered potential introduction sites for zebra mussels are the Narrow and Pawtuxet rivers, Pleasure, Rooosevelt, Saugatucket, and Stillwater ponds, Spalding and Wyassup lakes, Coventry, Sprague and Wenscott reservoirs. The results of this analysis can be seen in Appendices B.1 and B.2.

Table 5. Possible introduction areas for zebra mussels in Rhode Island due to boating activity

Name	Launch Type	Restrictions	Zebra Mussel Survival
Beach Pond	Boat launch	None	No survival
Boone Lake	Private launch	Landowner permission	No survival
Coomber's Reservoir	Boat launch	None	No survival
Flat River Reservoir	Public / private launch	Landowner permission	No survival
Hundred Acre Pond	Private launches	Landowner ermission	No survival
Larkin Pond	Private launch	No public access	No survival
Pascoag Reservoir	Boat launch	None	No survival
Pasquisett Pond	Private launch	Landowner permission	No survival
Ponaganset Reservoir	Boat launch	Limited boating	No survival
Queens River	Private boat launch	None	No survival
Schoolhouse Pond	Private boat launch	Landowner permission	No survival
Slater Pond	Town launch	Town residents	Low survival
Tiogue Lake	Gravel/private launch	None	Low survival
Wakefield Pond	Boat launch/private	Limited motor usage	No survival
Wash Pond	Private boat launch	None	No survival
Watchaug Pond	Boat launch	None	No survival
Waterman Reservoir	Private boat launch	None	No survival
White Pond	Private boat launch	None	No survival
Worden Pond	Boat launch	None	No survival
Wyoming Pond	Gravel launch	None	No survival

III. Rhode Island Invasion Potential

The 20 locations with suitable zebra mussel habitat from Table 4 were analyzed with respect to boating activity to determine which areas are potential zebra mussel infestation or survival sites.

Cross analysis of the boating activity (launch type and restrictions) at these waters identified only two potential invasion areas where mussel survival is possible, Slater Pond in Pawtucket and Tiogue Lake in Coventry. These areas have proper launch facilities and boat restrictions that make them accessible to larger boat trailers. However, further analysis of Slater Pond determined that the water depth is shallow and only small carry-in boats are allowed access. Pleasure, Roosevelt ponds and Wenscott reservoir are areas with undefined boating activity. The results of this analysis appear in Map 3 and Table 6.

Table 6. Boating activity at potential zebra mussel habitat areas in monitored Rhode Island lakes, ponds, reservoirs and rivers in relation to calcium (mg/L)

Name	Boat launch	Boating Restrictions	Invasion from boats	Zebra mussel survival & growth
Barney Pond	Shore access	-	Unlikely	Poor to moderate
Belleville-lower	Cartop launch	No motors	Unlikely	Low survival
Belleville-upper	Cartop launch	No motors	Unlikely	Low survival
Brickyard Pond	Cartop launch	No motors	Unlikely	Poor to moderate
Handy Pond	Shore access	Limited fishing	Unlikely	Poor to moderate
Mishnock Lake	Cartop launch	-	Unlikely	Poor to moderate
Moshassuck	Shore access	Carry - in boating	Unlikely	Poor to moderate
Olney Pond	Boat launch	10 hp limit	Unlikely	Low survival
Pleasure Pond	-	-	Unknown	Poor to moderate
Prince's Pond	Shore access	-	Unlikely	Very good
Regulating	Public prohibited	No boating	Unlikely	Low survival
Roosevelt Pond	-	-	Unknown	Poor to moderate
Scituate	Public prohibited	No boating	Unlikely	Low survival
Scott Pond	Shore access	-	Unlikely	Low survival
Secret Lake	Shore access	-	Unlikely	Poor to moderate
Silver Spring	Boat launch	No motors	Unlikely	Low survival
Slater Pond	Town launch	-	Possible	Low survival
Ten Mile River	Shore access	Carry - in boating	Unlikely	Poor to moderate
Tiogue Lake	Private/gravel	-	Possible	Low survival
Wenscott	-	-	Unknown	Low survival

DISCUSSION

Potential Zebra Mussel Habitats

There are 20 known potential zebra mussel habitats based on calcium concentration (see Table 4). Although Prince's Pond, displayed a calcium concentration of 53.7 mg/L and was rated as having "very good growth" for zebra mussels, this pond may be uninhabitable for zebra mussels because of high salinity resulting from its water exchange with Narragansett Bay. Barney, Brickyard, Handy, Pleasure, and Roosevelt ponds; Mishnock and Secret lake, Moshassuck and Ten Mile rivers are locations that were given a habitat rating of "poor to moderate growth". With the exception of Brickyard Pond, which also has an open exchange with Narragansett Bay and high salinities, these areas are all capable of supporting a population of zebra mussels. Consequently, if zebra mussels were introduced to these waters, their survival is likely. Those areas given "low survival" ratings were Belleville, Onley, Scott, and Slater ponds, Regulating, Scituate and Wenscottt reservoirs, Silver Spring and Tiogue lakes. These areas all displayed low calcium concentrations so that zebra mussel survival, growth and reproduction would be compromised. Several lakes, ponds and rivers displayed calcium concentrations that were considered too low for zebra mussel survival. As a result, these areas were given a "no survival" rating. However, some of these locations may be habitable for zebra mussels in the future because of the marginal nature of the calcium concentrations observed. If a slight increase in calcium concentration occurred, some areas could potentially support zebra mussels and would be placed in the "low survival" to "poor growth" categories. Thus, any locations having calcium concentrations between 6 and 10 mg/L should be monitored closely for both calcium changes and zebra mussels.

A wide range of calcium concentrations has been observed at monitoring sites in the Blackstone, Moshassuck, Pawtuxet, Ten Mile and Woonasquatucket rivers over the past 4 years. This wide range of calcium made classification difficult. Special attention should be given to these rivers as potential zebra mussel habitats, even though the mean calcium concentration for the 1993 monitoring season indicated otherwise. Survival might be possible if zebra mussels were transported into these areas. In the future, these rivers should be frequently monitored to assess zebra mussel invasion and to better define calcium concentrations.

Boating Activity

A majority of the monitored waters in Rhode Island are unlikely to experience an introduction of zebra mussels because boating is limited to small carry - in boats that do not require trailering. Many launch areas have restrictions on the allowable engine size, further limiting the use of larger boat trailers. Some areas that have suitable calcium concentrations and no launch restrictions could not physically allow the launching of a large boat because of the water depth. As a result, boating is limited to canoeing or other small carry-in boating activity.

However, Rhode Island does have potential introduction areas where zebra mussels or other aquatic exotic organisms could be introduced through boating transport. Analysis of the boating activity at the monitored locations identified 40 areas defined as boat, gravel, slab, or private launches. These are areas where larger boating is possible, but further invesigation of the restrictions at these sites determined that only 20 areas could potentially introduce zebra mussels. Of those 20 areas with launches and boating restrictions favorable to larger boats trailers, only Slater Pond and Tiogue Lake could support a zebra mussel habitat (see Table 5). The remaining 18 locations have unfavorable calcium concentrations. Other areas that are at risk of introducing zebra mussels to Rhode Island are the 11 sites with unknown boating activity.

Boating Activity at Potential Zebra Mussel Habitats

Conversely, of the 20 locations with suitable zebra mussel habitat and boating accessibility again only Slater Pond and Tiogue Lake might have zebra mussels transported by boating activity. Even though Slater Pond has suitable habitat, only small boating is possible because of the water depth. Pleasure, Roosevelt, and Wenscott reservoirs also have the potential to support a zebra mussel population, but the boating activity could not be determined at these locations (see Table 6).

The Moshassuck and Ten Mile rivers are also at low risk of introducing zebra mussels through boating. Even though these rivers could support zebra mussels, a review of the boating activity reveals that only small carry - in boating is possible. Even though the Blackstone, Woonasquatucket and Pawtuxet rivers have marginal calcium concentrations, these rivers are all at risk of introducing zebra mussels through the boating activity allowed within them or in their tributaries. The Narrow River appears to be an adequate introduction area because of the launch and lack of boating restrictions. However, zebra mussel survival is unlikely because of the very high salinity and open exchange with Narragansett Bay.

CONCLUSION

This report makes no attempt to determine invasion based on statistical analysis, but rather through qualitative assessment of suitable habitat based on calcium concentrations and boating activity. These two factors are influential to zebra mussel survival and growth, or transportation. Additionally, boat accessibility based upon launch types and boating restrictions is only an estimate of the possible inadvertent transportation mechanisms that could introduce zebra mussels into Rhode Island. This report assumes that small boats are not likely to transport zebra mussels because a trailer is not used; when in fact, the small boater may also inadvertently transport zebra mussels in the bait water, fishing gear, and other equipment. Thus, informing all boaters and anglers about the inadvertent transportation of zebra mussel is essential to reducing an invasion.

Lastly, this report does not include all the possible fresh water bodies in Rhode Island, only those that were monitored. The invasion maps produced for this report only include water bodies that are presently included in the GIS system. Some monitored areas are not entered into the GIS system such as, Spalding and Wyassup lakes. Areas without GIS coordinates were enhanced with color for this report.

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

A zebra mussel invasion into Rhode Island is possible through interstate boating activity from New York, Vermont, and Connecticut as well as any other state which is already infested. Rhode Island may experience infestation via boating traffic and drainage from the Blackstone River or its upper tributaries if zebra mussels invade and colonize in Massachusetts. Zebra mussel invasion via the Connecticut border only appears likely via interstate boating traffic and not by natural drainage. Water quality along the Connecticut and Rhode Island border is not suitable for zebra mussel survival because of the low calcium levels.

Ultimately, all New England states are at risk of invasion from zebra mussels. Some states have water quality parameters that are quite suitable to harboring large populations of zebra mussels, while other states report only marginal invasion possibilities. Yet, the zebra mussel continues to astound researchers with its rapid dispersal ability, wide physiological adaptation, and aggressive invasion behavior. It appears that most of New England will experience invasions of zebra mussels, but when, where, and to what extent are questions that only the future can answer.

DEFINITIONS

Alkalinity - The total ions in the water that buffer or prevent shifts in pH. Usually expressed as calcium carbonate equivalents

Bethic- Bottom-dwelling organisms

Biofouling - The encrusting of surfaces by living organisms

Calcium concentration - The amount of calcium ions in a volume of water

Chlorophyll a - The photosynthetic pigment in phytoplankton and most plants

Conductivity - The ability of water to conduct electricity

Detritus - Particulate organic matter formed by the decay of living material

Dissolved Oxygen - The concentration of oxygen in a given volume of water

Exotics - Organisms that are nonnative to North America or are outside of their normal habitat range

Geographic Information Systems (GIS) - A computer system that maps information based on the actual coordinates

Hardness - The concentration of all ions with double positive charge (mostly magnesium and calcium in freshwater)

Invertebrate - Organisms classified by their body structure as having no bones

Limiting factor - A single factor that is most important in controlling population size of organisms

pH - The degree of acidity or basicity of waters

Phytoplankton -Microscopic aquatic plants eaten by larger organisms

Planktonic - Floating plant and animal life in a body of water

Turbidity - The "cloudiness" of water

Unionids - Native North American freshwater clams and mussels

Vector - A carrier, or agent that spreads biological organisms

Veliger - Microscopic swimming larval stage of the zebr mussel

Zooplankton - Microscopic animals that feed on phytoplankton

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Communications

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Appendix A.1
Watershed Watch Monitoring Locations

NAME	LOCATION	WATERSHED	COUNTY
Alton Pond	Richmond	Wood - Pawcatuck	Washington
Barber Pond	South Kingstown	Wood - Pawcatuck	Washington
Barden Reservoir	Foster	Scituate Reservoir	Providence
Barney Pond	Lincoln	Moshassuck	Providence
Beach Pond	Voluntown, CT		Washington
Belleville Pond - Lower	North Kingstown	Annaquatuck- Pettaquamscutt	Washington
Belleville Pond - Upper	North Kingstown	Annaquatuck- Pettaquamscutt	Washington
Boone Lake	Exeter	Wood - Pawcatuck	Washington
Brickyard Pond	Barrington	Barrington River	Bristol
Carbuncle Pond	Coventry	Moosup River	Kent
Carr Pond	West Greenwich	Annaquatuck- Pettaquamscutt	Kent
Coomber's Reservior	Glocester	Pawtuxet	Providence
Coventry Reservior	Coventry	Pawtuxet	Kent
Deep Pond	Charlestown	Coastal	Washington
Flat River Reservoir	Coventry	Pawtuxet	Kent
Georgiaville Pond	Smithfield	Woonasquatucket	Providence
Handy Pond	Lincoln	Moshassuck	Providence
Hundred Acre Pond	South Kingstown	Wood - Pawcatuck	Washington
Indian Lake	South Kingstown	Saugatucket	Washington
J.L. Curran Reservoir	Cranston	Scituate Reservoir	Providence
Keech Pond	Glocester	Blackstone River	Providence
Larkin Pond	South Kingstown	Wood - Pawcatuck	Washington
Locustville Pond	Hopkinton Pond	Wood - Pawcatuck	Washington
Long Pond	South Kingstown	Coastal	Washington
Meadowbrook Pond (Sandy)	Richmond	Wood - Pawcatuck	Washington
Mishnock Lake	West Greenwich	Annaquatuck- Pettaquamscutt	Kent
Moswanicut Reservior	Scituate/Johnston	Scituate Reservoir	Providence
Olney Pond	Lincoln	Moshassuck	Providence
Pascoag Reservoir	Burrillville/Glocester	Blackstone River	Providence
Pasquisett Pond	Charlestown	Wood - Pawcatuck	Washington
Pawtucket River at Bradford	Westerly	Wood - Pawcatuck	Washington
Pawtucket River - Potter Hill	Westerly	Wood - Pawcatuck	Washington
Pleasure Pond	Providence	Pawtuxet	Providence
Ponaganset Reservoir	Glocester	Scituate Reservior	Providence
Prince's Pond	Barrington	Coastal/Barrington River	Bristol
Queen River at Usequepaug	South Kingstown	Wood - Pawcatuck	Washington
Quidnick Reservoir	Coventry	Pawtuxet	Kent
Regulating Reservoir	Scituate	Scituate Reservoir	Providence
Roosevelt Pond	Providence	Pawtuxet	Providence
Saugatucket Pond	South Kingstown	Saugatucket	Washington
Schoolhouse Pond - Lower	Charlestown	Coastal	Washington
Schoolhouse Pond - Upper	Charlestown	Coastal	Washington
Scituate Reservoir	Scituate	Scituate Reservior	Providence
Scott Pond	Lincoln	Moshassuck	Providence
Secret Lake	North Kingstown	Annaquatucket - Pettaquamscutt	Washington
Silver Lake	South Kingstown	Saugatucket	Washington
Silver Spring Lake	North Kingstown	Annaquatucket - Pettaquamscutt	Washington
Slack's Reservoir	Smithfield	Upper Woonsquatucket	Washington
Slater Pond	Pawtucket	Ten Mile Watershed	Providence
Smith and Sayles Reservoir	Glocester	Blackstone	Providence
Spalding Lake	N. Stonnington, CT	Wood - Pawcatuck	
Sprague Reservoir - Lower	Smithfield	Upper Woonsquatucket	Providence
Spring Grove Pond	Glocester	Blackstone	Providence
Spring Lake (Herring Pond)	Burrillville	Blackstone	Providence
Stafford Pond	Tiverton	Taunton	Newport
Stillwater Pond	Smithfield	Upper Woonsquatucket	Providence
Tiogue Lake	Coventry	Pawtuxet	Kent
Tucker Pond	South Kingstown	Wood - Pawcatuck	Washington
Wakefield Pond	Burrillville		Providence
Wash Pond	South Kingstown	Coastal	Washington
Watchaug Pond	Charlestown	Wood - Pawcatuck	Washington
Waterman Reservoir	Glocester	Upper Woonsquatucket	Providence

Wenscott Reservoir	Providence/Lincoln	Upper Woonsquatucket	Providence
Westconnaug Reservoir	Foster	Scituate Reservior	Providence
White Pond	South Kingstown	Coastal	Washington
Wilson Reservoir	Burrillville	Blackstone	Providence
Woonasquatucket Reservoir -	Smithfield	Upper Woonsquatucket	Providence
Woonasquatucket Reservoir -	Smithfield	Upper Woonsquatucket	Providence
Worden Pond	South Kigstown	Wood - Pawcatuck	Washington
Wyassup Lake	N. Stonnington, CT	Wood - Pawcatuck	
Wyoming Pond	Hope Valley	Wood - Pawcatuck	Washington
Yawgoo Pond	S. Kingstown/Exeter	Wood - Pawcatuck	Washington

Appendix A.2
River Monitoring Locations

River Name	SITE	LOCATION
Blackstone River	B - 1	Blackstone, Massachusetts
Blackstone River	B - 2	Slater Mill Pawtucket, R.I.
Blackstone River	B - lons	Rt 122 Lonsdale, R.I.
Moshassuck River	M - 1	Charles Street Providence, R. I
Moshassuck River	M - 2	Bonanza Bus Station Providence, R
Pawtuxet River	P - 1	Broad Street, Cranston, R.I.
Pawtuxet River	P - 2	East Avenue West Warwick, R.I
Ten Mile River	TM - 1	Roger Williams Avenue
Woonasquatucket River	W - 1	Valley Street Providence, R.I.
Woonasquatucket River	W - 2	Rt 44 North Providence, R.I.

Appendix B.1
Boating Activity and Zebra Mussel Survival at Watershed Watch Monitoring Locations

NAME	BOAT LAUNCH ACCESS	BOATING LIMITATIONS	INVASION POTENTIAL DUE TO BOATING	ZEBRA MUSSEL SURVIVAL
Alton Pond	Boat Launch	No Outboard Motors	Unlikely	No Survival
Barber Pond	Gravel Boat Launch	No Outboard Motors	Unlikely	No Survival
Burden Reservoir	No Boating	No Boating	Unlikely	No Survival
Barney Pond	Shore Access Only	-	Unlikely	Poor to Moderate Growth
Beach Pond	Boat Launch	-	Possible	No Survival
Belleville Pond - L	Cartop Boat Launch	No Outboard Motors	Unlikely	Low Survival
Belleville Pond - U	Cartop Boat Launch	No Outboard Motors	Unlikely	Low Survival
Boone Lake	Private Launch	Private	Possible	No Survival
Brickyard Pond	Cartop Boat Launch	No Outboard Motors	Unlikely	Poor to Moderate Growth
Carbuncle Pond	Boat Launch	No Outboard Motors	Unlikely	No Survival
Carr Pond	Shore Access Only	-	Unlikely	No Survival
Coomber's Reservoir	Boat Launch	-	Possible	No Survival
Coventry Reservoir	-	-	Unknown	No Survival
Deep Pond	No Boating	Fly Fishing Only	Unlikely	No Survival
Flat River Reservoir	Private & Public	Private	Unlikely/ Possible	No Survival
Georgiaville Pond	Cartop Boat Launch	Town Residents	Unlikely	No Survival
Handy Pond	Shore Access Only	Limited Fishing	Unlikely	Poor to Moderate Growth
Hundred Acre Pond	Launch Closed	-	Unlikely	No Survival
Indian Lake	Slab Boat Launch	10 HP Motor	Unlikely	No Survival
J.L. Curran Reservoir	Boat Launch	10 HP Motor	Unlikely	No Survival
Keech Pond	Boat Launch	10 HP Motor	Unlikely	No Survival

Larkin Pond	Private Launch	No Public Access	Unlikely	No Survival
Locustville Pond	Gravel Boat Launch	10 HP Motor	Unlikely	No Survival
Long Pond	Shore Access Only	-	Unlikely	No Survival
Meadowbrook Pond	Cartop Boat Launch	No Outboard Motors	Unlikely	No Survival
Mishnock Pond	Cartop Boat Launch	-	Unlikely	Poor to Moderate Growth
Moswanicut Reservoir	Public Usage Prohibited	Public Usage Prohibited	Unlikely	No Survival
Olney Pond	Boat Launch	10 HP Limit Motor	Unlikely	Low Survival
Pascoag Reservoir	Boat Launch	-	Possible	No Survival
Pasquisett Pond	Private Launch	Private	Possible	No Survival
Pawtucket River at Bradford	Boat Launch	-	Possible	No Survival
Pawtucket River at Potter Hill	-	-	Unknown	No Survival
Pleasure Pond	-	-	Unknown	Poor to Moderate Growth
Ponaganset	Boat Launch	Limited Boating	Possible	No Survival
Prince's Pond	Shore Access Only	-	Unlikely	Very Good Growth
Queen River at Usequepaug	Private Boat Launch	-	Possible	No Survival
Quidnick Reservoir	Private Boat Launch	7.5 HP motor Max.	Unlikely	No Survival
Regulating Reservoir	Public Prohibited	Public Prohibited	Unlikely	Low Survival
Roosevelt Pond	-	-	Unknown	Poor to Moderate Growth
Saugatucket Pond	-	-	Unknown	No Survival
Schoolhouse Pond - Lower	Private Boat Launch	Land Owner Permission	Possible	No Survival
Schoolhouse Pond Upper	Private Boat Launch	Private	Possible	No Survival
Scituate Reservoir	Public Prohibited	Public Prohibited	Unlikely	Low Survival
Scott Pond	Shore Access Only	-	Unlikely	Low Survival
Secret Lake	Shore Access Only	-	Unlikely	Poor to Moderate Growth
Silver Lake	Shore Access	No Public Access	Unlikely	No Survival
Silver Spring Lake	Boat Launch	No Outboard Motors	Unlikely	Low Survival
Slack's Reservoir	Shore Access Only	-	Unlikely	No Survival
Slater Pond	Town Ramp	Town Residents	Possible	Low Survival
Smith and Sayles	Boat Launch	10 HP Motor	Unlikely	Low Survival
Spalding Lake	-	-	Unknown	No Survival
Sprague Reservoir -	-	-	Unknown	No Survival
Spring Grove Pond	Shore Access Only	-	Unlikely	No Survival
Spring Lake	Slab Boat Launch	No Outboard Motors	Unlikely	No Survival
Stafford Pond	Boat Launch	10 HP Motor	Unlikely	No Survival
Stillwater Pond	-	-	Unknown	No Survival
Tiogue Lake	Private/Gravel	-	Possible	Low Survival
Tucker Pond	Boat Launch	10 HP Motor	Unlikely	No Survival
Wakefield Pond	Boat Launch	No Outboard Motors i	Possible	No Survival
Wash Pond	Private Boat Launch	-	Possible	No Survival
Watchaug Pond	Boat Launch	-	Possible	No Survival
Waterman Reservoir	Private Boat Launch	-	Possible	No Survival
Wenscott Reservoir	-	-	Possible	Low Survival
Westconnaug	Public Prohibited	Public Prohibited	Unlikely	No Survival
White Pond	Private Boat Launch	-	Possible	No Survival
Wilson Reservoir	Boat Launch	10 HP Motor	Unlikely	No Survival
Woonasquatucket Reservoir - South	Boat Launch	10 HP Motor	Unlikely	No Survival
Woonasquatucket	Boat Launch	10 HP Motor	Unlikely	No Survival
Worden Pond	Boat Launch	-	Possible	No Survival
Wyassup Lake	-	-	Unknown	No Survival
Wyoming Pond	Gravel Launch	-	Possible	No Survival
Yawgoo Pond	Private Launch	No Public Access	Unlikely	No Survival

Appendix B.2 Boating Activity and Zebra Mussel Survival at River Monitoring Locations

SITE	RIVER NAME	Ave. Calcium - 1993	Zebra Mussel Survival - 1993 Ca Ave.	Calcium Range	Zebra Mussel Survival - Calcium Range	Boating Activity	Invasion Potential from boating
B - 1	Blackstone River	5.6 mg/L	No Survival	1 - 16.1 mg/L	No Survival to Poor - Moderate Growth	Large boats in some areas	Possible
B - 2	Blackstone River	5.5 mg/L	No Survival	2 - 14.8 mg/L	No Survival to Poor - Moderate Growth	Large boats in some areas	Possible
B - Ions	Blackstone River	7.3 mg/L	Low Survival	1 - 11.1 mg/L	No Survival to Poor - Moderate Growth	Large boats in some areas	Possible
All Sites	Average Calcium	6.1 mg/L	No Survival	-	-		
M - 1	Moshassuck River	16.5 mg/L	Poor to Moderate Growth	8.3 - 27.1 mg/L	Poor to Moderate Growth	Small carry-in boats	Unlikely
M - 2	Moshassuck River	13.8 mg/L	Poor to Moderate Growth	11 - 24.3 mg/L	Poor to Moderate Growth	Small carry-in boats	Unlikely
All Sites	Average Calcium	15.2 mg/L	Poor to Moderate Growth	-	-		
P - 1	Pawtuxet River	5.7 mg/L	No Survival	3 - 19.6 mg/L	No Survival to Poor - Moderate Growth	Large boats in some areas	Possible
P - 2	Pawtuxet River	5.5 mg/L	No Survival	3 - 19.2 mg/L	No Survival to Poor - Moderate Growth	Large boats in some areas	Possible
All Sites	Average Calcium	5.6 mg/L	No Survival	-	-		
TM - 1	Ten Mile River	15 mg/L	Poor to Moderate Growth	4 - 17.7 mg/L	Poor to Moderate Growth	Small carry-in boats	Unlikely
W - 1	Woonasquatucket River	5.0 mg/L	No Survival	1 - 17.3 mg/L	No Survival to Poor - Moderate Growth	Large boats in some areas	Possible
W - 2	Woonasquatucket River	3.2 mg/L	No Survival	1 - 9.1 mg/L	No Survival to Poor - Moderate Growth	Small carry-in boats	Unlikely
All Site	Average Calcium	4.1 mg/L	No Survival	-	-		

MAPS

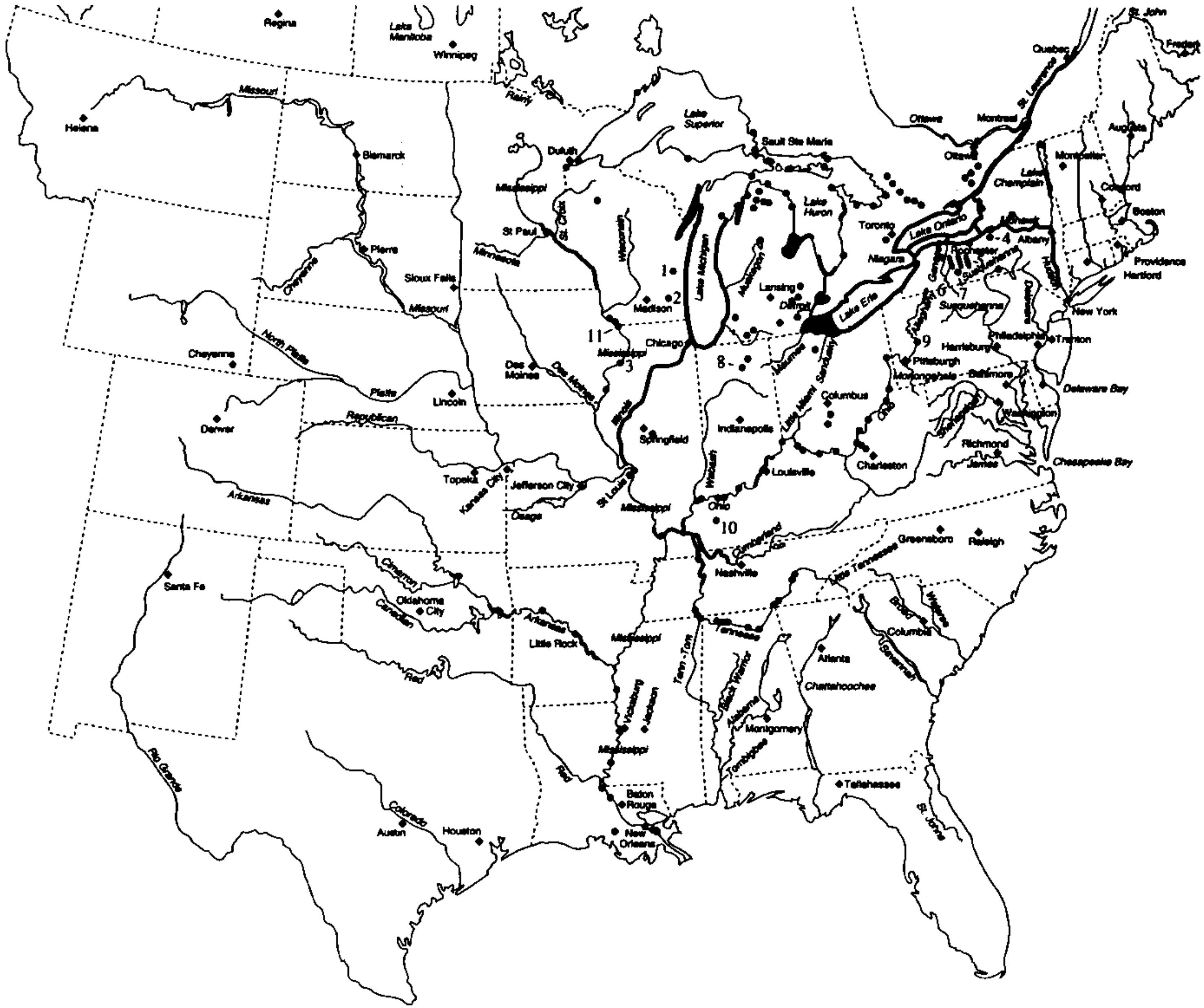
MAP 1

SIGHTINGS

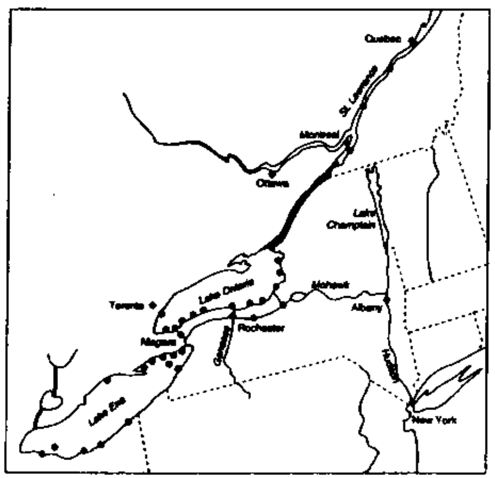
North American Range of the Zebra Mussel
as of 30 September 1994

Compiled by New York Sea Grant with information from: Empire State Electric Energy Research Corp., Fisheries and Oceans Canada, Great Lakes Sea Grant Network, Illinois Natural History Survey, Ontario Hydro, Ontario Ministry of Natural Resources, Tennessee Valley Authority, US Army Corps of Engineers, US Fish & Wildlife Service, and Utilities and others throughout North America.

Sitings:
1. Big Elkhart Lake, WI
2. Okauchee Lake, WI
3. Mississippi River, Davenport, IA.
4. Onondaga Lake, Syracuse, NY
5. Cayuga Lake – entire lake
6. Canandaigua Lake – entire lake
7. Keuka Lake, Penn Yan, NY
8. Tippecanoe Lake, IN
9. Allegheny River, river mile 43.7 (lock7), Kittanning, PA.
10. Green River, river mile 74, Livermore, KY
11. Mississippi River, Pool 11, river mile 586, Dubuque, IA



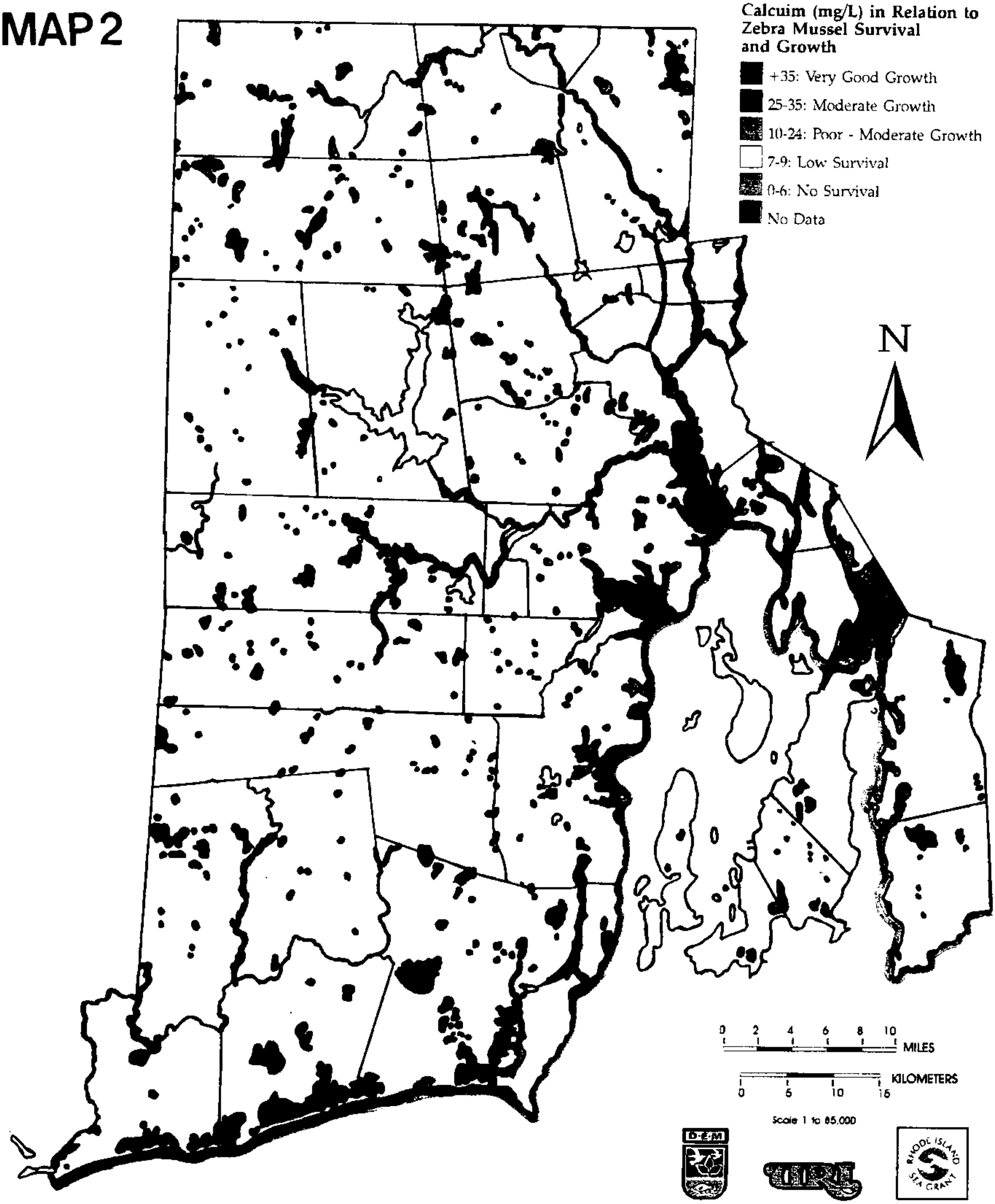
North American Range of the Quagga Mussel
as of 30 September 1994



The Likelihood Invasion of the Zebra Mussel into Monitored Fresh Water Areas in Rhode Island

1995 Report of Potential Zebra Mussel Habitats

MAP 2



The Likelihood Invasion of the Zebra Mussel into Fresh Water Systems

1995 Report of Boating Activity at Potential Zebra Mussel Habitats

College of Resource Development
University of Rhode Island

MAP3