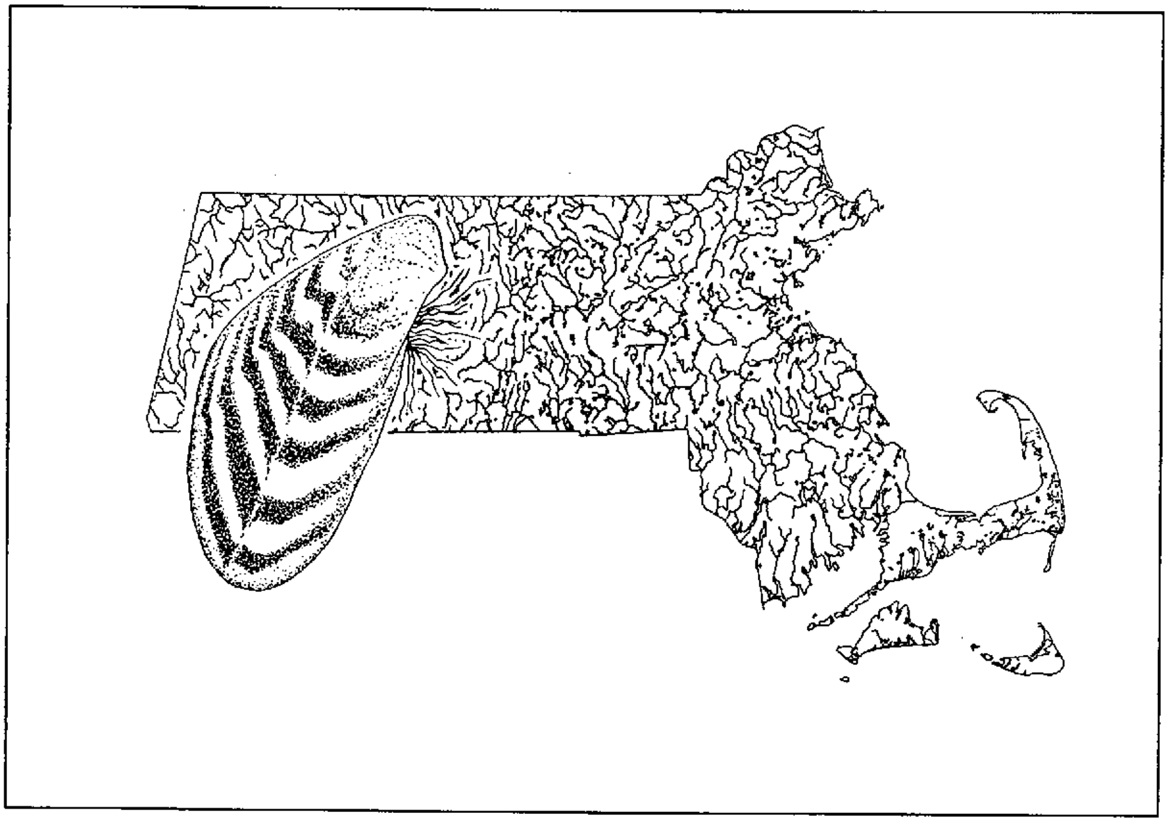
MS-Q-11

THE POTENTIAL FOR SPREAD OF THE EXOTIC ZEBRA MUSSEL (DREISSENA POLYMORPHA) IN MASSACHUSETTS



1993

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The Potential For Spread Of The Exotic Zebra Mussel (*Dreissena polymorpha*) In Massachusetts

(Report MS-Q-11)

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Abstract

The zebra mussel, _Dreissena polymorpha_, a native of European freshwater rivers and lakes, was first reported from the North American Great Lakes in 1988. Since the initial report, the species has spread throughout most of the Great lakes and has moved eastward into the St. Lawrence River and the Hudson River. In most places were the species has become established it has impacted both water dependent industries and native biotic communities. Concern exists towards the possibility of the species invading New England fresh waters. In order to prepare for the possible colonization of Massachusetts, in particular, and the problems that might arise from such colonizations, it is first necessary to determine what water bodies are most susceptable to colonization and successful growth of the mussel. Using water chemistry data derived from several different sources and applied to three basic freshwater types (surface flowing, surface standing and groundwater), maps have been prepared showing areas within Massachusetts where the zebra mussel could become established and to what degree the species will become successful.

I. Introduction

The colonization and spread of exotic aquatic species throughout North America has been the cause of much public and scientific concern. Aquatic exotic species, especially invertebrates, often become pests by invading public water works and water dependent industries and power supply stations that use water for cooling. They also can introduce parasites into their new habitats and interfere with native species by displacing them or out-competing them for resources. The economic cost of ecological impacts is usually high as both commercially and recreationally important native species are reduced in numbers due to either direct or indirect effects of the exotic species.

To date Massachusetts has remained relatively free from the effects of exotic invertebrate species experienced elsewhere. For example, the rusty crayfish (Orconectes rusticus), which has caused extensive ecological problems in the lakes and rivers into which it has been introduced in other parts of North America, has not produced similar problems in Massachusetts, though it is present. Among the mollusks, only four exotic aquatic species have been introduced and established, all gastropods, and none of these have become pests or increased in numbers at the expense of native species. These few case histories do not suggest, however, that the state is immune to the more problematic exotic forms that have become established in other parts of the continent. Connecticut has witnessed the arrival of the asian clam (Corbicula cf. fluminea) (Morgan et al., 1991). The species, first observed near the Haddam nuclear power facility in the Connecticut River in 1990, has survived two winters in the river while expanding its range upstream to North Cromwell and downstream to East Haddam, and within this range has become the dominant mollusk. The success of the asian clam in the Connecticut River is almost surprising given that the species is not supposed to tolerate sustained near freezing temperatures characteristic of southern New England winters. Northeast Utilities Service Company personnel are currently monitoring the species as there is concern that the species will invade two power facilities within its current range.

Yet a greater threat in the person of the zebra mussel (D. polymorpha), and possibly another related species, the quagga mussel (Dreissena sp.), is looming just to the west of southern New England. The zebra mussel, like the asian clam, is a bivalve mollusk that has a recent marine ancestry but which has itself become fully adapted to fresh water. Unlike the mobile asian clam, the zebra mussel is attached to the substrate by a tangled web of resilient fibers, collectively called a byssus. The small (<50 mm) wedge-shaped mussel superficially resembles small specimens of the common marine blue mussel along the coast. Uneroded shells have a characteristic pattern of broken or wavy alternating bands of light and dark pigment. As with the asian clam, the zebra mussel is enormously prolific, an adult female can produce up to 40,000 eggs, and no potentially effective competitors exist among the native bivalve species. Although adapted to fresh water, the zebra mussel can easily acclimate to salinities of 2.5 o/oo. An important difference between the two species is that the zebra mussel prefers cooler water and would thrive in near freezing water temperatures characteristic of southern New England winters.

From its first discovery in Lake St. Clair, Michigan, in 1988, and first notifications of its presence in North America in the scientific literature (Hebert et al., 1989; Griffiths et al., 1991), Dreissena polymorpha has spread through most of the lower Great lakes, portions of the remaining Great Lakes, and has entered the Illinois and Ohio rivers. Eastward, it has moved down the St. Lawrence River and migrated through the Erie Canal into the Susquehana and Hudson rivers. Powell and Strayer (undated) predicted that the zebra mussel will become a problem for water users in the Hudson River by the end of 1992. Their apprehension is well founded. In the Great lakes the species has invaded several municipal water supply systems causing stopage of flow and subsequent fouling of the water. Zebra mussels have been implicated in the reduction of lake plankton important to early life stages of fish (Hebert et al., 1991) and have impacted already stressed native mussel populations by attaching to the shells of living animals and impeding their physiological activities (Hebert et al., 1991; Gillis and Mackie, 1992; Hunter and Bailey, 1992). Municipalities and industry in areas supporting large populations can anticipate modification of water supply systems to avoid infestation by zebra mussels. Fisheries biologists and management personnel will have to monitor the affects on plankton and fish populations.

Interest and concern over the zebra mussel has precipitated a number of symposia on the biology and control of the species and have been sponsored by such professional societies as the National Shellfisheries Association, American Fisheries Society, North American Benthological Society, Environment Canada, and Sea Grant (NOAA) affiliates. Countless newspaper and magazine articles have been written tracking the species' spread and discussing its realized and potential impacts. For comprehensive reviews on the brief history of the zebra mussel in North America see O'Neill and MacNeill (1991), Miller et al. (1992), and Klauber (1992). A national clearinghouse has been created and can be consulted for information on the zebra mussel. This organization (Zebra Mussel Information Clearinghouse, State University of New York, Brockport, NY 14420) produces a newsletter which updates the status of the species in North America and ongoing research.

An often cited concern is the need to assimilate data that can be used to alert and enable agencies to prepare for the arrival of exotic species and develop management plans to control their spread. The present document attempts to determine, on the basis of certain chemical parameters, areas in Massachusetts (drainage systems and municipalities) in which the zebra mussel could become established and survive. With such information, agencies can focus their attention on potentially affected areas and develop public awareness and strategies concerning monitoring activity and control.

II. Colonization and spread of the zebra mussel

Criteria for Colonization

Several recent studies discuss environmental and chemical parameters identified or suggested to be important to the survival and reproduction of the zebra mussel. The species is generally tolerant of a wide temperature range (Strayer, 1991) but seems to prefer water temperatures above 16^{o}C for successful reproduction. The annual temperature pattern of Massachusetts clearly falls within the preferred range of the species and will not be a limiting factor to its colonization of the state (see Strayer, 1991). Certain chemical factors are important, especially pH and calcium content. The zebra mussel is apparently sensitive to calcium levels during early development (Sprung, 1987). Subsequent investigations, which include reviews the of European literature, further show that the zebra mussel would need water relatively high in calcium content to complete development. Ramcharan et al. (1992) list certain chemical parameters of several European lakes supporting the species and the largest populations exist in waters averaging 40 mg/l calcium. Strayer (1991) has provided estimates indicating that survivorship occurs above 20 mg/l calcium while the preferred range seems to be above 30 mg/l. Neary and Leach (1992) categorized Sprung's (1987) observed requirements. These are 12 mg/l for minimal survival, partial recruitment up to 20 mg/l, and most successful growth and development at levels above 28 mg/l. Hincks and Mackin (1992) experimentally determined that current North American populations require >9 mg/l of calcium, measured alkalinities of >15 mg/l (as $CaCO_3$) or measured hardness of >32 mg/l (as $CaCO_3$) for successful growth. Another factor taken into consideration was pH. Sprung (1987) indicated that pH >7.4 was necessary for continued existence of the zebra mussel in European lakes. Neary and Leach (1992) utilized this parameter (along with calcium content) to determine the liklihood of spread of the species in the Canadian Great lakes region.

Limiting Factors

Three important limiting factors in the colonization and spread of zebra mussels in Massachusetts are the loss of buffering capacity in certain watersheds (acidification), naturally occurring acidic waters, and periodic pollution of waterways including the presence of phosphorus. Ramcharan et al. (1992) concluded from a study of European lakes containing zebra mussels that the species was found only in waters with low phosphorus concentrations (averaging <0.12 mg/l). The presence of >0.12 mg/l phosphorus was considered in determining the possibility of existence in surface standing waters (Fig. 6). From time to time most of the surface waters in Massachusetts have levels of phosphorus above 0.12 mg/l and this factor in conjunction with other forms of pollution might prevent the successful colonization and spread of zebra mussels in several lakes and ponds of the state. The Nashua and French River basins have relatively high nutrient levels, especially phosphorus, and although containing adequate calcium to support zebra mussels, may be impaired beyond the species level of tolerance.

Areas of Potential Colonization

The first three maps (Figures 1-3) are for reference. Figures 1 and 2 are from the Massachusetts Department of Environmental Protection and show the drainage system arrangement followed in this study. Figure 3 is from the Massachusetts Department of Environmental Management. The maps showing areas of likely colonization (Figs. 4-6) were prepared using biological and threshold data discussed above under criteria. Since the majority of water quality surveys undertaken in Massachusetts use alkalinity or hardness as an indication of the presence and amount of calcium, rather than measuring calcium alone, a minimum sustained value of 20 mg/l alkalinity or hardness was elected as the lower limit for optimal growth and spread of the zebra mussel. In a few instances, calcium data was available and used (such as groundwater evaluations). Additionally, measured pH above 7.4 was considered necessary for "optimal" growth of the species in Massachusetts.

A number of sources have been consulted in the preparation of the maps. Flowing surface water (rivers and streams) data used to develop Fig. 4 were derived from a number of water quality reports generated by the Division of Water Pollution Control (DWPC), Massachusetts Department of Environmental Protection (Appendix 1). The area in extreme western Massachusetts considered to contain the most favorable conditions (Hoosic and Housatonic River drainages) shows alkalinity consistently over 20 mg/l. Other areas marginally to moderately suitable demonstrate a range of 10 to 20 mg/l alkalinity. Groundwater information from Trombley (1992) was used to generate Fig. 5. The area of highest liklihood of survival is similar to Fig. 4 and is characterized by high calcium concentration (>20 mg/l). An alkalinity concentration of 15 to 20 mg/l is considered suitable for moderate and possibly highly successful infestation, while areas with 10 to 15 mg/l will permit sustained but somewhat limited existence. Standing surface water (lakes and ponds) data were analyzed by township (Fig. 6) as most studies of this nature are concerned with acidity in municipal public water supplies. A number of DWPC studies (Appendix 1) provided data on this aspect along with Anon. (1986a,b), Bratton (1991), Godfrey (1988), Layzer et al. (1988), and Mattson et al. (undated). The determination of successful and moderate to marginal survival is the same as developed for Fig. 4. However, the analysis presents the smallest area within the state in which the zebra mussel is predicted to survive. Among the three aquatic parameters assessed (surface flowing, surface standing, and groundwater) standing surface water has apparently become the most susceptible to acidification and according to Godfrey (1988), 66% of the monitored standing waters in Massachusetts have alkalinity levels below 10 mg/l, levels presumably too low for successful growth of zebra mussel populations.

No attempt was made to compare statistically areas or drainages partly because differences existed in sampling and water analysis methodology from study to study. The maps are at best simplistic and present only a general picture of potential areas of colonization. Notwithstanding these shortcomings a "summary" map (Fig. 7) is presented that shows regions within the state believed to be most susceptible to the establishment of large, potentially problematic populations. East of the carbonate rich Taconic region in Berkshire County, the species will encounter some difficulty surviving everywhere it is introduced because of any or a combination of limiting factors discussed above. One of the two principal areas that could support large populations of the species is the Connecticut River basin. The major tributaries, especially to the east, fluctuate with respect to their alkalinity and pH values, and may be marginal habitats at best. Also, within the Connecticut River watershed many lakes, ponds and reservoirs will certainly not support populations of the zebra mussel due to their persistently low pH. The other likely area of successful colonization is a zone roughly corresponding to the Eastern Plateau and encompassing most portions of the Merrimack River drainage. Most of the drainage could support large populations of the species, however, unsuitable water quality within the Nashua River portion of the drainage has resulted in its elimination from the potential range. The Eastern Plateau is favored over other nearby physiographic regions by the moderate buffering capabilities of the underlying rocks. The remaining portions of the state will most likely not support the species. Water of the Central Upland is poor in calcium and much of the region has lost its buffering capability. The eastern and southeastern parts of the state are naturally acidic and most of the drainages in the south central part of Massachusetts (Fig. 7, Thames and Narragansett Bay) which include the French and Blackstone rivers are impaired. Increased colonization can be expected if the water quality improves. Liming (Anon., 1984) of acidified standing water may restore some of the buffering capabilities of affected water but will probably not ever achieve the levels the alkalinity necessary to support zebra mussels.

Means or Vehicle of Colonization

For reasons stated by Smith (1991), introduction of zebra mussels into Massachusetts would be by artificial means, primarily by trailered boats that have picked up adults or larvae while in mussel infested waters elsewhere. The larvae can survive in undrained bait wells, buckets, live tanks, and bilge water. Larvae attach to hulls left in water for a period of time and as adults can survive out of water for up to several days depending upon weather conditions. A less likely process would be release of individuals otherwise purchased or collected for use as bait or aquarium pets. The asian clam, which has invaded the Connecticut River in Connecticut, was likely introduced by the latter method. The asian clam has been observed for sale in pet stores in Massachusetts (Smith, Pers. obser.) and Connecticut (E. Jokinen, Pers. comm.).

III. Summary and Recommendations

A review of several sources of information on the chemistry of three different freshwater habitats (surface flowing, surface standing, and groundwater) in Massachusetts has revealed that the zebra mussel (and possible related forms) could colonize and infest certain waters of the state. It is important that a public information program be initiated alerting the sport fishing community, especially, and the pet trade industry to the need for keeping the zebra mussel (and other exotic species) out of Massachusetts. State agencies with jurisdiction over public water supply or recreational use of public water should consider promoting programs to carry out this warning.

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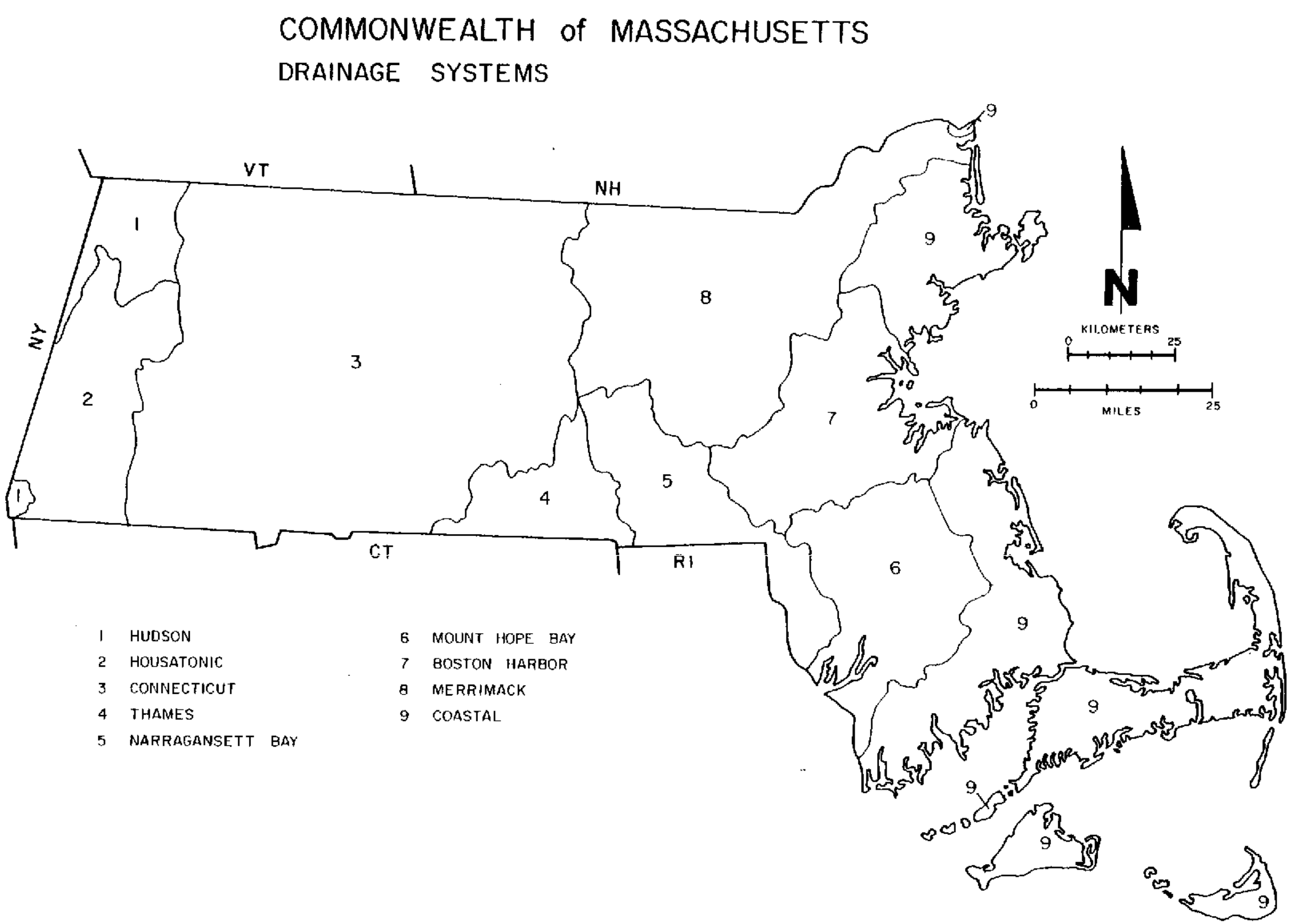

Figure 1. Map of principal drainage systems in Massachusetts.

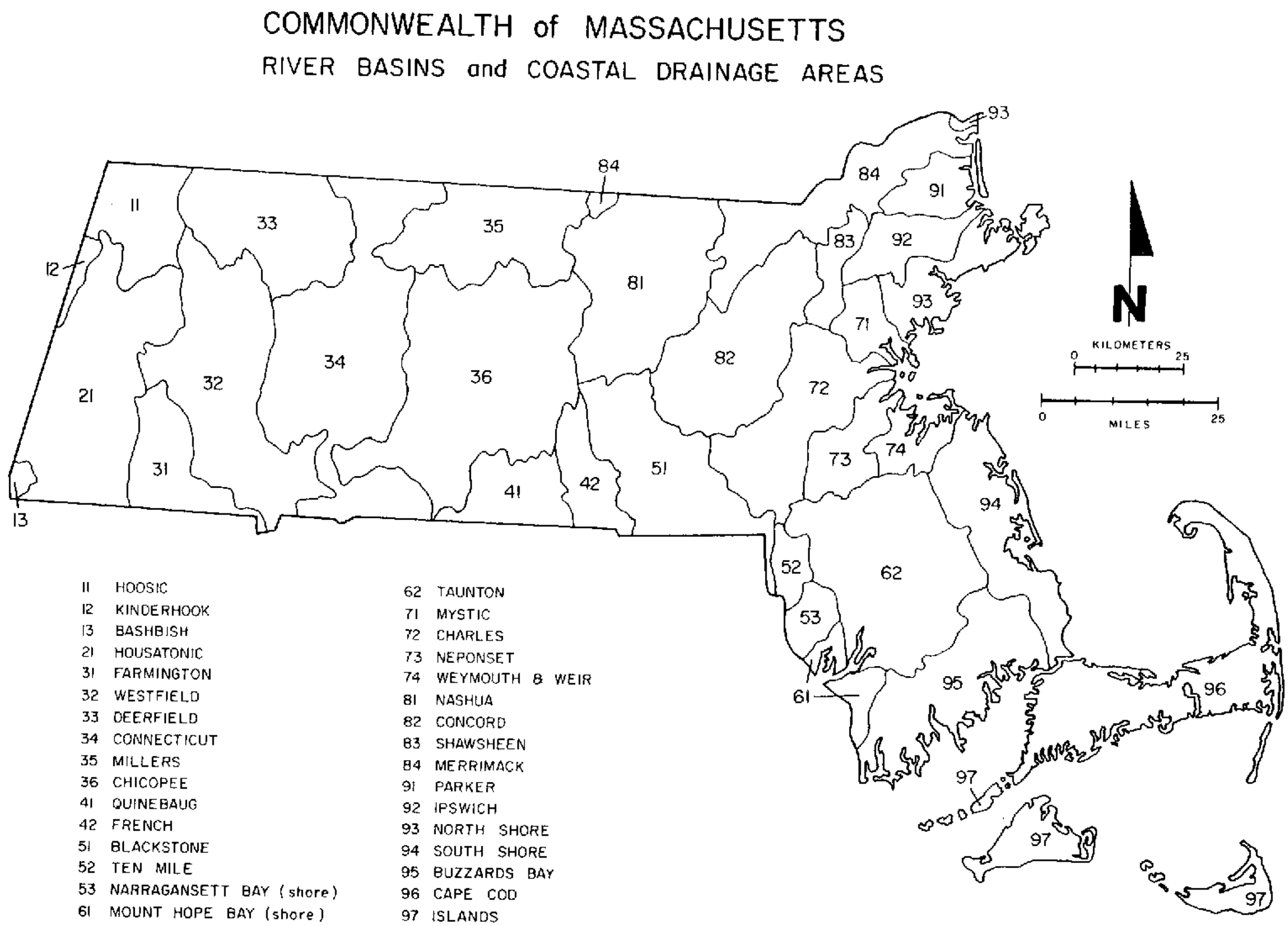

Figure 2. Map of principal drainages of Massachusetts divided into specific basins and coastal drainage areas.

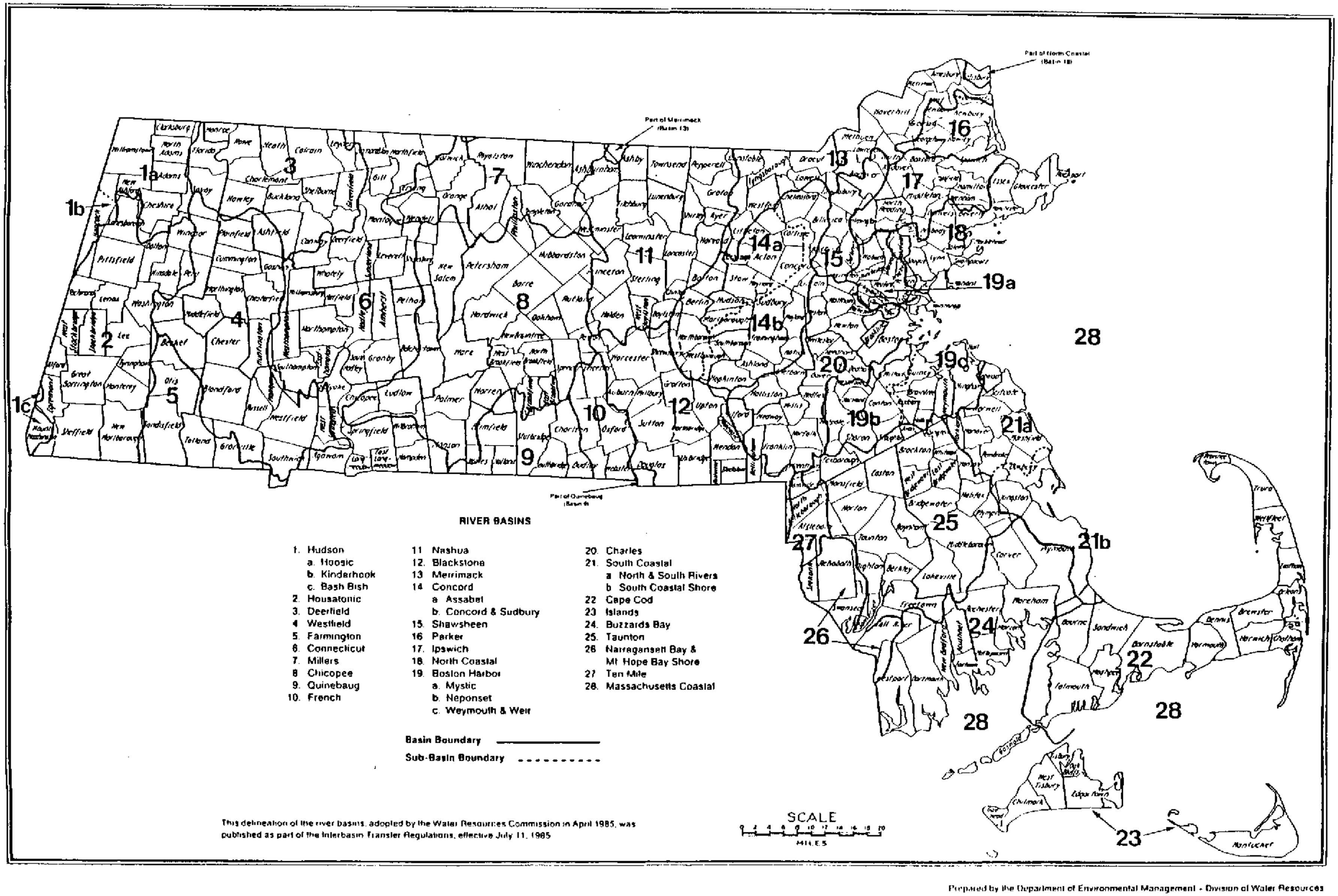

Figure 3. Map of municipalities and drainage areas in Massachusetts.

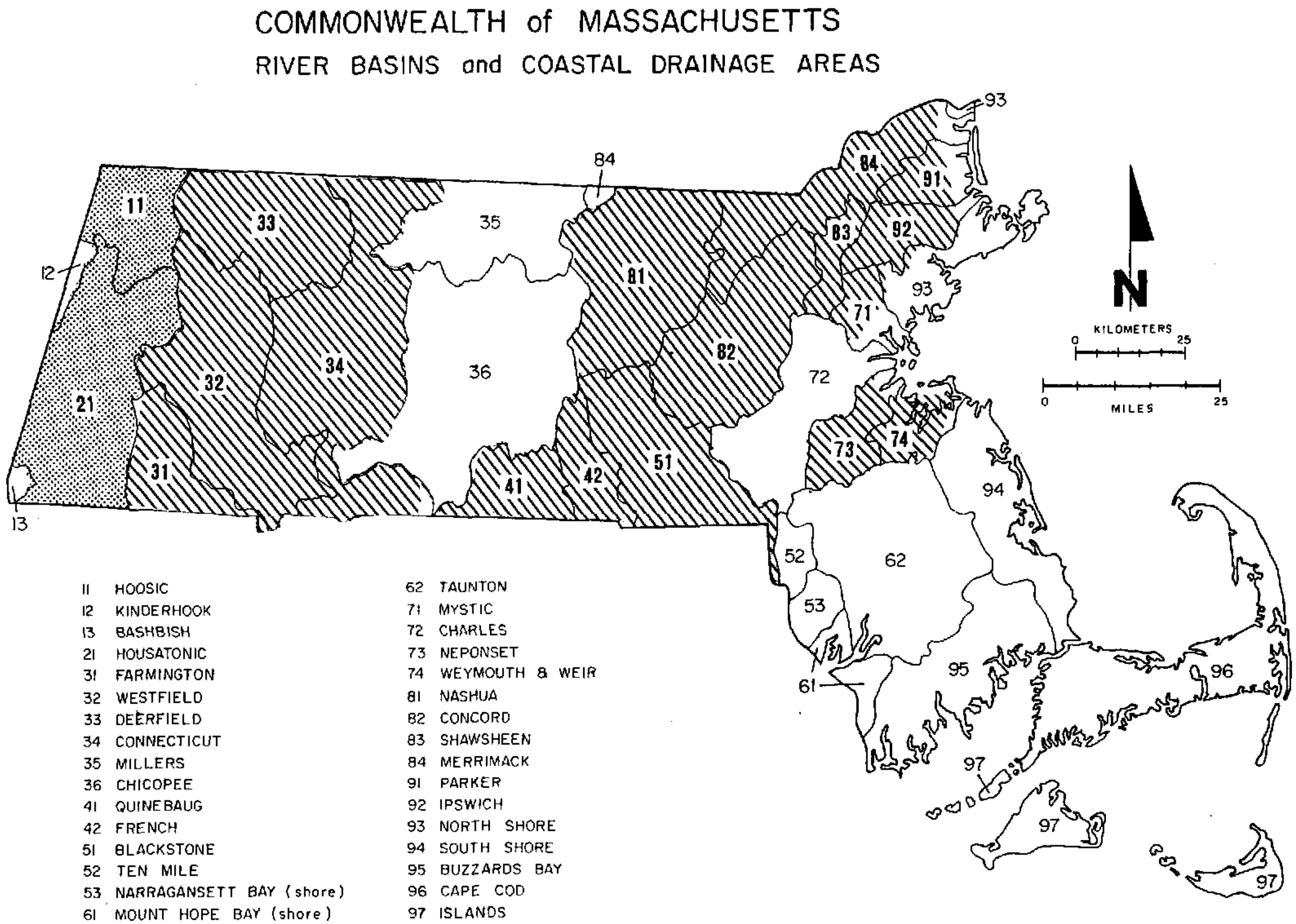

Figure 4. Map showing watersheds in Massachusetts susceptable to colonization by the zebra mussel using river survey (surface flowing water) data; high (stippled), moderate to marginal (cross hatching), no colonization (clear).

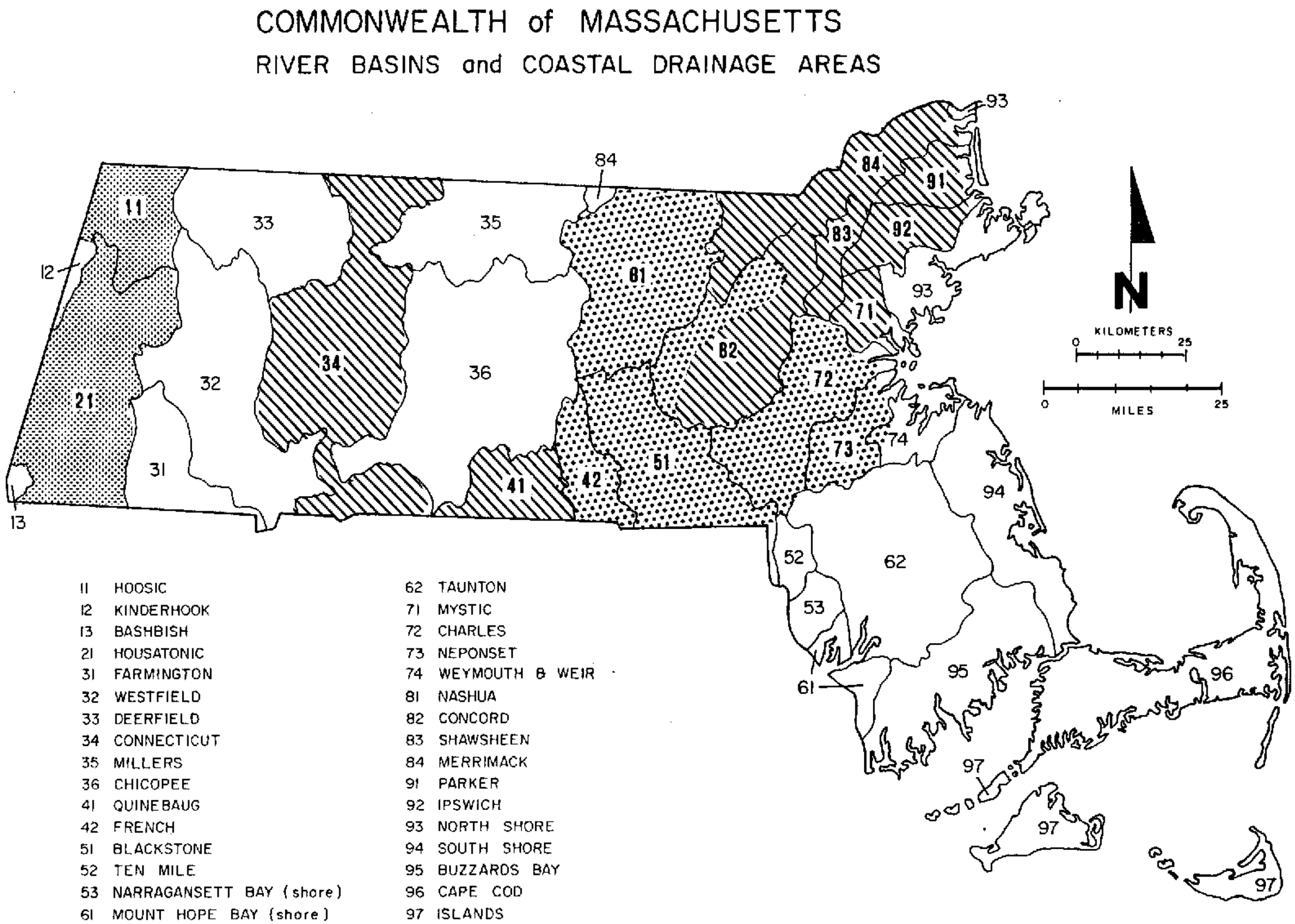

Figure 5. Map showing watersheds in Massachusetts susceptable to colonization by the zebra mussel using groundwater data; high (fine stipple), high to moderate (cross hatching), moderate to marginal (coarse stipple), no colonization (clear).

COMMONWEALTH of MASSACHUSETTS

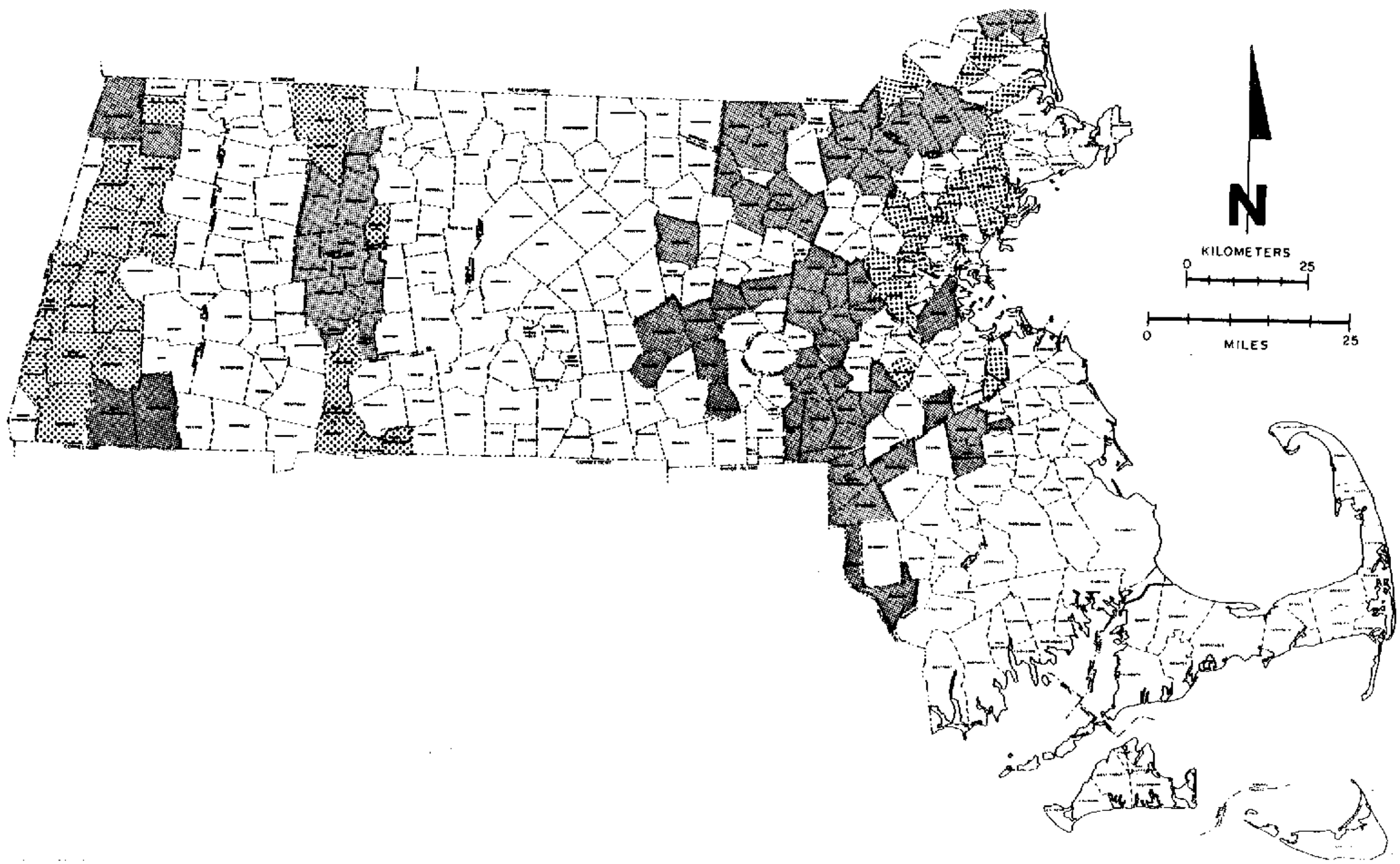

Figure 6. Map showing municipalities in Massachusetts susceptable to colonization by the zebra mussel using acid monitoring (surface standing water) data; high (light shading), moderate to low (dark shading), no colonization (clear).

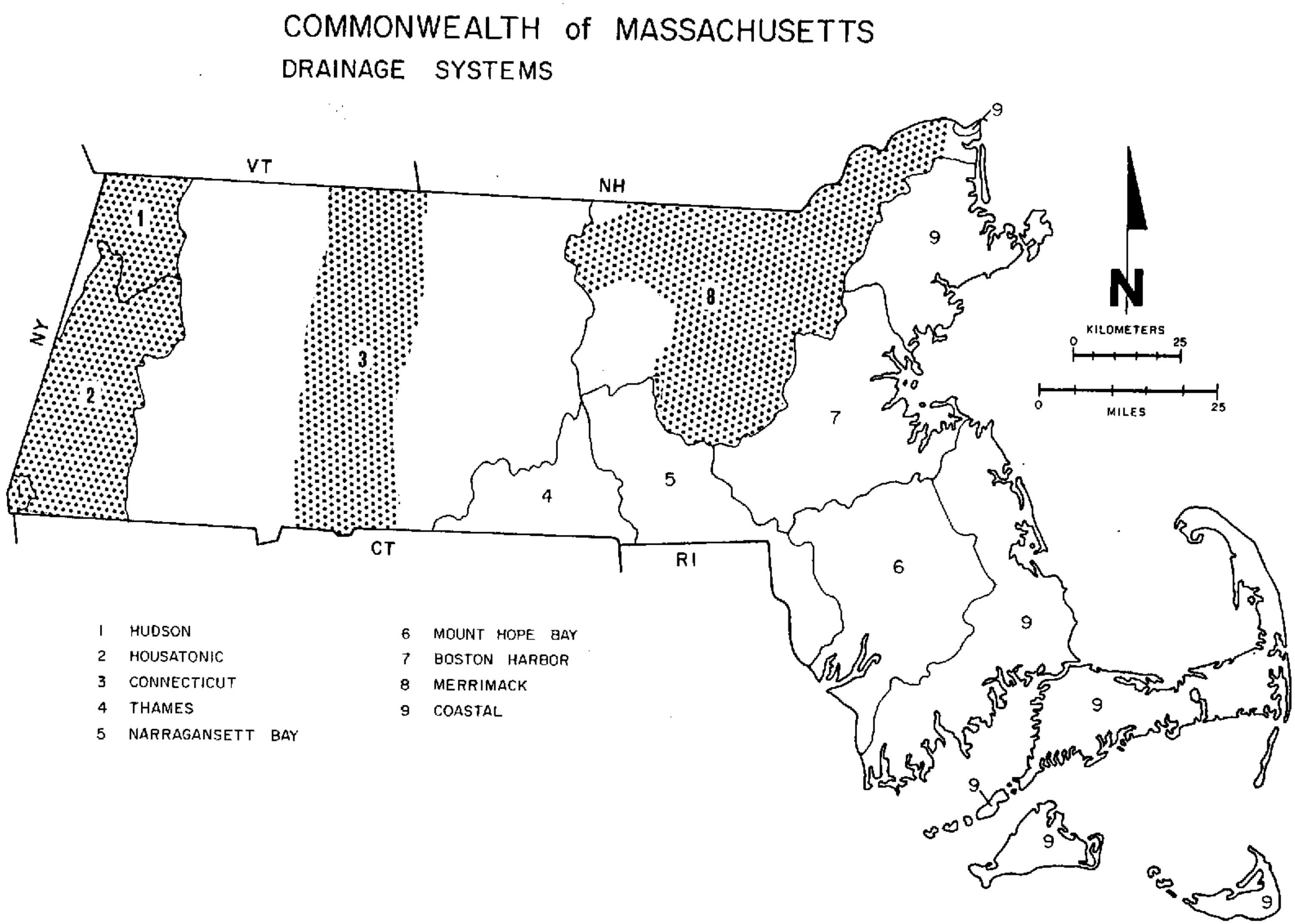

Figure 7. Summary map showing areas (stippled) of highest liklihood of successful colonization and growth of the zebra mussel in Massachusetts.

Appendix 1

HUDSON DRAINAGE SYSTEM (1)[1]
HOOSIC RIVER BASIN (11)

Hoosic River Basin Water Quality Survey Data. 1977. 77 p., 24 tables, 19 figs.

Hoosic River Basin Water Quality Survey Data. 1977 and 1978. 84 p., 26 tables, 23 figs.

Cheshire Lake Water Quality Study. 1980. 66 p., 20 tables, 6 figs.

HOUSATONIC DRAINAGE SYSTEM (2)
HOUSATONIC RIVER BASIN (21)

Housatonic River Basin Special Water Quality Survey Data. 1976 and 1977. 13 p., 9 tables.

Housatonic River Basin Water Quality Analysis. 1969 and 1974. 115 p. + appendices, 17 tables, 15 figs.

Baseline Water Quality Studies of Selected Lakes and Ponds in the Housatonic River Basin. 1974. 131 p., 23 tables, 36 figs.

Pontoosuc Lake Water Quality Study. 1975 and 1976. 43 p. + appendices, 9 tables, 12 figs.

Baseline Water Quality Studies of Selected Lakes and Ponds in the Housatonic River Basin. 1976. 91 p., 16 tables, 36 figs.

CONNECTICUT DRAINAGE SYSTEM (3)
FARMINGTON RIVER BASIN (31)

Farmington River Basin Water Quality Survey Data. 1974. 45 p., 18 tables, 12 figs.

Baseline Water Quality Studies of Selected Lakes and Ponds in the Farmington River Basin. 1974 and 1979. 78 p., 21 tables, 24 figs.

CONNECTICUT DRAINAGE SYSTEM (3)
WESTFIELD RIVER BASIN (32)

Westfield River Basin Water Quality Analysis. 1978. 121 p., 21 tables, 27 figs.

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[1] Number in parenthesis following drainage system corresponds to Figs. 1 and 7, number following river basin corresponds to Figs. 2, 4, 5.

Baseline Water Quality Studies of Selected Lakes and Ponds in the Westfield River Basin. 1978 and 1979. 143 p. + appendices, 49 tables, 47 figs.

CONNECTICUT DRAINAGE SYSTEM (3)
DEERFIELD RIVER BASIN (33)

Deerfield River Basin Water Quality Survey Data. 1977. 105 p., 28 tables, 49 figs.

CONNECTICUT DRAINAGE SYSTEM (3)
CONNECTICUT RIVER BASIN (34)

Connecticut River Water Quality Survey Data. 1980. 60 p., 29 tables, 5 figs.

Connecticut River Water Quality and Wastewater Discharge Survey Data. 1982 and 1983. 198 p., 83 tables, 38 figs.

Baseline Water Quality Studies of Selected Lakes and Ponds in the Connecticut River Basin. 1978 and 1979. 150 p. + appendices, 74 tables, 77 figs.

CONNECTICUT DRAINAGE SYSTEM (3)
MILLERS RIVER BASIN (35)

Millers River Basin Water Quality Survey Data. 1987. viii + 88 p., 38 tables, 38 figs.

Millers River Basin Water Quality Analysis. 1987. xiv + 175 p. (including appendices), 43 tables, 25 figs.

CONNECTICUT DRAINAGE SYSTEM (3)
CHICOPEE RIVER BASIN (36)

Chicopee River Basin Water Quality Survey Data. 1972 and 1974. 117 p., 50 tables, 33 figs.

Chicopee River Basin Water Quality Survey Data. 1981. 55 p., 21 tables, 12 figs.

Quabbin Tributaries Water Quality Data Report. 1989 and 1990. 143 p., 101 tables, 3 figs.

Lake Mattawa Water Quality Study. 1975 and 1976. 49 p. + appendices, 8 tables, 12 figs.

Red Bridge Impoundment Water Quality Study. 1977 and 1978. 102 p., 19 tables, 9 figs.

Queen Lake Water Quality Study. 1978 and 1979. 85 p., 22 tables, 5 figs.

Baseline Water Quality Studies of Selected Lakes and Ponds in the Chicopee River Basin. 1978, 1979 and 1980. 94 p. + appendices, 33 tables, 43 figs.

THAMES DRAINAGE SYSTEM (4)
QUINEBAUG RIVER BASIN (41) AND FRENCH RIVER BASIN (42)

French and Quinebaug River Basins Water Quality Survey Data. 1972 and 1974. 80 p., 16 tables, 23 figs.

Baseline and Water Quality Studies of Selected Lakes and Ponds in the French and Quinebaug River Basins. 1974 and 1976. 144 p., 36 tables, 59 figs.

Webster Lake Water Quality Study. 1975 and 1976. 140 p., 34 tables, 14 figs.

Cedar Pond Diagnostic Study. 1980 and 1981. 100 p., 24 tables, 8 figs.

NARRAGANSETT BAY DRAINAGE SYSTEM (5)
BLACKSTONE RIVER BASIN (51)

Blackstone River Basin Water Quality Survey Data. 1980. 67 p., 21 tables, 14 figs.

Lake Quinsigamond Water Quality Data. 1971. 71 p., 53 tables, 2 figs.

Indian Lake Water Quality Study. 1975 and 1976. 44 p. + appendices, 9 tables, 8 figs.

Baseline Water Quality Studies of Selected Lakes and Ponds in the Blackstone River Basin. 1977. 172 p., 56 tables, 63 figs.

NARRAGANSETT BAY DRAINAGE SYSTEM (5)
TEN MILE RIVER BASIN (52)

Ten Mile River Basin Water Quality Survey Data. 1984. viii + 90 p., 57 tables, 2 figs.

Attleboro Wastewater Treatment Plant Survey Report. 1985. vii + 22 p. + appendices, 6 tables, 5 figs.

Ten Mile River Basin Water Quality Analysis. 1968. 59 p., 8 tables, 13 figs.

MOUNT HOPE BAY DRAINAGE SYSTEM (6)
MOUNT HOPE BAY (SHORE) DRAINAGE AREA (61)

Mount Hope Bay Water Quality Survey Data. 1971. 49 p., 29 tables, 5 figs.

South Watuppa Pond Water Quality Study. 1974 and 1975. 69 p., 17 tables, 8 figs.

MOUNT HOPE BAY DRAINAGE SYSTEM (6)
TAUNTON RIVER BASIN (62)

Taunton River Basin Water Quality Survey Data. 1975. 225 p., 25 tables, 5 figs.

Baseline Water Quality Studies of Selected Lakes and Ponds in the Taunton River Basin. 1975. 85 p., 27 tables, 27 figs.

Baseline Water Quality Studies of Selected Lakes and Ponds in the Taunton River Basin. 1975, 1979 and 1980. 116 p., 41 tables, 38 figs.

Norton Reservoir Water Quality Study. 1975 and 1976. 113 p., 29 tables, 10 figs.

BOSTON HARBOR DRAINAGE SYSTEM (7)
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