Report to the

MASSACHUSETTS BAYS PROGRAM

# THE MASSACHUSETTS BAYS MANAGEMENT SYSTEM: A VALUATION OF BAYS RESOURCES AND USES AND AN ANALYSIS OF ITS REGULATORY AND MANAGEMENT STRUCTURE

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## FOREWORD

The roots of the Massachusetts Bays Program extend back to 1982, when the City of Quincy filed suit against the Metropolitan District Commission and the Boston Water and Sewer Commission over the chronic pollution of Boston Harbor, Quincy Bay, and adjacent waters. Outdated and poorly maintained sewage treatment plants on Deer Island and Nut Island were being overwhelmed daily by sewage from the forty-three communities in the Metropolitan Boston area. Untreated and partially treated sewage were spilling into Boston Harbor.

Litigation over the pollution of Boston Harbor culminated in 1985 when the United States Attorney filed suit on behalf of the Environmental Protection Agency against the Commonwealth of Massachusetts for violations of the Federal Clean Water Act. The settlement of this suit resulted, in 1988, in the creation of the Massachusetts Water Resources Authority, the agency currently overseeing a multi-billion dollar project to repair and upgrade Metropolitan Boston's sewage treatment system. In addition, the settlement resulted in the establishment of the Massachusetts Environmental Trust - an environmental philanthropy dedicated to improving the Commonwealth's coastal and marine resources. Two millon dollars in settlement proceeds are administered by the Trust to support projects dedicated to the restoration and protection of Boston Harbor and Massachusetts Bay.

The Trust provided $1.6 million to establish the Massachusetts Bays Program, a collaborative effort of public officials, civic organizations, business leaders, and environmental groups to work towards improved coastal water quality. The funding was used to support both a program of public education and a scientific research program focusing on the sources, fate, transport and effects of contaminants in the Massachusetts and Cape Cod Bays ecosystem. To maximize the efficiency of limited research funding, the sponsored research program was developed in coordination with research funded by the MWRA, the United States Geological Survey, and the Massachusetts Institute of Technology Sea Grant Program. The study described in this report provides a strategy for assessing the value of the resources and uses of the Bays and their relationship to water quality. In addition, it provides an analysis of the regulatory and management structure of the Bays.

In April, 1990, following a formal process of nomination, the Massachusetts Bays Program became part of the National Estuary Program. The additional funding provided as part of this joint program of the Environmental Protection Agency and the Commonwealth of Massachusetts is being used to continue a coordinated program of research in the Massachusetts Bays ecosystem, as well as supporting the development of a comprehensive conservation and management plan for the coastal and marine resources of Massachusetts and Cape Cod Bays.

The information in this document has been subject to Massachusetts Bays Program peer and administrative review and has been accepted for publication as a Massachusetts Bays Program document. The contents of this document do not necessarily reflect the views and policies of the Management Conference. The reader is advised to keep in mind the limitations acknowledged by the authors of this report. In particular, note that in several key areas, reliable data is unavailable (e.g., the value of recreational shellfishing). Further, note that the public health focus used in this report is only one possible approach to specifying the relationship between water quality and Bays resource values.

The Massachusetts Bays Program is sponsored by the Massachusetts Executive Office of Environmental Affairs through the Coastal Zone Management Office and the U.S. Environmental Protection Agency, Region I, John F. Kennedy Federal Building, Boston, MA 02203.

## EXECUTIVE SUMMARY

Research for this project was designed to address two overall goals. First, we develop an approach to enhance the ability of Massachusetts Bays managers to assess the likely impact of changes in Bays water quality on the use and value of coastal resources. Second, we analyze the existing mix of coastal management strategies in order to determine the degree to which existing governance practices are sufficient for Bayswide resource management. These two goals are addressed in Parts I and II of our report.

### Part I

### Determination and Benefit Valuation of the Uses and Resources of the Massachusetts Bays

The central organizing theme of Part I is to focus on the social value provided by the Bays system. We provide a strategy to articulate and value those uses and resources which supply value to humans. Accordingly, this part of the report addresses three major tasks. First, we discuss the broad range of resources and uses within the Massachusetts Bays system that provide value to the people of the Commonwealth. Second, we describe and analyze those resources and uses for which anthropogenic contaminants limit their value and benefit to society. To the degree allowed by available data, we also characterize the relationship among: (i) resources/uses which provide the most direct human benefit, (ii) the contaminants limiting those human uses, and, (iii) the management strategies designed to reduce environmental contaminants and enhance human use. And, third, we evaluate the methods available to determine the benefit value of Bays system uses and resources, and provide estimates of such values where data are sufficient.

**Modeling Human Influences**

An assertion that human activities influence both ecological and public health attributes is hardly controversial. However, effective management practices require not only the assertion of a relationship but insights sufficient to enable quantification. The ability to quantify those relationships requires a dynamic and interactive model which describes the nature of important relationships and provides a mechanism to analyze critical information. Such a model is represented in Figure 2 (from the report).

This model describes a system in which various **environmental control** strategies (such as Combined Sewer Overflow (CSO) controls, chlorination of wastewater effluent, or non-point source controls) regulate the level of critical environmental attributes/limiting factors (such as enteric pathogens or residual chemicals). These **limiting factors** can impact directly the nature of **resources and uses** (such as commercial shellfishing or recreational bathing) within the Bays system. The importance of this part of the model is that it more precisely defines a set of discrete relationships which affect the ability of humans to use Bays system resources.

However, simply characterizing the impact on use levels does not add directly to our understanding of effective management regimes. A central thrust of our work has been to focus on the need to calculate the social value gained from reductions in contaminant loads. Considerations of **use/resource value** (for individual uses) and for bay-wide total **benefit value** should contribute to the development of **management options** to enhance sustainable human use. While conceptualizing such a model may be easy, developing a fully specified, parametarized and operational version is not. Indeed it is important to distinguish between the process of specifying critical relationships and generating sufficient, focused and detailed information to allow for a fully dynamic and parameterized model.

In order be able to move beyond the general conceptual model illustrated in Figure 2, the first step is to specify the nature of a series of critical relationships that articulate the influence of various environmental controls on environmental factors which limit the sustainable use of Massachusetts Bays resources and uses. For example, what would be the impact of fully chlorinating all Boston Harbor wastewater effluent (including CSO discharges) on levels of enteric pathogens in nearshore areas?; what would be the impact on benthic finfish populations of broad-based dredging of residual chemical contaminated sediments?; and, what impact would shifting the Massachusetts Water Resources Authority (MWRA) outfall have on bay-wide productivity of potentially toxic phytoplankton species?

However, for the proposed model to be fully operational an additional quantification or parameterization step must follow specification. Not only must the system be sufficiently understood to define critical relationships but data describing the degree to which changes will occur need to be available. When such insights and data are available the model herein described would provide managers with a dynamic, iterative and implementable model.

In general, one can articulate two ways in which human activity can influence the value of marine resources and coastal uses: those that affect the **ecological health** of the system and those that impact **public health**. The focus of the approach described in this report was to use public health parameters as an illustration of how Massachusetts Bays managers could use such an approach to better specify the relationship between changes in water quality and Bays resource value. We chose this strategy not because of a lack of interest in or concern for parameters that affect general ecological health, but rather, because these relationships lack, in general, the kind of empirical specifity required of the model. Alternatively, for questions relating to public health, the establishment of state and federal regulatory limits which define an "adulterated product" provide at least some minimum criteria to specify part of our resource valuation problem.

**Estimating Benefit Value**

Indeed, it is primarily because of the lack of clear insights concerning the relationship between water quality levels and resource use that made a determination of overall benefit value difficult. The estimates of Bays system use values provided in the report are admittedly incomplete and substantially underestimate the total value of the Bays resources. This is not only because of incomplete data, but also because many of the linkages between improvements in ecosystem health and various human uses are not yet understood enough to enable their value to be quantified.

Also, for management policy purposes, it is the change in human use value, rather than the current human use values, resulting from changes in water quality initiated by particular policies that is of greater interest. Each proposed regulatory change will have a unique impact on the Bays ecosystem and thus will require its own individual benefit valuation and thus the estimates discussed in this report cannot serve as general evaluative tools for potential policy changes, but only as a guide to the uses that need more investigation and that are likely to result in the largest value improvements if expanded or enhanced.

We are not presenting a comprehensive number of the total benefit value of the Mass Bays because this would be misleading. All values of the Mass Bays have not been measured because of insufficient data. Also, due to data constraints in some cases economic benefits (consumer surplus or the difference between total benefit value and current expenditures on the resource) are estimated in relation to hypothesized scenarios, while in other cases gross benefits are estimated (usually as a minimum value based on gross expenditures), and in other cases estimation of neither is possible.

In what follows, we summarize our key findings and valuation estimates for each of the major resources identified in our report as being limited by environmental contamination in the Mass Bays. The context for this discussion will be the model introduced in Section I and the subsequent valuations of the resources derived from it.

Commercial Fishing

Commercial fishing was divided into two areas: finfishing and lobstering; and shellfishing. This division was necessitated by the inability to quantify one of the linkages in our model (illustrated in Figure 2) for finfish and lobstering. This was the relationship between limiting factors and impacts on the finfish and lobster resources. The knowledge of how specified improvements in water quality affect the primary limiting factors of residual chemicals and natural toxins and how specified changes in these limiting factors impact the stocks of these resources was not available. However, in the case of shellfish, except for the case of natural toxins, we were able to be much more precise about this linkage. A reduction of fecal coliform counts to a point at or below the existing regulatory limit would clearly enable most shellfish beds to legally reopen.

In the case of finfish and lobsters, the absence of the limiting factors/use-resource impacts linkage prevented us from estimating changes in these resource values from likely water quality control scenarios. Instead, we provided market value estimates of these species caught in Mass Bays waters and divided the species into groups to identify those species likely to be of longest residence in the Bays system. This provides a minimum value of the gross benefit of these species of $53 million annually, although as we have shown the additional consumer surplus value produced from any change in water quality is likely to be small because Mass Bays does not appear to contribute a significant enough portion of market supply to influence price. Moreover, additional producer surplus is also likely to be small because of the existence of substantial overfishing. A key point raised here is that if overfishing is allowed to continue, any gains in the value of finfish or lobster stocks through environmental improvements will be substantially lower than in the case of a properly managed finfish industry.

For shellfishing, we estimated the annual benefits from the elimination of depuration due to lower fecal coliform counts to be at least $174,000 annually. The minimum gross benefit - measured by the market value of additional product - from opening currently closed commercial shellfish beds is estimated to be $500,000 annually. As in the case of finfish, the Mass Bays contribution to the overall shellfish market is too small for the opening of these beds to result in any significant impact on shellfish prices. Likewise, there are substantial dangers of overfishing in the shellfish industry due primarily to the fact that shellfish management is focused on health issues and is substantially understaffed at the state level. Further, shellfish management is controlled by the towns and thus there is no overall statewide management of the commercial resources devoted to shellfishing.

**Key Results:**

*** The presence of overfishing in the finfish industry and the likely presence in the shellfishing industry reduces the value of any improvements in these stocks resulting from improvements in Bays water quality.**

*** There is insufficient scientific information available to allow for the quantification of likely improvements in finfish or lobster stocks from specified improvements in Mass Bays water quality parameters.**

*** The contribution of Mass Bays finfish and shellfish to the New England market is too small to substantially impact prices of these seafoods.**

*** Herring and pollock, which may be active spawners in Mass Bays, and cod, flounder, and hake, which are the most highly valued resident species in the Mass Bays should be the focus of initial studies to determine the impact of changes in Bays water quality on their health and development.**

Recreational Fishing

Obviously, the same lack of knowledge of the limiting factors/use-resource impact linkage discussed above constrained this analysis also. Another key missing data set was survey data on the socioeconomic characteristics and fishing habits of Mass Bays recreational marine fishermen. In lieu of these data, we first described the approach Mass Bays managers can use to create the survey database. We then use the Massachusetts sample from national survey data to estimate the average number of recreational finfishing trips conducted in Bays waters over the 1984-1989 period. A different national sample is used to report the number of recreational shellfishing trips conducted in 1985. This same study reveals that recreational shellfishermen readily substitute saltwater fishing for shellfishing and that they tend to be much more highly educated and from households with much higher incomes than the general population.

The range of estimates from many studies from all around the country on the consumer surplus value of a recreational marine fishing day is used to estimate a range of \$45-\$355 million in annual economic benefit of Mass Bays recreational finfishing. Similar estimates for recreational shellfishing were not calculated because of the lack of recreational shellfishing day value estimates in the literature. The only available scenario from the literature to estimate changes in recreational fishing value (additional annual economic benefits) from assumed changes in water quality from the Boston Harbor cleanup reported a range of \$299,000-\$7,911,000 in 1982 dollars. However, this study readily acknowledges the lack of scientific basis for the assumed affects of water quality on recreational fish populations and subsequent changes in the behavior of recreational fishermen.

**Harbor are already contaminated, the costs of incurring such contamination in other areas is likely to be substantial. Hopefully, one of the outcomes of the current State Dredging Disposal Task Force will be some estimates of the cost such contaminated sediments impose on ports and harbors.**

Public Health

**Key Findings/Suggestions for Future Research**

*** One of the costs of not improving Bays water quality is the risk to public health both through seafood consumption and viral contamination from water contact. Although the data required to measure both health risks are not available for Mass Bays, we use national data and Massachusetts Department of Public Health data to estimate that the cost of seafoodborne disease in the Commonwealth generally in terms of lost work, medical expenses, and liability claims could be as high as $60 million annually.**

Ecosystem Benefits

The valuation of ecosystem benefits suffers from the same missing linkage in our model present in the case of fisheries. We do not yet know enough about the Mass Bays ecosystem to precisely link specific changes in water quality to specific improvements in characteristics of the ecosystem that can be further linked to direct human uses. However, one component of the ecosystem that has received considerable attention recently is wetlands. Although the precise contribution of Mass Bays wetlands to the Mass Bays ecosystem has not been documented, we illustrate the worthiness of such an undertaking by estimating the potential magnitude of just the recreational benefits such wetlands might generate. We do not attempt to value other benefits of wetlands, such as flood control, fish spawning sites, and groundwater filtration systems.

**Key Results/Suggestions for Future Research**

*** Valuation of Mass Bays ecosystem benefits related to direct human use requires a more precise understanding of the relationship between water quality and characteristics of the ecosystem and these characteristics and human uses of the Bays.**

*** An illustration of the methodology available for measuring one component of this value, the recreational value of wetlands, is illustrated, but because of lack of Mass Bays recreational day value estimates, per acre day value estimates from a recently published study on Louisiana wetlands were used. Applying such values to Mass Bays wetlands yields a**

**recreational value estimate of $600,000 annually in economic benefits and $3.2 million annually in gross economic benefits.**

*** Some of the Mass Bays ecosystem benefits are not captured by their relationship to direct human uses, but have a perceived value among the general population even if direct use is not contemplated. This non-use value (willingness to pay for cleaner Mass Bays waters even if one is not a current user of the system or does not contemplate future use) has been found to be quite substantial in several recently conducted studies looking at a variety of resources in other parts of the country. The Mass Bays program should seriously consider conducting such a study for the Mass Bays system as a whole as this non-use valuation is likely to be sizable and should be used as part of the justification for expenditures on water quality improvements.**

## Part II

## Analyzing the Current Massachusetts Bays Management System and Assessing Its Impacts

Part II examines major legal authorities comprising the extant Bays governance structure at federal, state and local levels. Two distinguishable sets of interactions, local-state and state-federal, serve as the analytical framework for discussion of issues selected as vital to strengthen and improve the Mass Bays system.

At the local level, principal issues include the role of local decisionmakers and planners in Bays management, the use of local regulatory tools for Bays resource protection, and some remaining problems with such key land use management areas as stormwater and sediment erosion control, groundwater protection and cumulative effects. Because such environmental concerns also significantly intersect with federal and/or state authority, some overlap of issues is inevitable. Consequently, some of the topics reviewed under the heading of federal and state programs, for example, non-point source pollution control, and special and critical area and resource management, including wetlands, will be redundant. Rather than a simple research artifact, however, this repetition more importantly reflects the historic development of pollution control efforts if not completely the current political reality.

Under federal and state rubrics, as discussed below, this report also explores new directions (the "quiet revolution") in environmental policy and two doctrinal areas of legal note: takings and the public trust doctrine.

With respect to critical area management at the local level (wetlands, Areas of Critical Environmental Concern (ACECs), river protection, etc.), hard-won protective measures currently in-place have been put at risk by the changes proposed to statutes and federal Corp of Engineers (COE) regulations. At the same time, projections for steady growth in coastal communities make further environmental degradation likely unless land use planning and management practices are bolstered. Information and data needs, including a permanent monitoring program for coastal water quality, fish and shellfish resources, nearshore sediments, and wetlands, is urgently needed. In addition, funding for staffing and enforcement remain inadequate.

Priority non-point sources affecting Bays resources, such as stormwater and On-Site Disposal System (OSDS) leachate, point up the need for technical assistance which might be addressed by regional agencies or by the establishment of incentives for municipalities to share technical staff, and possibly local funds for site inspections and other activities of mutual concern. Enabling statutes need to be updated, among other things, to reflect current scientific understanding, to encourage local board members on a sustained basis to pursue training opportunities and to enhance the local use of administrative penalties.

While it is not an official focus of this report, public education efforts should be supported and expanded. At a time when the amount of oil improperly disposed of by home mechanics has been estimated as greater than the Exxon Valdez debacle, the individual's role in pollution prevention clearly matters. This is more true, given the findings of the report, because pollution prevention constitutes one of two major emphases in what has been termed the "quiet revolution" in environmental policy. The other major emphasis - enforcement, while scarcely new, needs to be re-integrated within a comprehensive, more cost-effective approach which incorporates nonregulatory as well as regulatory paradigms. Generally, the strategies of "targeting" and "cross-compliance" - need to be more dexterously woven into the current multi-dimensional structure.

At the same time, because the U.S. Supreme Court has devoted renewed attention to the law of takings, leaving local government officials uncertain, if not alarmed, over the possible extent of the fifth amendment "just compensation" requirement, this report urges that supplementary strategies be explored to augment the traditional reliance upon a purely police power approach. Thus, where feasible this report recommends recourse to the property-based common law "Public Trust" doctrine. In addition, tax-based incentives to preserve privately-owned wetlands, and funding to purchase fee simple interests and development rights in wetlands and other critical areas may also be necessary.

With some exceptions, this report concludes that sufficient authority exists to operate an effective Mass Bays program. Given the management perspective informing this report, namely that the cross-media nature of environmental pollution requires an area or basin-wide ecosystemic approach, this report recommends reliance upon the coordinative intergovernmental mechanisms of Massachusetts Coastal Zone Management Program (MCZMP) to define and/or resolve Bays management problems. In addition, and given adequate funding, the authors also urge that the MCZMP take the lead in pursuing the other recommendations with which the report concludes.

# PART I

## DETERMINATION AND BENEFIT VALUATION OF THE THE USES AND RESOURCES OF THE MASSACHUSETTS BAY

by

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# PART I

## INTRODUCTION

The waters of the Massachusetts Bays system support a rich mix of resources and uses which provide benefit to the people of Massachusetts. Indeed, it can be reasonably said that the human history of the Commonwealth is fundamentally linked to the Massachusetts Bays and resources it has nurtured. Fish and shellfish harvested in the Bays have provided food and industry, the calm of Boston Harbor has sheltered commercial fleets, its beauty has inspired, and, more recently, its beaches and waters have provided respite for a population stressed by the pace of modern society. In short, these waters have served as a primary catalyst for economic and social development in Massachusetts for several centuries. However, these contributions have not come without cost. The exploitation of the Massachusetts Bays system has severely stressed its ecology and has reduced the capacity of the Bays system to provide the benefits it once did.

The central organizing theme of Part I is to focus on the social value provided by the Bays system. We provide a strategy to articulate and value those uses and resources which supply value to humans. Accordingly, this part of the report addresses three major tasks. First, we discuss the broad-range of resources and uses within the Massachusetts Bays system that provide value to the people of the Commonwealth. Second, we describe and analyze those resources and uses for which anthropogenic contaminants limit their value and benefit to society. To the degree allowed by available data, we also characterize the relationship among: (i) resources/uses which provide the most direct human benefit, (ii) the contaminants limiting those human uses, and, (iii) the management strategies designed to reduce environmental contaminants and enhance human use. And, third, we evaluate the methods available to determine the benefit value of Bays system uses and resources, and provide estimates of such values where data are sufficient.

## SECTION ONE

### THE RESOURCES AND USES OF THE MASSACHUSETTS BAYS

Our effort, is not to describe in detail all the resources and uses within the Massachusetts Bays system. Several such efforts are available and together provide a fairly comprehensive picture of the Bays (for example, Brown 1987; Archer 1990; MWRA 1987a). Rather, our effort is to build a model to value Bays resources and to better understand how human influences and interventions affect these values. Figure 1 comprehensively describes the uses and resources of the Bays relevant to a study of human benefit and value. One could describe the Bays system in a number of different ways. Figure 1 represents a human centered view. The waters of the Massachusetts Bays provide living and non-living resources, and opportunities for sustained human use. The uses listed share a dependence on a healthy coastal environment and on a set of management practices dedicated to the goal of resource conservation. In other words, the benefit derived from these uses is tied, in fundamental ways, to human action.

### FACTORS INFLUENCING RESOURCE VALUE AND COASTAL MANAGEMENT

In general we can articulate two ways in which human activity can influence the value of marine resources and coastal uses: those that affect the **ecological health** of the system and those that impact **public health**. Each of these perspectives will be addressed in turn.

# FIGURE 1

## RESOURCES AND USES OF THE MASSACHUSETTS BAYS SYSTEM

**Resources**

Living Resources

Pelagic Finfish
Demersal Finfish
Anadromous Species
Catadromous Species
Mulluscan Shellfish
Crustacea
Game Birds
Coastal Birds
Turtles
Whales
Other Marine Mammals
Coastal Wetlands
Ecological Support Species

Non-Living Resources

Marine Minerals
Barrier Beaches
Recreational Beaches

**Human Uses**

Finfishing

- Commercial
  - Harvesting
  - Processing
  - Shoreline Support
- Recreational
  - Shore and Pier Line Fishing
  - Private Vessel Fishing
  - Private Charter Fishing

Shellfishing

- Commercial
  - Mollusca
  - Crustacea

Recreational

- Mollusca
- Crustacea

Aquaculture

Recreational Swimming

Recreational Boating

- Motorized
- Non-motorized
- Shoreline Support

Other Recreational Uses

- Hunting
- Bird Watching
- Walking
- Whale Watching

Ports, Harbors and Marinas

- Capital Construction
- Maintenance Dredging

**Ecological Health Factors**

Given the highly interdependent and interrelated nature of nearshore environments even modest changes in contaminant loads or nutrient flux can lead to significant changes in the coastal ecology. Such changes can influence such critical ecological attributes as biodiversity and reproductive capacity. From the perspective of a benefit valuation strategy such issues are important for several reasons. Reductions in biodiversity are potential influences on value because there are fewer species with the capacity to provide value; that is, with fewer opportunities for exploitation the direct benefits from resource exploitation are reduced. Further, and perhaps more importantly, reductions in biodiversity may reduce value by impacting species critical to the coastal food web. Important disruptions in the ecological structure of coastal environments can lead to dramatic changes in stocks which provide directly, through commercial or recreational harvest, economic benefit. Impacts on reproductive capacity can influence benefit value by changing the amount of a resource available for use. Simply, fewer animals means less value.

For example, as wetland areas become healthier and thus expand their viability for supporting wildlife, those people who gain pleasure from wildlife observation will find the value of their trips to the Bays coastline enhanced. Further, expanded wetland health may result in an improvement in commercial and recreational fish stocks because wetlands serve as important spawning environments for these stocks. Improvements in fish stocks will then lead to increased value in terms of commercial harvest and enhancement of the recreational fishing experience.

**Public Health Factors**

A second influence involves the role of public health in coastal management and benefit valuation. If resources or activities in the coastal zone are deemed unsafe for human use then their value is reduced. If shellfish beds are shown to have unacceptable levels of certain regulated contaminants harvest restrictions are imposed and the value of those stocks is reduced. If coastal waters used for swimming are contaminated with high levels of enteric pathogens they are closed and cannot provide a benefit to those who wish to use them.

**Modeling Human Influences**

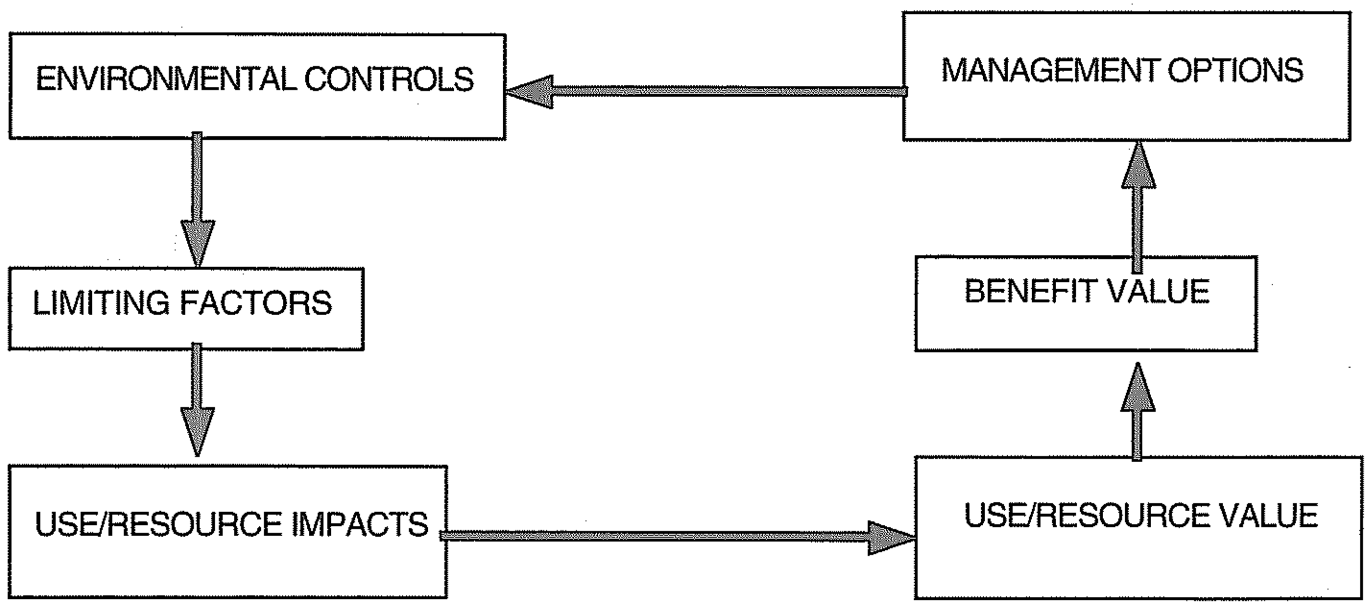
The assertion that human activities influence both ecological and public health attributes is hardly controversial. However, effective management practices require not only the assertion of a relationship but insights sufficient to enable quantification. The ability to quantify those relationships requires a dynamic and interactive model which describes the nature of important relationships and provides a mechanism to analyze critical information. Such a model is represented in Figure 2.

This model describes a system in which various **environmental control** strategies (such as CSO controls, chlorination of wastewater effluent, or non-point source controls) regulate the level of critical environmental attributes/limiting factors (such as enteric pathogens or residual chemicals). These **limiting factors** can impact directly the nature of **resources and uses** (such as commercial shellfishing or recreational bathing) within the Bays system. The importance of this part of the model is that it more precisely defines a set of discreet relationships which affect the ability of humans to use Bays system resources.

However, simply characterizing the impact on use levels does not add directly to our understanding of effective management regimes. A central thrust of our work has been to focus on the need to calculate the social value gained from reductions in contaminant loads. Considerations of **use/resource value** (for individual uses) and for Bay-wide total **benefit value** should contribute to the development of **management options** to enhance sustainable human use. While conceptualizing such a model may be easy developing a fully specified,

# FIGURE 2

## HUMAN INFLUENCES IN COASTAL RESOURCE USE AND BENEFIT VALUATION



parameterized and operational version is not. Indeed it is important to distinguish between the process of <u>specifying</u> critical relationships and generating sufficient, focused and detailed information to allow for a fully dynamic and <u>parameterized</u> model.

In order be able to move beyond the general conceptual model illustrated in Figure 2, the first step is to <u>specify</u> the nature of a series of critical relationships that articulate the influence of various environmental controls on environmental factors which limit the sustainable use of Massachusetts Bays resources and uses. For example, what would be the impact of fully chlorinating all Boston Harbor wastewater effluent (including CSO discharges) on levels of enteric pathogens in nearshore areas?; what would be the impact on benthic finfish populations of broad-based dredging of residual chemical contaminated sediments?; and, what impact would shifting the MWRA outfall have on Bay-wide productivity of potentially toxic phytoplankton species?

However, for the proposed model to be fully operational an additional quantification or <u>parameterization</u> step must follow specification. Not only must the system be sufficiently understood to define critical relationships but data describing the degree to which changes will occur need to be available. When such insights and data are available the model herein described would provide managers with a dynamic, iterative and implementable model.

Accordingly, at least three kinds of information need to be available for such an effort. First, the relationship between various environmental control strategies and reductions in specific contaminant loads needs to be specified. In some instances this process is rather straightforward, in others, the relationship highly uncertain. For example, in limited areas such as Boston Harbor one might argue that the introduction of enteric pathogens is dominated by a limited number of point sources. By eliminating CSO discharges, removing contaminated solids and chlorinating wastewater effluent, substantial reductions in pathogenic levels might be expected. In other part of the Bays system, the introduction of pathogens constitutes a much more complex question requiring an understanding of the relative contribution of both point and non-point sources (such as septic fields) to total pathogenic levels.

Further, residual chemicals, such as heavy metals, industrial organics and agricultural chemicals are introduced into the systems by multiple mechanisms. Wastewater effluent, atmospheric and riverine inputs and runoff all contribute significantly to the system. For this class of contaminants the relationship between various control strategies and changes in contaminant loads remains uncertain. Insights into these kinds of relationships are critical for the **environmental controls > limiting factors** step in the model.

A second class of needed information relates to the link between changes in **limiting factors > use/resource impacts**. That is, can we specify the magnitude of the relationship between levels of critical environmental attributes and the amount of available resource use? Here, our distinction between ecological and public health is useful. The relationships between various environmental attributes and issues such as biodiversity and reproductive capacity are, at present, extremely difficulty to define. It is insufficient to assert that improvements in environmental quality will lead to increases in resource value. In addition to that necessary insight, effective management needs information quantifying the relationship.

Information is presently being developed that may eventually allow for such judgments to be made. Studies presently being carried out under the Massachusetts Bays Program such as: "Living Resources and Habitat Protection in Massachusetts Bays," and "Relative Impact Assessment for Massachusetts Bays" will provide essential insights into relationship between environmental health and resource use. Also the monitoring program currently being designed by EOEA's "Steering Committee for the Establishment of a Coastwide Monitoring Program" will generate similarly critical information. However, at present, existing scientific information is not yet sufficient to determine in any systematic or comprehensive way the degree to which changes directed at environmental health will affect the scope and level of human resource use within the Bays system.

However, for questions relating to public health, information is better determined and an approach directed at these questions may be able to provide useful insights for policy choice. Therefore, in order for this step in our model to be specified, an orientation which emphasizes public health questions is, at least for the present, preferred.

A third kind of information needed to parameterize the model addresses the question of existing coastal use. This information is critical in the **use/resource impact > use/resource value > benefit value** step in the model. Although this study is directed at valuing existing uses, management decisions in the future will require an evaluation of the net change in resource use caused by changes in environmental policies and controls. For the Massachusetts Bays, available information is generally sufficient for some resource uses, but insufficient for others. This is a point to which we shall return.

In short, the model we have described can, if supported with relevant scientific insight and sufficient data, provide a useful mechanism to address a dynamic series of "what-if" questions responding to the relationship between changes in coastal environmental quality and the benefit value of Mass Bays resources/uses. The next section will serve to illustrate how one can build an increasingly rigorous level of detail into the conceptual model depicted in Figure 2. This illustration will make use of questions related to management practices designed to enhance public health attributes of coastal resource use.

**Coastal Water Quality and Public Health**

The preceding analysis suggests strongly that in order to better specify our model our focus should, at this time, be on those environmental attributes and contaminant loads which most directly affect public health. We have chosen this strategy not because of a lack of interest or concern for parameters that affect general ecological health, but rather, because these relationships lack, in general, the kind of empirical specificity required of the model. Alternatively, for questions relating to public health the establishment of state and federal regulatory limits which define an "adulterated product" provide at least some minimum criteria to specify part of our resource valuation problem.

However, the specification description which follows is not conceptually limited to public health criteria and could, as more and better insights emerge concerning environmental/ecological health issues, be used to structure and assess those relationships. Even with an analytical focus on public health critical data that would allow for the development of a fully parameterized model is still lacking. Several assumptions are made both here and in Section Two that are designed to allow for a more precise methodological description. The validity of these occasionally heroic assumptions and transfer functions can only be assessed by way of generating data that examines more precisely the nature of resource/use relationships within the Mass Bays system.

**Regulatory Limits and Public Health**

If a seafood product is shown to hold contaminant loads in excess of an established limit, or if recreational waters exceed certain standards, then the product or activity is restricted. The benefit value of that product or activity is, therefore, diminished or eliminated. The advantage of using these regulatory limits is that they provide a straightforward mechanism to discuss the issue of resource value. If regulatory limits are not exceeded, the product or activity is available. If limits are exceeded then access is restricted and value reduced. For issues of public health, relationships between limits and value are easily articulated by way of established regulatory limits, and uncertainty, at least from the perspective of resource management, is marginally reduced. From the perspective of the model, this means that the "success" of individual control strategies can be evaluated in terms of the degree to which they reduce critical limiting factors to the point at which public health concerns are eliminated or minimized.

One disadvantage of this public health oriented approach is that it is driven by those resources and uses for which established regulatory limits are currently in place. While most of the important resources within the Bays are regulated in this fashion, some are not. The resources and uses which are so regulated are presented in Figure 3. As this figure illustrates, all commercial and recreational seafood stocks and all recreational bathing are regulated according to a specified limit which allows, disallows, or significantly restricts that resource or activity.

Regulatory limits designed to mitigate public health risk are contained in Table 1. The effort in developing Table 1 was not only to define regulatory limits established or recommended by existing state and federal regulations, but also to define areas of risk that have been articulated by other responsible governments and bodies. We have included a characterization of risks articulated by others because of their potential importance to the management of the Massachusetts Bays. As has been shown elsewhere, the Massachusetts Bays system is one in which anthropogenic contaminants are of greater concern than for the nation as a whole (Brown 1987). Further, the nature of regional coastal use, and in particular, regional seafood consumption patterns are, almost by definition, different from the national norm.

## TABLE 1

## REGULATORY LIMITS AND ARTICULATED RISKS FOR MASSACHUSETTS BAYS RESOURCES/USES

| RISK | U.S. REGULATORY LIMIT | RISK ARTICULATED BY OTHERS | RESOURCE/USE | SOURCE |
|---|---|---|---|---|
| Pathogenic Microorganisms | | | | |
| Enteric Bacteria | Fecal Coliform | | | |
| | 14MPN/100ml | | Growing Water | FDA/NSSP[1] |
| | 230MPN/100gm | | Shellfish Product | FDA/NSSP[1] |
| | | 200MPN/100ml | Bathing Waters | DEP[3] |
| | Enterococcus | | | |
| | 35MPN/100ml | | Growing Water | FDA/NSSP[2] |
| Indigenous vibrios | | (No limits set) | Shellfish | NAS[6] |
| Natural Toxins | | | | |
| Saxotoxin (PSP) | 80μg/100gm | | Shellfish | FDA[4] |
| | | 80μg/100gm | Lobster Tomally | Canada[5] |
| Domoic Acid | | 20μg/g | Shellfish | Canada[5] |

| RISK | U.S. REGULATORY LIMIT | RISK ARTICULATED BY OTHERS | RESOURCE/USE | SOURCE |
|---|---|---|---|---|
| **Residual Chemicals** | | | | |
| Industrial Organics | | | | |
| PCB | 2.0ppm | | Seafood | FDA[2] |
| PAH | | (No Limits set) | | |
| Dioxin | | 20ppt | Seafood | Canada[5] |
| Chlorination Products | | (No Limits set) | | |
| **Metals** | | | | |
| Antinomy | | (No Limits set) | | NAS[6] |
| Arsenic | | (No Limits set) | | NAS[6] |
| Cadmium | | 3.6-4.4ppm | Seafood | WHO/FAO[7] |
| Chromium | | (No Limits set) | | NAS[6] |
| Lead | | 26.1ppm | Seafood | WHO/FAO[7] |
| Methylmercury | | 1.8ppm | Seafood | WHO/FAO[7] |
| Mercury | 1.0ppm | | Seafood | FDA[4] |
| Nickel | | (No Limits set) | | NAS[6] |
| Selenium | | (No Limits set) | Seafood | NAS[6] |
| **Agricultural Chemicals** | | | | |
| Aldrin | 0.3ppm | | Seafood | FDA[4] |
| Chlorine | 0.3ppm | | Fish | FDA[4] |
| DDT,DDE and TDE | 5.0ppm | | Fish | FDA[4] |
| Dieldrin | 0.3ppm | | Seafood | FDA[4] |
| Endrin | 0.3ppm | | Seafood | FDA[4] |
| Heptachor | 0.3ppm | | Seafood | FDA[4] |
| Kepone | 0.3ppm | | Seafood | FDA[4] |
| | 0.4ppm | | Crabmeat | FDA[4] |
| Mirex | 0.1ppm | | Fish | FDA[4] |
| Toxaphene | 5.0ppm | | Fish | FDA[4] |
| All other Agriculture Chemicals | | 0.1ppm | Seafood | Canada[5] |

Table 1: Notes

1. FDA (Food and Drug Administration), 1989. NSSP Shellfish Sanitation Program. Manual of Operations, Part II: Sanitation of the Harvesting, Processing and Distribution of Shellfish. Washington, D.C.

2. FDA (Food and Drug Administration), 1989. NSSP Shellfish Sanitation Program. Manual of Operations, Part I: Sanitation of Shellfish Growing Areas. Washington, D.C.

3. DEP (Massachusetts Department of Environmental Protection), 1990. Personel Communication.

4. FDA (Food and Drug Administration), 1985. Compliance Policy Guide, Chapter 8: Fish and Seafood. 7108.01-7108.25, 10/80 - 6/85. Washington, D.C.

5. DFO (Canadian Department of Fisheries and Oceans), 1989. Canadian Guidelines for Chemical Contamination in Fish and Fish Products. Government of Canada. Ottawa.

6. National Academy of Sciences/Institute of Medicine, Committee on Evaluation of the Safety of Fishery Products, 1991. Seafood Safety. National Academy Press, Washington, D.C. Risks identified in committee report.

7. FAO (U.N. Food and Agriculture Organization), 1989. Codex Alimentarius Standards for Fish and Fishery Products. Joint FAO/WHO Food Standards Programme, Vol. V, 1st Ed. Geneva, Switzerland.

## FIGURE 3

## RESOURCES AND USES OF THE MASSACHUSETTS BAYS SYSTEM LIMITED BY ENVIRONMENTAL CONTAMINATION

**FISHING**

- **SHELLFISHING**
  - **Commercial**
  - **Recreational**
- **FINFISHING**
  - **Commercial**
  - **Recreational**

**RECREATION**

- **BATHING BEACHES**
- **OTHER RECREATIONAL USES**

**TRANSPORTATION AND PORT MANAGEMENT**

- **COMMERCIAL SHIPPING**
- **COMMERCIAL PORTS, HARBORS AND MARINAS**

**MINING**

- **MARINE MINERALS**

On this point, the EPA has stated that, "consumption levels of fish on a national per capita basis are generally considerably less than that typical of sports fishermen, or of most . . . coastal regions of the U.S. (EPA 1989: Appendix A). However, the regulatory approach developed by the appropriate federal agencies does not effectively take into account regional differences in coastal contaminant loads or differences in seafood consumption. Federal action levels and formal tolerances are designed to provide national protection to the "average consumer of a food product, assuming the consumer eats from a typical 'national market basket' (EPA 1989)". Such limits are not intended to protect local or regional populations whose consumption of seafood from a given water body may exceed the national average.

Given the potential importance of such regional issues, it is apparent that the effective management of public health risks within the Bays system may require a marginal expansion of regulated risks. We have, therefore, included in Table 1, a minimal survey of risks articulated by others.

We have chosen to divide these risks into four major categories: (i) enteric pathogens, (ii) indigenous vibrios, (iii) natural toxins, and, (iv) residual chemicals. This typology was chosen because it provides the most direct way to relate the control of such public health risks to various risk control strategies. These relationships are specified in Figures 4-9. These figures represent an initial attempt on our part to specify the relationship between resource use and environmental control strategies. However, even with an emphasis on public health factors, complete specification of the model is not possible.

In order for such a model to be an effective management tool more precise relationships between environmental controls and factors limiting use need to be developed. Those areas of existing uncertainly will be identified in the sections which follow. However, we feel that the approach we have developed provides value by articulating a model that simplifies, to as great a degree possible, an enormously complex policy problem. One result of such a simplification strategy is the improved ability to focus on critical, as opposed to merely relevant, relationships.

**The Role of Limiting Factors in the Determination of Resource Use**

The discussion which follows identifies critical ways in which levels of certain contaminants limit the nature and level of resource use within the Massachusetts Bays system. While much of the focus in this discussion will be on the influence of public health attributes, we will also characterize the degree to which elevated levels of residual chemicals in marine sediments can affect resource use and value. As such, the analysis of contaminated sediments provides an illustration of a non-public health impact.

Shellfish Use and Public Health

An evaluation of shellfish stocks provides a useful place to start a discussion of contaminant loads and resource use. Shellfish contribute significant recreational and commercial value to the Commonwealth and they represent a resource for which management is dominated by considerations of public health. In our treatment of shellfish, we first describe the factors which limit resource use and then characterize the influence of various control strategies on those factors.

Shellfish: Limiting Factors. The management of shellfish resources, for both commercial and recreational harvest, provides the most complex example of resource management for public health. Indeed, all four categories of risk play some role in the management of shellfish stocks or in the articulation seafood risk.

The most significant risk imposed by shellfish consumption is that contributed by enteric pathogens. These pathogens can cause a broad range of symptomatic responses in humans, ranging from mild gastrointestinal distress to more severe forms of illness, including death. The majority of seafoodborne disease associated with enteric pathogens cause mild to moderate symptoms. Pathogens of concern include vibrio cholerae 01, Norwalk and Snow Mountain viruses, and Hepatitis A (NAS/IOM 1991).

The management of pathogenic risk in Massachusetts is carried out under the guidelines of the Interstate Shellfish Sanitation Conference's (ISSC), National Shellfish Sanitation Program (NSSP). The NSSP is a cooperative program in which the FDA, state agencies, and industry work to control the quality and safety of oysters, clams, and mussels sold in interstate commerce (FDA, 1989 a,b). The most significant contribution of the program has been the creation of classification and monitoring strategies designed to ensure that shellfish are taken from harvesting waters significantly free of microbial contaminants. For a state to continue as a certified member of the program, it is required to survey all growing waters within its jurisdiction and classify those waters as to their acceptability for harvesting shellfish. Waters that have not been surveyed and classified must be closed.

The regulatory mechanism used to control access of contaminated product utilizes a combination of "Good Manufacturing Practices" and limits for organisms which may indicate the presence of enteric pathogens. The NSSP guidelines rely primarily on levels of fecal coliform in harvesting waters and shellfish product to define acceptable levels of public health risk. As Table 1 identifies, the sanitary quality of shellfish is based on an allowable level of 14 most probable number (MPN) fecal coliforms/100 ml, with no more than 10% of samples exceeding 43 MPN. (FDA, 1989a). As noted above, the NSSP manual of operations also requires a sanitary survey of growing waters prior to approval for shellfishing, relaying, or depuration. Those limits suggest a fecal coliform density of not more than 230 MPN/100g and aerobic plate count (APC) of not more than 500,000/g.

A second area of potential, although unregulated, risk involves that introduced by indigenous vibrios; that is, vibrios that occur and thrive naturally in coastal environments. In the Massachusetts Bays, the indigenous vibrio of greatest potential concern is *V. parahaemolyticus.* This vibrio is found coastal waters generally and can cause moderate gastrointestinal distress even in health individuals. Indeed, in public health data reported in Japan, *V. parahaemolyticus* was associated with nearly 13% of all foodborne disease (JJMSB, 1987), and nearly one-third of seafoodborne disease (MHW, 1988). Relatively little work has been done on *V. parahaemolyticus* in the United States, however, one study has suggested that, "*V. parahaemolyticus* is common in Boston Harbor, where it was recovered from 80% of the samples [included in the study]. (Rex, 1989). Because indigenous vibrios are not associated with human fecal material, monitoring for fecal coliform will not indicate their presence.

A third category of shellfish risk is exposure to natural toxins, such as paralytic shellfish poison (PSP) and domoic acid. Both PSP and domoic acid are produced by phytoplankton which periodically bloom in coastal and marine environments. Both substances are potent neurotoxins which can cause severe illness or death. As Table 1 notes, the regulatory limit for PSP in shellfish is 80 mg/100 g of meat (FDA, 1985). A formal regulatory limit for domoic acid has not, as yet, been determined. However, the 20 P.P.M. set by the Canadian government has been used by regulators as a general characterization of risk in U.S. waters. Both PSP and domoic acid have been isolated in Massachusetts waters (Nassif, 1991). Restrictions on shellfish harvest because of elevated concentrations of PSP are relatively common in the Massachusetts Bays. While at least one of the phytoplankton species implicated in domoic acid production has been identified in the Massachusetts Bays, to date, domoic acid has not been identified within the Bays system (although existing monitoring is extremely limited).

The final category of risk imposed by shellfish consumption are those introduced by residual chemicals. The Food and Drug Administration has developed (in most instances, in cooperation with the Environmental Protection Agency (EPA) a set of formal tolerances (for PCB) and action levels for residual chemicals in seafood. Those limits are also contained in Table 1. However, as earlier noted, federal regulatory limits for residual chemicals are not designed to take into account regional differences in coastal contaminant loads or local seafood consumption patterns that may differ from the national norm. Therefore, we have attempted (see Table 1) to identify certain contaminants that may require additional attention from environmental managers concerned with public health risk from regionally harvested seafood product. In addition to federal tolerances and action levels we have identified potential risks articulated by three other groups. They are: the Canadian Department of Health and Welfare, the World Health Organization and the U.S. National Academy of Sciences/Institute of Medicine.

In order to better understand how local conditions might influence a determination of residual chemical risk a short description of established risk assessment protocols might be of value. The risk determination model used by both federal and state officials includes, minimally, the following steps:

> **Hazard Identification:** Defines the toxicological hazards posed by certain chemical contaminants (as summarized by a toxicity profile), identifies the potential for chemicals of concern to bioaccumulate in seafood stocks, and considers the degree to which such chemicals persist over long periods in the coastal environment. These toxicity assessments are further modified by an analysis of available monitoring data.
>
> **Dose-Response Assessment:** Estimates the relationship between the dose of a substance and the probability of an adverse health effect (primarily characterized in terms of carcinogenic risk).

**Exposure Assessment:** Characterizes the environmental fate and pathways of chemicals; and the magnitude, frequency and duration of exposure.

**Risk Characterization:** Integrates the results of information in the previous three steps leading to an overall estimate of health effects for a given chemical (EPA, 1989).

However, there are critical assumptions in this risk assessment strategy that make extremely difficult any efforts to specify the impact of chemical loads on patterns of resource use. First, carcinogenic potency is calculated on the basis of the lifetime cancer risk (70 years) in a 70 kg. male. This strategy has been criticized as not taking to account the possible sensitivity of children to hazardous chemicals, raising the question of whether different, or additional, regulatory limits (or advisories) for women of childbearing age, pregnant women and children need to be imposed (NAS/IOM 1991). Second, consumer exposure is determined on the basis of national eating habits (exposures are calculated on the basis of 6.5 g/day, 20 g/day or 165 g/day) leaving potentially important regional consumption habits unaddressed (EPA 1989). Because the model requires data on magnitude, frequency and duration of exposure, regional information describing contaminant loads in seafood product and on the amount and frequency of seafood consumed are required.

In order to understand the significance of these risks to consumers of Massachusetts Bays shellfish, data designed to meet risk assessment assumptions and uncertainties needs to be available. While there has been some regional seafood consumption data collected within Massachusetts Bay (specifically, Quincy Bay), the kind of consumption data required to fully resolve a formal risk assessment model does not exist. In order to fully meet such requirements, studies will have to better determine not only the geographic source of consumed product, but, also, a measure of insight into the mix of species that dominate regional consumption.

Further, while there have been efforts to determine levels of contaminants within seafood product (edible tissue) within specific areas of the Bays system, or at specific points in time, routine, Bays-wide monitoring for residual chemicals in seafood (and in the present context, shellfish) does not exist. This is a point to which we shall return.

The Massachusetts Water Resources Authority (MWRA 1992) has attempted to develop, using the risk assessment model characterized above and the information available to them, a set of regional "Target-level Concentrations" for certain metals and industrial organics. For metals, those calculations yielded the following:

| | | |
|---|---|---|
| Cadmium | 2.1 | (all concentrations are in ppm wet weight |
| Lead | 3.0 | |
| Copper | 89.2 | |
| Chromium | 12.3 | |
| Nickel | 43.0 | |
| Zinc | 440 | |
| Arsenic | 2.1 | |

Indeed, as more information relating to consumption and concentration is developed this strategy could determine the kind of risk data needed to better specify our model.

With these uncertainties in mind, what can be said about the influence of residual chemical concentrations and the benefit value of Massachusetts Bays shellfish? Residual chemicals can influence value in two ways. If concentrations are particularly high within a well defined geographic region or species, then harvest restrictions would remove potentially valuable stocks from the marketplace. For example, consumption advisories, which respond to elevated levels of industrial organics in winter flounder and lobster tomalley from Quincy Bay have been in place for nearly four years. If, on the basis of those advisories, recreational fishing effort has been reduced in Quincy Bay, one could articulate a measure of resource value lost.

A second influence on value relates to costs of disease. However, given the uncertainties in risk assessment previously discussed it is clear that any specification of the influence of Massachusetts Bays residual chemical risk would be nearly impossible. One may be able to calculate the cost of cancer nationwide in any given year. But, in order to develop a useful estimate for our purposes one would first need to be able to distinguish foodborne from other risks, seafoodborne from foodborne, Massachusetts seafood cancer risk and finally the risk from Massachusetts Bays shellfish to the general population (including women, children and males of average weight). Such calculations are beyond the scope of the present study. However, while the public health costs that may be attributable to residual chemicals may difficult to calculate, efforts have been made to address those attributable to pathogenic and natural toxin exposure. Those costs are addressed in "Public Health" section of this report.

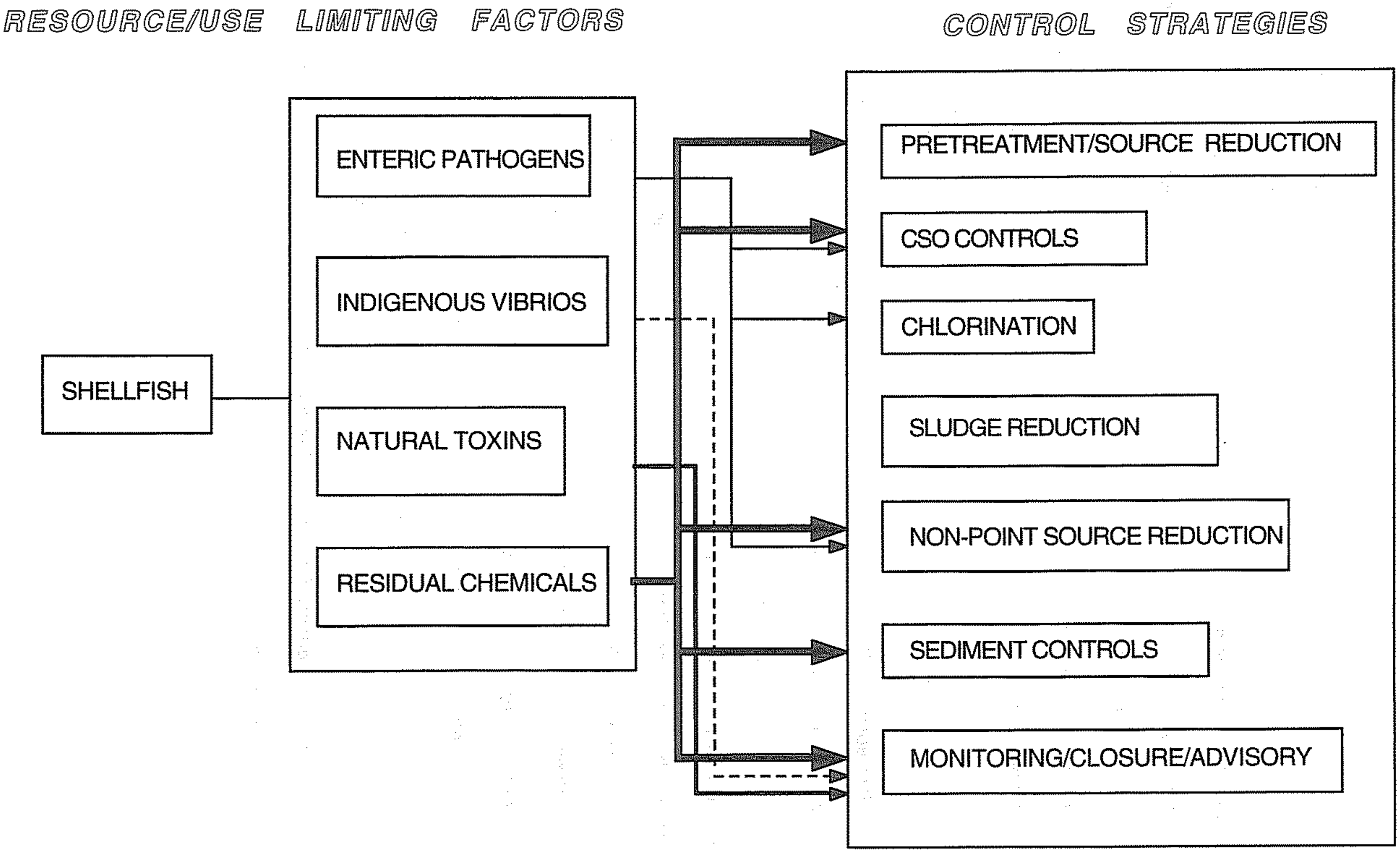
Shellfish: Control Strategies. The previous discussion has identified four areas of public health risk which manifest some measure of influence on the value of shellfish stocks within the Massachusetts Bays system. The next step in specifying our model is to identify the degree to which various environmental controls and management protocols can mitigate those risks and potentially increase the benefit value of those resources. Figure 4 is an initial effort to represent those relationships. However, before we discuss the case of shellfish it is important to introduce some caveats about this step in the specification of the model.

While we feel it is generally possible to articulate various ways in which environmental control strategies may reduce public health risk, it is not possible, given existing scientific insight and information, to precisely determine the amount of risk reduction expected from individual strategies. Many of the limiting factors discussed here are introduced into the system by a variety of sources and activities. While it is generally possible to suggest that a source or activity contributes to overall risk, it is not yet possible to describe with sufficient rigor the contribution of one relative to others. This is an important caveat, and yet, in many instances it may not be so important as to preclude the development of useful insights from our model-based approach. In some instances, it is possible to identify a small set of strategies that dominate the control of relevant risks. In others, we have attempted a simplification strategy (as with controls for residual chemicals) to suggest that by concentrating on certain parts of an admittedly complex question that sufficient insight might be gained.

With this caveat in mind, we can return to the question of public health and shellfish value. Strategies to effectively control elevated levels of enteric pathogens, as illustrated in Figure 4, include (i) controls to reduce or eliminate discharges from CSOs, (ii) chlorination of wastewater effluent, and, (iii) non-point source controls designed to reduce the potential of microbial contamination of private septic systems. Given that a final resolution to CSO discharges has not been determined a precise characterization of impact on levels of enteric pathogens cannot be defined. However, if one assumes that an approved CSO plan would move to eliminate dry-weather flows and reduce wet-weather flows to small number, then one should expect a significant reduction in CSO sourced pathogens.

Chlorination of wastewater effluent is another major means of pathogen reduction. With the cessation of sludge dumping into Boston Harbor and subsequent chlorination of the effluent stream, it has been estimated that fecal coliform levels would be reduced to less than 14/100 ml (the water quality limit for shellfish harvesting areas) beyond an 100 foot zone of initial dilution around the outfall pipe (MWRA 1987b). This suggests that, for at least the major point source within the Bays, planned effluent chlorination would nearly eliminate this source of bacterial pathogens.

# FIGURE 4



RESOURCE/USE
LIMITING FACTORS
CONTROL STRATEGIES
SHELLFISH
ENTERIC PATHOGENS
INDIGENOUS VIBRIOS
NATURAL TOXINS
RESIDUAL CHEMICALS
PRETREATMENT/SOURCE REDUCTION
CSO CONTROLS
CHLORINATION
SLUDGE REDUCTION
NON-POINT SOURCE REDUCTION
SEDIMENT CONTROLS
MONITORING/CLOSURE/ADVISORY

However, for areas outside of metropolitan Boston, providing for the control of CSO (Combined Sewer Overflow) discharges and chlorination of MWRA wastewater effluent does little to control enteric pathogens. As is noted in Table 8 less than four percent of total shellfish bed closures and restrictions are located within Boston Harbor. The control over the remaining 96% of Massachusetts Bays shellfish is dominated by other strategies; such as upgrading the large point-source discharges within the Plymouth and South Essex Sewer District. However, perhaps the most important sources of pathogenic contamination Bay-wide are non-point source introductions attributable to septic leachate and storm-water runoff. This is particularly true for local embayments with the Bays system. Reducing these will required a concerted and coordinated effort between local public health authorities and state officials.

A second potential source of shellfish risk is that introduced by elevated levels of indigenous vibrios such as *V. parahaemolyticus*, and natural toxins such as paralytic shellfish poison and domoic acid. Effective control strategies for these risk are limited to routine monitoring and harvest restrictions. While there have been suggestions that changes in nutrient concentrations may influence the level and location of the noxious phytoplankton that produce PSP and domoic acid, certainly existing understanding of the question is too limited to suggest that environmental control strategies should be directed to respond to it (Smayda 1989).

The final category of risk is that of residual chemical risk. Figure 4 argues that effective control over the introduction of chemical toxin could be limited by (i) pretreatment and source reduction strategies, (ii) CSO controls, (iii) non-point source controls, (iv) sediment controls, and, by (v) routine monitoring and harvesting restrictions. By articulating the nature of controls in this way we attempt to avoid at least some of the uncertainty surrounding this very complex question. Indeed, the complexity of reducing toxic chemicals in the coastal environment can be overwhelming. As we have already suggested, one strategy in facing the kind of policy complexity inherent in this question is to search for simplification strategies and for policy surrogates. We suggest that for the question of reducing public health risk a policy emphasis on pretreatment strategies (including residential source reductions) and on a more effective set of sediment controls, that the existing level of articulated risk could be significantly reduced. In addition to source reduction strategies, routine monitoring for residual chemical levels in seafood, and the imposition of harvest restrictions or advisories (as is presently the case in Quincy Bay) would serve to further mitigate potential residual chemical risks.

We suggest this simplification strategy for three reasons. First, there is evidence that a significant amount of the total contaminant load could be reduced by better ensuring that such toxics do not enter the wastewater stream. Simply, if residual chemicals are not introduced into wastewater they do not have to be taken out by subsequent treatment. Second, there are good indications that contaminant loads in Massachusetts Bays sediment may be the source of a significant amount toxics in the coastal food web (Capuzzo, et al. 1988; Hubbard and Bellmer 1989). This appears to be particularly true for shellfish and demersal finfish stocks within the Bays. And, third, all available evidence suggests that for the question of public health, levels of residual chemicals within the Bays appear to contribute only marginally to total seafoodborne risk within the Bays system (Wallace et al. 1988; MWRA 1987).

This is not to suggest, however, that within the Bays system risks from residual chemicals are absent. There are areas of the Bays system, such as Quincy Bay and the Inner Harbor in Boston (and others), where existing levels of residual chemicals are high. However, policy responses which work to reduce levels from the largest sources and restrict harvest from areas where contamination is particularly high may suffice to meet the regulatory limits established for public health protection.

Even with such a simplification strategy in mind, critical ecosystem health questions remain fundamentally unresolved. It is unclear as to whether regulatory limits designed to protect human health are sufficient to protect the health of other species within the Bays. However, we assert that control strategies designed to meet public health standards will not introduce greater risk for other species. Such strategies would, we feel, provide necessary, if not sufficient, goals for more broad-based environmental health.

Finfish - Pelagic and Demersal

In our treatment of finfish stocks we have chosen to specify stocks according to several functional variables. In so doing, we feel we can more effectively address various management options designed to maximize sustainable and safe use of the resource. An initial typology would group finfish stocks into two major categories; that is, pelagic and demersal stocks. This habitat and feeding distinction would allow managers to better determine the relative importance of such issues as sediment concentration of residual chemicals in the uptake of chemical compounds by finfish. We further suggest that species be categorize in terms of whether they spawn, are resident in or migrate through the waters of the Massachusetts Bays. This variable may allow for a better understanding of issues relating to kind and length of exposure to Massachusetts Bays contaminants and, therefore, the degree to which regional control strategies may influence finfish stocks.

For example, the degree to which local control strategies influence the level of residual chemicals in highly migratory stocks may be rather limited. The degree of that influence would be at least marginally determined by the amount of time that species spent with Bays waters. Alternatively, for residential stocks (that is; stocks which spend a majority of their life-cycle within the Bays) control over contaminant levels may be relatively greater.

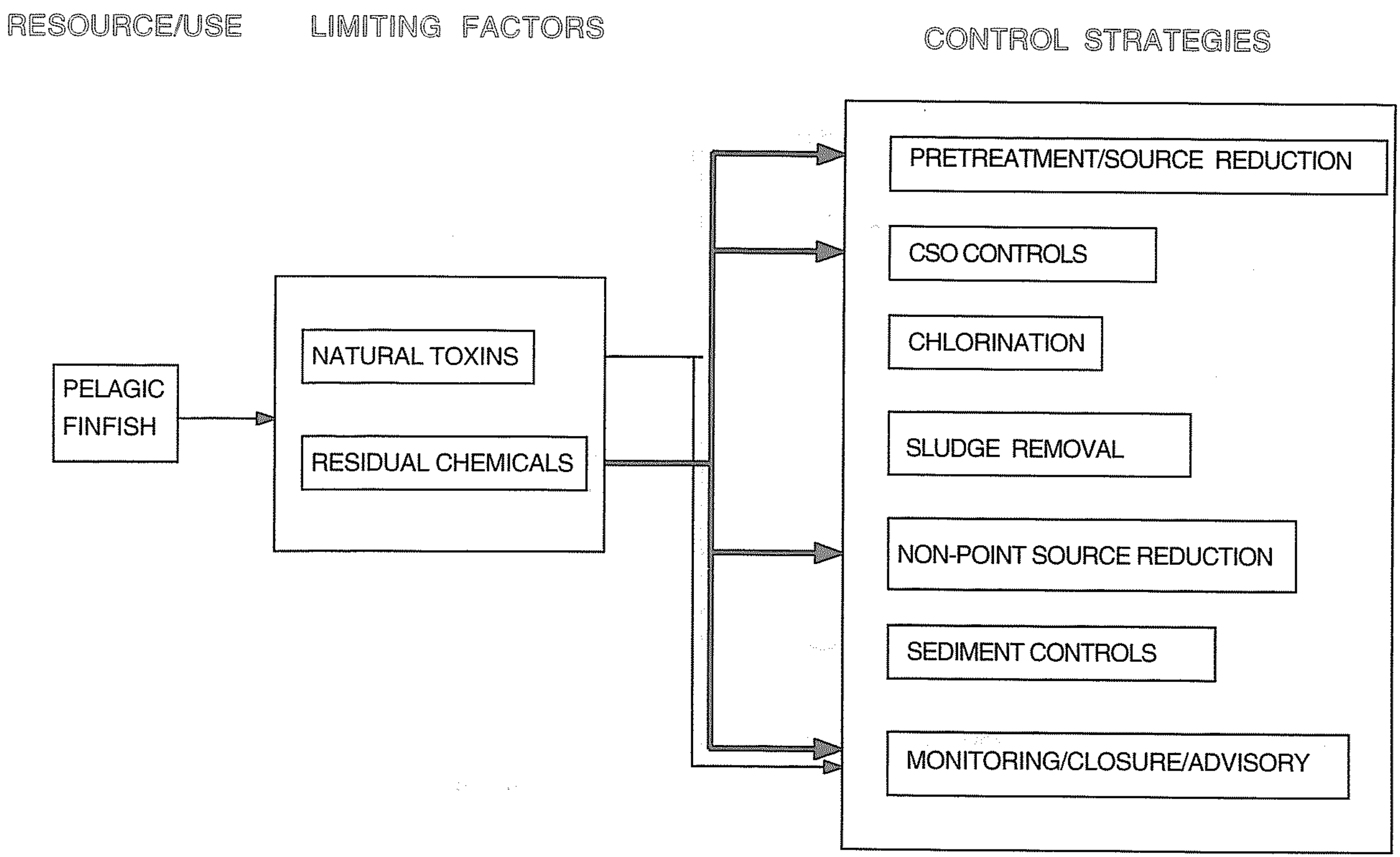
As Figures 5 and 6 illustrate, the primary limiting factors for finfish are (i) natural toxins, and, (ii) residual chemicals. The public health limits for finfish are, for the most part, the same as those that have been established for seafood generally and are, as for the case of shellfish, listed in Table 1. The primary difference between demersal and pelagic species is the degree to which control of sediment concentrations for residual chemicals may play a greater or lesser role in finfish contaminant loads. For demersal stocks the importance of sediment levels in total chemical uptake may be greater than for pelagic stocks.

Recreational Bathing Beaches

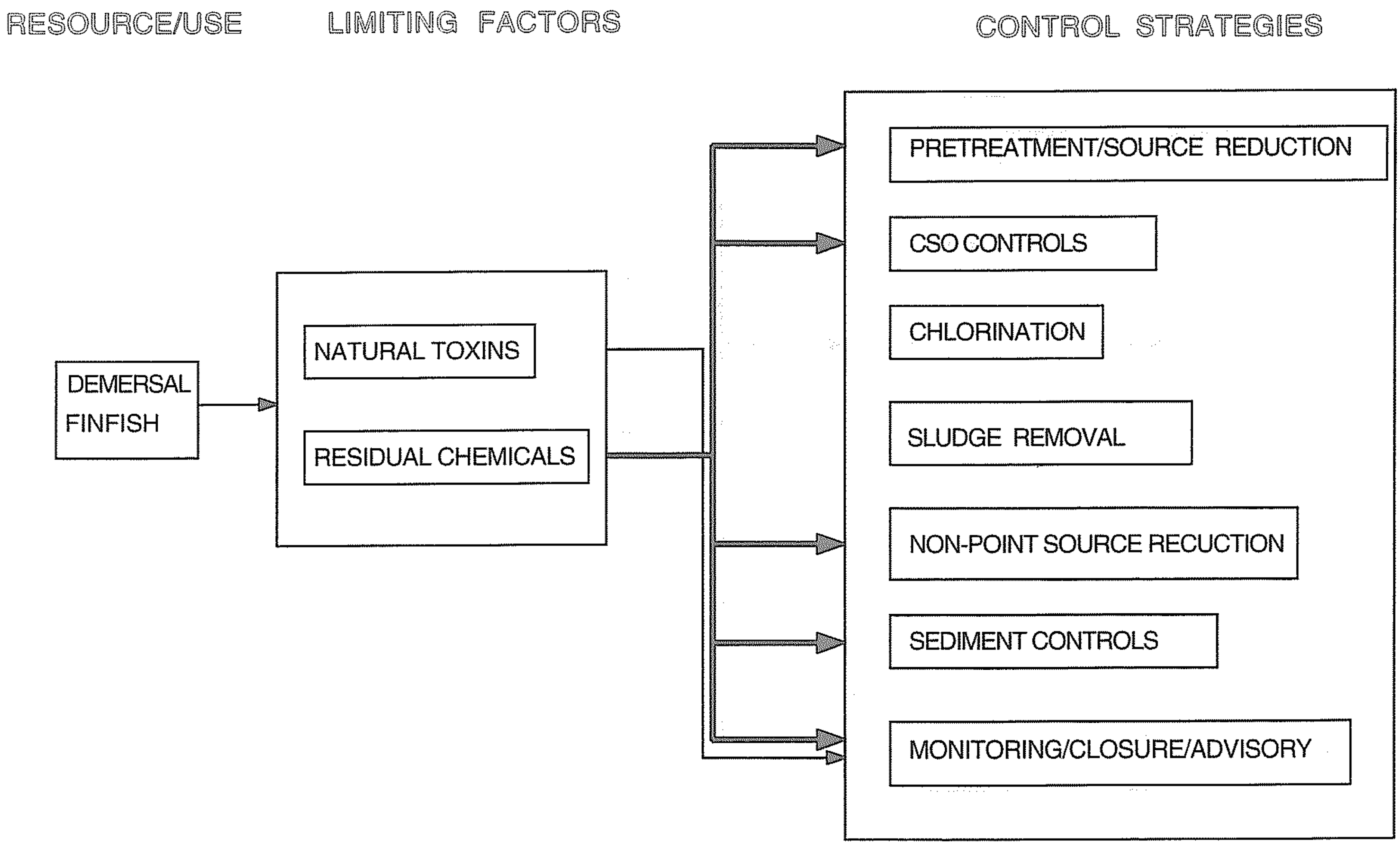
There are almost 150 recreational bathing beaches within Massachusetts Bays which are open to the general public. These beaches provide important recreational opportunities to both residents of Massachusetts and those from far beyond the boundaries of the Commonwealth. Indeed, the quality of Massachusetts Bays beaches contributes significantly to the overall value of our coast.

As is illustrated in Figure 7, beach use can be limited by levels of enteric pathogens. When levels of fecal coliforms exceed 200 organisms per 100 ml of water, Massachusetts regulations specify that the beach must be posted as unsafe for swimming. Additionally, the EPA has articulated a limit for Enterococcus for bathing beaches. Levels of Enterococcus should not exceed an average count of 33/100 ml of water, and should be posted as unsafe if the Enterococcus count exceeds 104/100 ml. Levels of Enterococcus are recommended because this organism persists longer in the marine environment and is, therefore, a better indicator of viral contamination (MWRA 1987).

# FIGURE 5

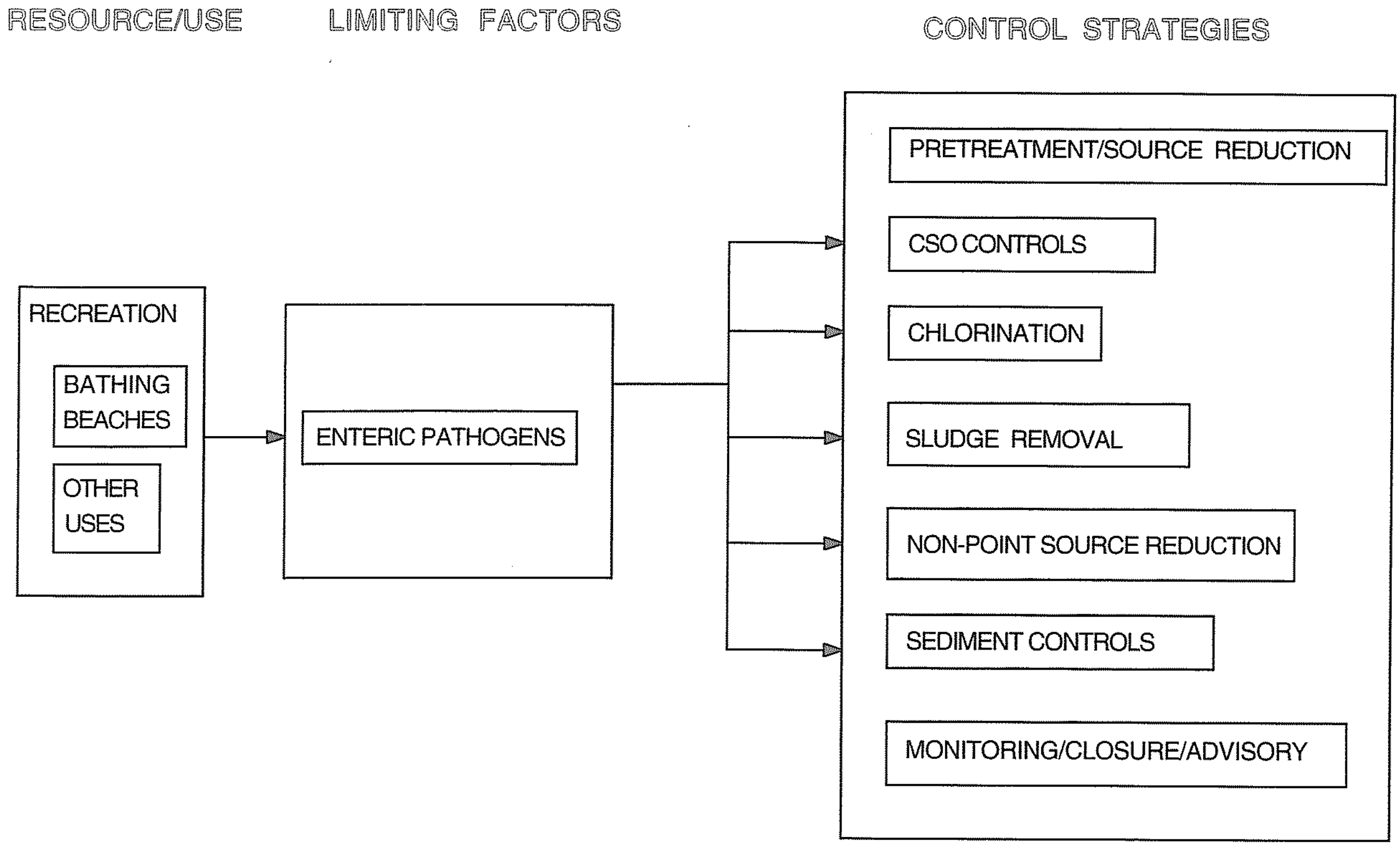

RESOURCE/USE
LIMITING FACTORS
CONTROL STRATEGIES
PELAGIC FINFISH
NATURAL TOXINS
RESIDUAL CHEMICALS
PRETREATMENT/SOURCE REDUCTION
CSO CONTROLS
CHLORINATION
SLUDGE REMOVAL
NON-POINT SOURCE REDUCTION
SEDIMENT CONTROLS
MONITORING/CLOSURE/ADVISORY

# FIGURE 6



RESOURCE/USE
LIMITING FACTORS
CONTROL STRATEGIES
DEMERSAL FINFISH
NATURAL TOXINS
RESIDUAL CHEMICALS
PRETREATMENT/SOURCE REDUCTION
CSO CONTROLS
CHLORINATION
SLUDGE REMOVAL
NON-POINT SOURCE RECUCTION
SEDIMENT CONTROLS
MONITORING/CLOSURE/ADVISORY

# FIGURE 7


RESOURCE/USE
LIMITING FACTORS
CONTROL STRATEGIES
RECREATION
BATHING BEACHES
OTHER USES
ENTERIC PATHOGENS
PRETREATMENT/SOURCE REDUCTION
CSO CONTROLS
CHLORINATION
SLUDGE REMOVAL
NON-POINT SOURCE REDUCTION
SEDIMENT CONTROLS
MONITORING/CLOSURE/ADVISORY

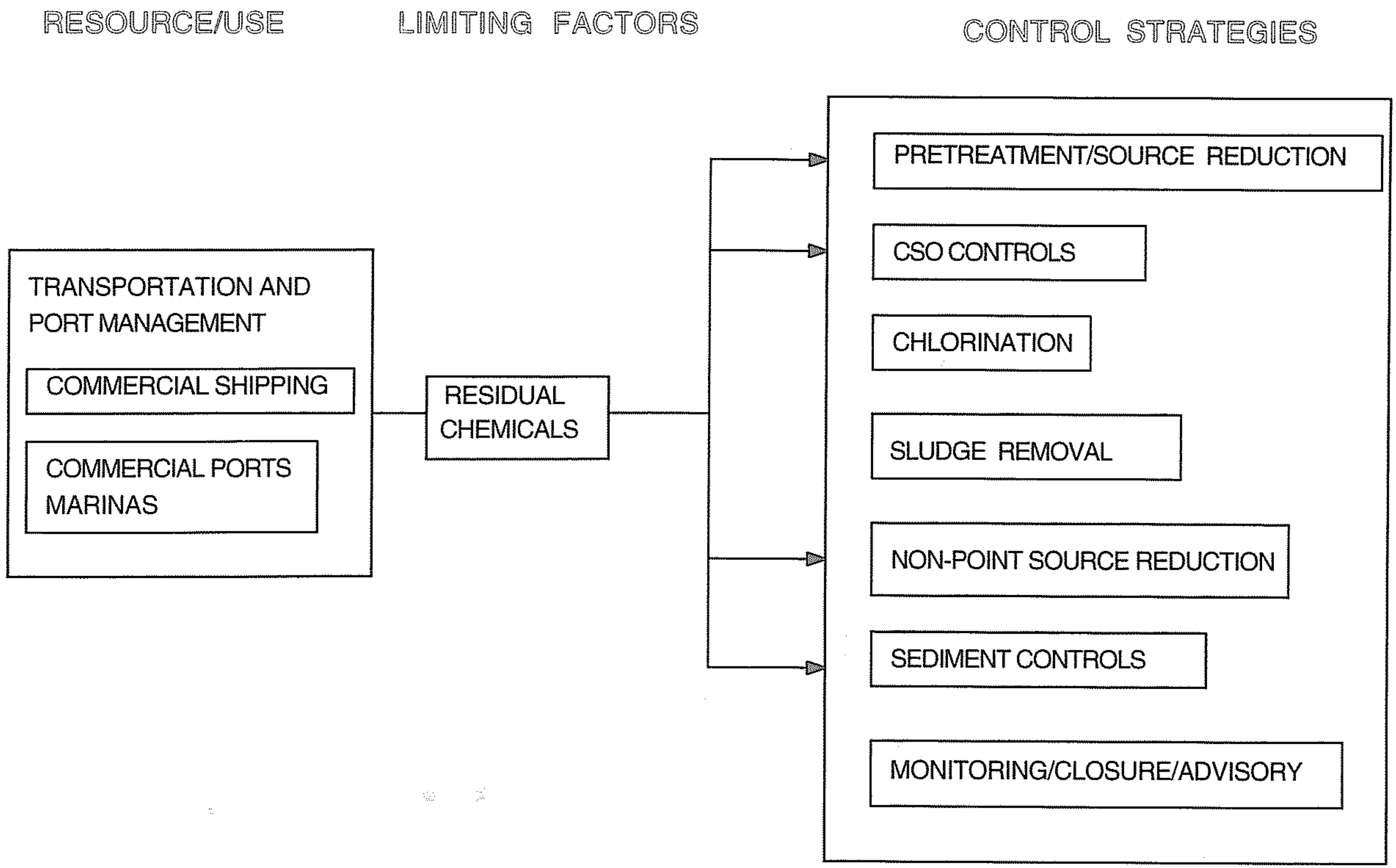
Most of the posted closing within Massachusetts Bays have historically been located within the general area of Boston Harbor and have been associated with storm-related CSO discharges. It might be anticipated, therefore, that CSO controls that effectively manage such events would significantly reduce the number of beach closings. However, it has been estimated that other control strategies, specifically sludge removal and effluent chlorination would contribute to further reduction in levels of viruses in the Harbor. For example, for primary treatment, which includes screening, grit removal and primary settling, the virus removal efficiency is estimated to be 6.6%. With subsequent chlorination of effluent, the removal rate moves to approximately 90% (MWRA 1987b).

Given the proximity of beach closing to Boston Harbor CSOs, the additional Bay-wide risk introduced by non-point sources is unclear. However, it is likely that more effective control of septic fields would serve to further reduce bathing risk, particularly in semi-enclosed embayments.

Transportation and Port Management

An additional Bays use which can be limited by elevated levels of contaminants is the development and maintenance of marine transportation infrastructure. Anthropogenic contaminants serve to limit these uses primarily by way of restrictions placed on the dredging and disposal of contaminated sediments. If sediments are shown to contain elevated concentration of residual chemicals, significant additional costs, relative to those for the dredging and disposal of clean sediments, may be incurred. In situations where sediments are relative free of chemical contaminants, dredging can be a rather straightforward activity. Dredged material may be disposed of by way of sidecasting (where dredged material is merely discharged to the side of the dredging operation), or transported by pipe to an adjacent area for the purpose of beach nourishment.

# FIGURE 8



RESOURCE/USE
LIMITING FACTORS
CONTROL STRATEGIES
TRANSPORTATION AND PORT MANAGEMENT
COMMERCIAL SHIPPING
COMMERCIAL PORTS MARINAS
RESIDUAL CHEMICALS
PRETREATMENT/SOURCE REDUCTION
CSO CONTROLS
CHLORINATION
SLUDGE REMOVAL
NON-POINT SOURCE REDUCTION
SEDIMENT CONTROLS
MONITORING/CLOSURE/ADVISORY

However, if sediments in a proposed dredge location are deemed to hold excessive levels of residual chemicals, significant restrictions are imposed. In such circumstances, dredging operations may be required to be enclosed by a system of booms which limit the movement of suspended sediments to move into adjacent coastal areas. Further, regulations may required that contaminated dredge material be disposed of in designated aquatic or upland locations and capped to prevent further environmental damage.

If such restrictions are imposed, the cost of dredging operations can be increased significantly. The cost of environmental monitoring and analysis, transportation of contaminated sediments to new disposal locations, the cost of upland acquisitions and of area capping all have the potential to add significantly to the cost of new port/marina construction and of shipping channel maintenance. Limitations on levels of residual chemicals in sediments differ from those previously discussed within the context of controls over public health risk. A determination of sediment suitability for ocean disposal is based on the levels of residual chemicals (particularly, trace metals and organohalogen compounds (such as PCBs and PAHs), mercury and organomercury, and oil compounds (Dolin and Pederson 1991). Testing protocols require a determination of the bioaccumulation potential of the sediments of concern and bioassays on selected test organisms (EPA/COE 1991). If the results of such tests indicate a high propensity of food web transfer of contaminants and/or test organisms show negative health effects, the sediment is deemed contaminated and dredging and disposal restrictions are imposed.

These regulations, then, offer an example of one way in which factors relating to ecological health (as opposed to public health) influence resource use and benefit valuation within the Bays system. The present regulation of these questions will likely change if, and when, the EPA establishes formal sediment quality criteria (EPA 1989). Control over residual chemical levels in sediments is a questions of enormous complexity, however, a "first order" strategy would resemble that previously discussed for residual chemicals in seafood.

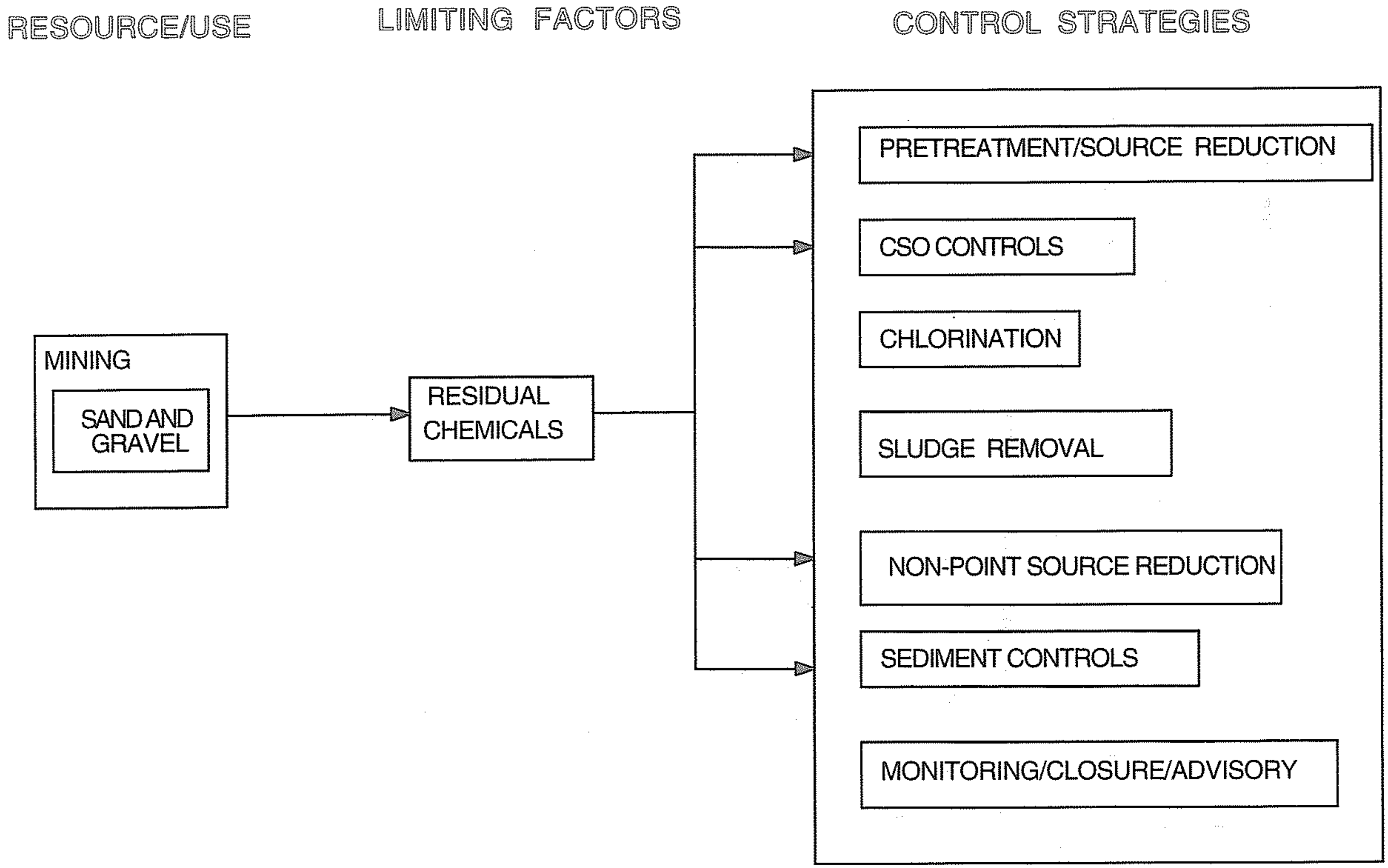
Marine Mining

A final use to be briefly discussed here is that related to marine mining activities. The opportunities for mining within the Bays system appear to be limited. However, some opportunities for sand and gravel mining and for muds (used in ceramic manufacture) have been articulated (Archer 1991; Manheim 1972). Limitations on these uses include (i) the kinds of dredging restrictions characterized above, and, (ii) the degree to which elevated levels of residual chemicals would make muds unattractive to ceramics manufacturers.

Section One has articulated a model which allows for the systematic analysis of the role of environmental contamination in determining levels of resource use within the Massachusetts Bays system. By focusing on those limiting factors which influence public health we have identified a way in which an initial specification of our model is possible. In the next section, we turn to the further specification of the next set of linkages in our model; that is, the development of a strategy which would allow for an estimate of the value of Massachusetts Bays resources and of changes in resource value which may result from reductions in environmental contamination.

The following discussion of benefit valuation methodology is designed to allow Bays program managers to estimate either the gross or net benefit value of Bays system resources. That is, these methods enable one to calculate both the total existing value of resources/uses within the system and the additional value gained by specified improvements in Bays water quality. However given the paucity of data which would allow for a clear description of potential changes in ecosystem health due to water quality improvement, estimates provided

# FIGURE 9



RESOURCE/USE
LIMITING FACTORS
CONTROL STRATEGIES
MINING
SAND AND GRAVEL
RESIDUAL CHEMICALS
PRETREATMENT/SOURCE REDUCTION
CSO CONTROLS
CHLORINATION
SLUDGE REMOVAL
NON-POINT SOURCE REDUCTION
SEDIMENT CONTROLS
MONITORING/CLOSURE/ADVISORY

in Section Two characterizing net benefit gained are focused on those resources/use that are most directly tied to managing public health attributes.

## SECTION TWO

## VALUATION OF BAYS RESOURCES

The previous section has detailed the difficulty in linking environmental improvements to increases in the value of different human uses of the Bays system. However, it is vital that continued efforts be directed toward specifying precisely the linkages between the reduction in concentration of particular pollutants in Bays systems waters and the goals of such reductions which are often expressed as improvements in human uses of the Bays resources. Until improvements are perceived by users, there will be no changes in the level or quality of human use of the Bay or the valuation of the Bay by nonusers. Once perceived, it is the changes in human use initiated by the regulatory policies that are then subject to valuation in terms of the quantitative benefits generated by reduced emissions. In addition to direct human use benefits, regulatory policies may also increase value to the non-users of the Bays.

Although the linkage between policy change and improved value of use is fraught with uncertainty, it is important to begin to develop a precise understanding of how people benefit from cleaner water. This is especially vital when resources for improving Bays water quality are limited. Valuation of human uses of the Bays can aid in allocating these limited resources to correcting those environmental problems likely to lead to the greatest increases in value.

In furthering this goal, this section of the report briefly discusses the general analytical framework that can be used to value water quality improvements and then focuses on quantifying the value of the uses that serve to focus the discussion in the previous section

(See Figure 3). A consistent theme of this discussion will be the lack of data currently available on what motivates people's uses of the Bays systems resources.

In many cases, the development of baseline estimates of the current value of resource uses in order to compare increases in value generated by future regulatory changes is not possible with the existing data available. However, this report will characterize as fully as possible with the limited available data, the use value of the major resources of the Bays. The appropriate methodologies for valuing each use will be described and the data required to fully utilize the methodologies will also be specified. When possible, the change in use value that might be generated by specific improvements in water quality is also estimated.

## CALCULATING BENEFIT VALUE

Before discussing the valuation of particular uses of the Bays, we will describe the general procedures upon which benefit evaluation is based. Usually the techniques for benefit valuation are applied to a specific type of change in use of a resource initiated by a change in regulatory policy. Managers are usually interested in the benefits to society resulting from an enhancement of particular uses by water quality improvements. In the case of this study, no management changes were specified, but instead an estimate of the gross value of the uses and resources of the Bays system was developed. In either case, whether measuring the benefit from a change in resource use or the gross or net value of a particular use, the same techniques apply.

There are several good reference manuals on how to value improvements in water quality (EPA 1990; Feenberg and Mills 1980; Freeman 1979; Huppert 1983; EPA 1983; EPA 1985; U.S. Water Resources Council 1979). In particular, (EPA 1990) is an excellent guide to the basic procedures for evaluating benefits of a fairly comprehensive list of estuary uses.

list of estuary uses. Rather than repeat the framework for analysis provided in these documents, the theoretical basis for benefit evaluation will only be briefly discussed here and the reader will be referred to these other documents for more detail.

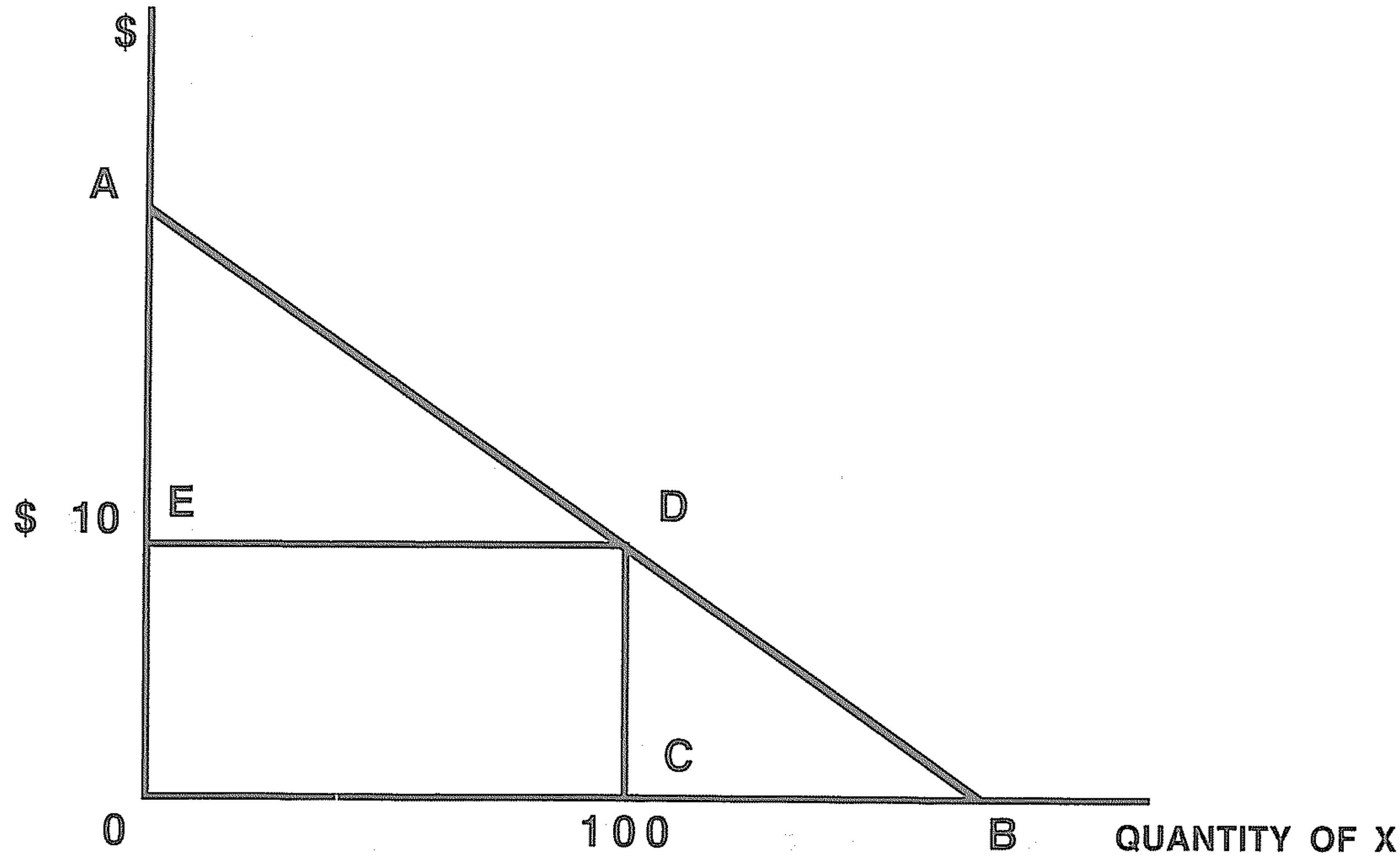
Measuring the economic benefits of any good is based upon the willingness to pay of an individual for the consumption of the good. This willingness to pay can then be aggregated among all users to determine the total gross benefit from the consumption of the good. Willingness to pay is measured by an individual's demand curve as represented by AB in Figure 10.[1] This indicates the maximum an individual is willing to pay for different quantities of the good X. The good X can be a privately traded good, such as fish, or a more typical environmental resource, such as beach access or recreational fishing, where the price of the good is zero or minimal.

The economic benefit of the good is defined as the net value of the good to the consumer or the difference between the amount spent on the good and the willingness to pay for the good. This benefit is also called consumer surplus. Consumer surplus is created since most goods are sold at a single price no matter what quantity of the good is purchased. Therefore, in the case of typical demand curve such as AB, it is only for the last unit of the good that the cost of the good is equal to the consumer's willingness to pay for it. For all previous units of the good purchased, the consumer is willing to pay more than the price charged for the good, thus yielding a surplus to the consumer.

One way to envision this measurement of economic benefit is to see what would be lost to a beach goer if the beach were to be closed to human activity. While the consumer would be able to transfer whatever expenses she was incurring to visit the beach to some other form of consumption, the consumer surplus generated by the beach would be lost until it was reopened.

FIGURE 10

ILLUSTRATION OF WILLINGNESS TO PAY AND CONSUMER SURPLUS



In Figure 10, if the price of the good is $10, then according to the demand curve, the consumer will purchase 100 units of good X. Therefore, total expenditure on good X will be $1000 and the difference between this and the total willingness to pay for 100 units of the good (area 0ADC) is the consumer surplus generated by the consumption of X. In this case, this is the area of triangle EAD. If the market price of good X were zero, as is often the case with environmental resources, then consumer surplus is equal to the entire area under the demand curve (area 0AB).

In summary, the total economic benefit to users generated by the Bays systems resources is measured by the sum of all the consumer surpluses generated by the use of these resources. This sum plus the expenditures incurred in the use of these resources would measure the total gross benefit generated by the Bays system to users of the system. Likewise, any change in the quantity and/or quality of these resources can be quantified by the resulting change in the consumer surpluses it generates. In addition to these user benefits, there are also likely to be benefits generated to non-users of the Bays system which will be discussed at the end of this section.

Those resources, such as finfish and shellfish, that are sold in the private market may also generate a producer surplus. This is analogous to consumer surplus, and can be measured precisely at any level of fish supplied by the difference between the minimum price at which harvesters would be willing to supply the fish and the market price received for the fish (see EPA 1990 for a detailed discussion of this concept). Thus, measuring the increase (or decrease in rare cases) in value generated by one of the Bays system resources due to an improvement in water quality requires estimating the increases (or decreases) in consumer and producer surpluses that are likely to result from this change.

**Secondary Benefits**

The discussion so far has focused on the concept of primary or direct benefits generated by Bays systems resources. However, in policy discussions the additional employment and income generated by the initial use of these resources are often cited as added benefits. For example, once fish are harvested from the Bays they become inputs into onshore processing activities which themselves generate income and employment. In addition, the harvesters themselves generate additional jobs and income when they spend their earnings onshore.

The measurement of these secondary benefits is beyond the scope of this study, but it is important to keep in mind a pitfall that policymakers need to avoid when referring to these benefits. When a project to improve water quality is being evaluated, the possible generation of secondary benefits needs to be closely examined, and very often will be found to be quite small or nonexistent. If the local area where the project is likely to have its greatest impact does not have an extremely large amount of unemployed resources, secondary benefits from the project are likely to be countered by the loss of secondary benefits from other parts of the economy. On the other hand, if considerable unemployment is present, than any previously unemployed resources employed by the project would be correctly added to its total economic benefit.

For example, if consumers increase their expenditures on marine recreation in response to a perceived increase in Bays water quality, the secondary benefits generated by these expenditures are likely to be largely countered by the corresponding reduction in expenditures on other activities. In a relatively fully employed economy, this will result in simply a transfer of employment and income from these other activities to those associated with marine recreation. Thus, there is no net gain in secondary benefits to the area. The only way that the switching of expenditures to marine activities is likely to generate substantial additional income and employment for the area, in this case, is if previous expenditures were made largely outside the area.

Even then, the valuation of secondary benefits would depend on what level of government is conducting the analysis. A transfer of resources from an inland community, such as Springfield, MA to a coastal community, such as Plymouth, MA would be valued by Plymouth, but on a statewide level no additional value has been generated. Alternatively, the transfer of expenditures from the north shore of the Bays region to Cape Cod would benefit Cape Cod at the expense of the north shore but not the Bays region as a whole. Likewise increases in expenditures on the Massachusetts coast by residents of neighboring states would be valued by Massachusetts, but not by the country as a whole.

If the coastal area is suffering from substantial unemployment, some additional benefit value could be generated by secondary expenditures. In this case, the transfer of resources to the coastal area would not be necessary as the resource needs for marine recreation, for example, could be met with previously unemployed or underemployed resources. Obviously, it is not possible to generalize about the secondary benefit value generated by coastal resources as the context in which they are generated determines this value.

Thus, the decision on whether to attempt to calculate secondary benefits and how to use such calculations needs to be approached with caution. (EPA 1990 and EPA 1985) discuss some of the means for calculating these benefits and provide citations for further information.

The rest of this section will examine each of the major uses identified in this study, indicating the methodology for estimating their value, the data requirements for this estimation, and what portion of their value can be estimated with existing data.

## VALUING THE RESOURCES OF THE BAYS SYSTEM

### Commercial Fishing

Finfishing

The knowledge of how specific water quality improvements are likely to affect the stocks of various finfish species is still too uncertain to support the estimation of likely benefit value changes from such improvements. This difficulty of associating changes in water quality with changes in the quantity and/or quality of the fish stock has been reported in other studies (EPA 1990 and EPA 1985). Recently commissioned studies by the Massachusetts Bays Program on the impact of pollution on living resources of the Bays may eventually shed some light on this issue.

Even then, under certain realistic market conditions, increases in the quantity or quality of finfish from improvements in water quality will not yield significant increases in economic benefit (as measured by net changes in consumer and producer surpluses). There are two characteristics of the Mass Bays fishery which make this a likely possibility.

First, finfish caught in Massachusetts Bays account for a very small percentage of total New England finfish landings, and an even smaller percentage of total consumption, and thus fluctuations in their supply are unlikely to have significant affects on the market prices of the different species harvested (MWRA 1987b).[2] This means that there will be no consumer surplus gains from additional fish supply do to improved water quality, since no price reductions are likely to result. In other words, all locally caught additions to the area fish market will simply substitute for fish currently imported from elsewhere, thus leaving consumers overall no better off.

One exception to this case could be a particular Mass Bays species which represented a large portion of its market supply. Another exception would be a case where the perceived improvement in the quality of the fish stocks leads to an increased willingness to pay on the part of consumers for Mass Bays fish. This would shift out the demand curve for fish, generating additional consumer surplus as measured by the area between the old and new demand curve above the price line. Neither of these exceptions seem likely enough to occur in the Mass Bays context to result in large consumer surplus changes from improved finfish stocks.

Second, if no additions to consumer surplus are produced by expanded fish stocks, the only other source of economic benefit would be an increase in producer surplus. However, considerable over-fishing is occurring in the industry right now and thus any producer surplus generated by increased catch due to improved fish populations is likely to be quickly dissipated by competition due to the lack of rigid entry restrictions into the industry (Massachusetts Task Force 1990). Thus, it is vitally important that water quality improvements be accompanied by better fisheries management. Otherwise, gains in value from improved fish stocks are likely to be countered by the increased expenditures by fishermen in trying to capture these new stocks, thus leaving no additional economic benefit for society in the long run (McConnell and Strand 1989).

In order to determine the economic benefit value of the existing finfishing resources of the Bays system, it would be necessary to measure the consumer and producer surpluses created from the marketing of each species. Unfortunately, demand functions for these species in Massachusetts do not exist. Supply functions indicating the cost of harvesting these different species are also not readily available. In light of these data constraints, we have instead developed estimates of the landed value of finfish harvested from the Bays. These are reported for the Boston Harbor area in Table 2 and for the rest of the Massachusetts Bays system in Table 3 for the years 1987-1990.

TABLE 2:
BOSTON HARBOR AREA COMMERCIAL FINFISH, SHELLFISH,
CRUSTACEAN, AND MOLLUSCAN VALUES (1987-1990)

| | 1987 | | 1988 | | 1989 | | 1990 | |
|---|---|---|---|---|---|---|---|---|
| FISH TYPES | LBS. LANDED | $ VALUE | LBS. LANDED | $ VALUE | LBS. LANDED | $ VALUE | LBS. LANDED | $ VALUE |
| DEMERSAL | | | | | | | | |
| RESIDENTIAL | | | | | | | | |
| Monkfish | 155 | 236 | 5 | 8 | 140 | 259 | 250 | 371 |
| Atlantic cod | 27,273 | 30,028 | 5,947 | 5,397 | 9,109 | 7,373 | 15,700 | 9,658 |
| Cusk | 410 | 197 | 35 | 15 | 0 | 0 | 345 | 78 |
| Winter flounder | 32,582 | 42,396 | 57,847 | 97,265 | 22,880 | 30,899 | 2,390 | 3,080 |
| Witch flounder | 3,661 | 6,410 | 0 | 0 | 0 | 0 | 90 | 145 |
| Yellowtail flounder | 5,915 | 7,709 | 5,068 | 7,624 | 5,025 | 6,018 | 1,175 | 1,350 |
| Unclass. flounder | 1,085 | 755 | 0 | 0 | 0 | 0 | 0 | 0 |
| American plaice | 3,930 | 4,506 | 0 | 0 | 65 | 90 | 815 | 665 |
| Sand dab | 285 | 155 | 275 | 168 | 495 | 393 | 40 | 16 |
| Silver hake | 6,865 | 5,039 | 0 | 0 | 0 | 0 | 700 | 245 |
| Ocean pout | 4,440 | 688 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unclass. Skates | 3,740 | 1,081 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wolffishes | 1,195 | 616 | 20 | 9 | 0 | 0 | 170 | 41 |
| SUBTOTAL | 91,536 | 99,816 | 69,197 | 110,486 | 37,714 | 45,032 | 21,675 | 15,649 |
| MIGRATORY | | | | | | | | |
| White hake | 1,850 | 1,595 | 0 | 0 | 0 | 0 | 0 | 0 |
| Red hake | 4,075 | 1,998 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spiny dogfish | 0 | 0 | 0 | 0 | 0 | 0 | 6900 | 621 |
| Redfish | 6,735 | 3,881 | 0 | 0 | 0 | 0 | 75 | 15 |
| SUBTOTAL | 12,660 | 7,474 | 0 | 0 | 0 | 0 | 6,975 | 636 |
| MIGRAT./SPAWN | | | | | | | | |
| Haddock | 615 | 992 | 0 | 0 | 0 | 0 | 360 | 324 |
| Pollock | 5,810 | 2,419 | 3,240 | 918 | 0 | 0 | 425 | 138 |
| SUBTOTAL | 6,425 | 3,411 | 3,240 | 918 | 0 | 0 | 785 | 462 |
| PELAGIC | | | | | | | | |
| MIGRATORY | | | | | | | | |
| Bluefish | 494 | 169 | 0 | 0 | 0 | 0 | 15 | 19 |
| MIGRAT./SPAWN | | | | | | | | |
| Atlantic herring | 710,000 | 35,500 | 806,725 | 36,302 | 435,000 | 19,574 | 1,288,000 | 57,872 |
| ANADROMOUS | | | | | | | | |
| Menhaden | 0 | 0 | 441,675 | 22,460 | 137,000 | 5,545 | 99,500 | 3,980 |
| CRUSTACEAN | | | | | | | | |
| RESIDENTIAL | | | | | | | | |
| Northern lobster | 3,453,114 | 10,462,935 | 3,597,362 | 11,295,717 | 4,670,538 | 13,170,917 | 5,236,643 | 12,882,142 |
| Shrimp | 8,630 | 8,630 | 0 | 0 | 0 | 0 | 0 | 0 |
| SUBTOTAL | 3,461,744 | 10,471,565 | 3,597,362 | 11,295,717 | 4,670,538 | 13,170,917 | 5,236,643 | 12,882,142 |
| MOLLUSCAN | | | | | | | | |
| RESIDENTIAL | | | | | | | | |
| Soft shell clam | * | 2,283,587 | * | 1,571,519 | * | 1,330,563 | * | 2,030,646 |
| BOST. HARB. TOTAL | 4,282,859 | 12,901,522 | 4,918,199 | 13,037,402 | 5,280,252 | 14,571,631 | 6,653,593 | 14,991,406 |
| MASS. BAYS TOTAL | 31,171,737 | 34,805,847 | 47,774,948 | 39,179,771 | 43,652,042 | 35,769,400 | 70,114,815 | 37,740,474 |
| GRAND TOTAL | 35,454,596 | 47,707,369 | 52,693,147 | 52,217,173 | 48,932,294 | 50,341,031 | 76,768,408 | 52,731,880 |

* Shellfish harvest weight values are reported in bushels.

Finfish data from: National Marine Fisheries Service, Northeast Fisheries Center, Conservation & Utilization Division, Fisheries Statistics & Economics Branch, Woods Hole Laboratory, Woods Hole, MA.
Shellfish data from: Massachusetts Division of Marine Fisheries, Shellfish Sanitation & Management Program, Sandwich and Newburyport, MA.
Lobster data from: Massachusetts Division of Marine Fisheries, Cat Cove Marine Laboratory, Statistics & Data Processing Project, Salem, MA

TABLE 3:
MASSACHUSETTS BAYS COMMERCIAL FINFISH, SHELLFISH,
CRUSTACEAN, AND MOLLUSCAN VALUES (1987-1990)

| | 1987 | | 1988 | | 1989 | | 1990 | |
|---|---|---|---|---|---|---|---|---|
| FISH TYPES | LBS. LANDED | $ VALUE | LBS. LANDED | $ VALUE | LBS. LANDED | $ VALUE | LBS. LANDED | $ VALUE |
| DEMERSAL | | | | | | | | |
| RESIDENTIAL | | | | | | | | |
| Monkfish | 276,644 | 422,449 | 216,455 | 330,383 | 179,798 | 271,995 | 224,356 | 347,762 |
| Atlantic cod | 1,400,362 | 1,386,688 | 2,541,386 | 1,603,879 | 3,286,007 | 2,211,743 | 3,876,402 | 2,599,278 |
| Cusk | 61,432 | 35,556 | 52,613 | 37,580 | 72,404 | 39,124 | 39,530 | 21,653 |
| Winter flounder | 1,349,876 | 1,381,291 | 1,513,734 | 1,521,975 | 1,795,342 | 1,969,930 | 1,482,139 | 1,317,977 |
| Witch flounder | 241,186 | 352,717 | 222,145 | 359,525 | 128,876 | 239,947 | 136,391 | 241,206 |
| Yellowtail flounder | 1,318,980 | 1,748,459 | 1,326,017 | 1,569,573 | 980,253 | 1,207,657 | 1,669,958 | 1,507,470 |
| Unclass. flounder | 29,200 | 35,205 | 19,995 | 24,114 | 6,895 | 7,361 | 22,455 | 20,429 |
| American plaice | 230,546 | 209,786 | 421,923 | 377,437 | 177,239 | 199,055 | 202,217 | 184,950 |
| Sand dab | 82,279 | 41,478 | 98,988 | 42,157 | 108,246 | 40,446 | 62,559 | 14,748 |
| Atlantic halibut | 1,119 | 2,670 | 163 | 487 | 426 | 967 | 1,640 | 2,855 |
| Silver hake | 3,984,878 | 791,941 | 2,252,499 | 598,423 | 1,398,675 | 369,458 | 3,276,736 | 748,231 |
| Ocean pout | 2,673,132 | 286,923 | 1,317,165 | 156,619 | 528,529 | 56,698 | 319,723 | 40,451 |
| Unclass. dogfish | 0 | 0 | 0 | 0 | 34,290 | 6,858 | 0 | 0 |
| Unclass. Skates | 343,504 | 55,013 | 937,577 | 144,090 | 767,801 | 136,100 | 1,013,923 | 197,929 |
| Wolffish | 112,935 | 49,564 | 87,631 | 33,074 | 62,468 | 24,284 | 74,335 | 30,017 |
| Sturgeons | 1,883 | 1,100 | 2,758 | 2,211 | 220 | 180 | 75 | 75 |
| SUBTOTAL | 12,087,956 | 6,800,840 | 11,011,069 | 6,799,527 | 9,525,469 | 6,781,803 | 12,402,439 | 7,275,031 |
| MIGRATORY | | | | | | | | |
| Fourspot flounder | 2,093 | 442 | 1,053 | 174 | 67 | 40 | 0 | 0 |
| Summer flounder | 45,481 | 50,983 | 176,055 | 199,583 | 27,041 | 45,040 | 4,631 | 8,370 |
| White hake | 112,443 | 56,702 | 112,769 | 44,776 | 38,060 | 17,659 | 139,252 | 71,298 |
| Red hake | 457,908 | 65,383 | 519,157 | 59,114 | 472,300 | 57,748 | 559,901 | 86,877 |
| Redfish | 20,099 | 12,184 | 29,049 | 19,010 | 10,014 | 5,179 | 21,982 | 8,721 |
| Spiny dogfish | 4,709,774 | 301,481 | 4,501,425 | 273,413 | 4,048,979 | 323,098 | 13,295,533 | 1,168,560 |
| Tautog | 61,097 | 16,143 | 21,264 | 6,174 | 23,882 | 9,477 | 20,248 | 9,464 |
| Unclass. Shark | 5,729 | 9,524 | 758 | 539 | 90 | 49 | 529 | 667 |
| SUBTOTAL | 5,414,622 | 512,822 | 5,361,530 | 602,783 | 4,620,433 | 458,288 | 14,042,076 | 1,353,957 |
| MIGRAT. SPAWN | | | | | | | | |
| Haddock | 54,883 | 138,548 | 56,773 | 91,780 | 49,765 | 71,633 | 43,988 | 61,546 |
| Pollock | 2,260,797 | 906,228 | 2,108,129 | 593,195 | 1,197,973 | 543,785 | 830,150 | 433,593 |
| Scup | 15,165 | 8,152 | 16,582 | 9,894 | 9,742 | 6,979 | 612 | 306 |
| SUBTOTAL | 2,330,845 | 1,052,928 | 2,181,484 | 694,869 | 1,257,480 | 622,397 | 874,750 | 495,445 |
| PELAGIC | | | | | | | | |
| RESIDENTIAL | | | | | | | | |
| Weakfish | 0 | 0 | 1,227 | 1,177 | 10 | 2 | 0 | 0 |
| MIGRATORY | | | | | | | | |
| Bluefish | 146,168 | 20,608 | 241,154 | 29,564 | 312,105 | 41,627 | 329,808 | 47,457 |
| Butterfish | 530 | 191 | 1,868 | 465 | 3,580 | 1,273 | 4,043 | 790 |
| Atlantic mackerel | 107,447 | 33,722 | 257,404 | 88,508 | 139,307 | 42,554 | 354,353 | 59,768 |
| Black sea bass | 5,438 | 8,505 | 2,618 | 3,674 | 2,817 | 5,869 | 990 | 1,719 |
| Stripped bass | 89 | 30 | 0 | 0 | 338 | 564 | 1,113 | 1,868 |
| Mako | 4,016 | 6,851 | 2,480 | 3,490 | 303 | 63 | 225 | 158 |
| Bluefin tuna | 978,754 | 6,915,992 | 1,209,909 | 8,483,504 | 1,000,547 | 8,998,742 | 751,261 | 7,534,528 |
| SUBTOTAL | 1,242,462 | 6,985,897 | 1,716,660 | 8,608,382 | 1,459,007 | 9,090,694 | 1,441,793 | 7,646,288 |

## TABLE 3:
## MASSACHUSETTS BAYS COMMERCIAL FINFISH, SHELLFISH, CRUSTACEAN, AND MOLLUSCAN VALUES (1987-1990)

| FISH TYPES | 1987 LBS. LANDED | 1987 $ VALUE | 1988 LBS. LANDED | 1988 $ VALUE | 1989 LBS. LANDED | 1989 $ VALUE | 1990 LBS. LANDED | 1990 $ VALUE |
|---|---|---|---|---|---|---|---|---|
| MIGRAT. SPAWN | | | | | | | | |
| Atlantic herring | 3,916,715 | 178,472 | 15,707,720 | 710,260 | 20,016,096 | 1,484,330 | 33,650,288 | 1,503,825 |
| ANADROMOUS | | | | | | | | |
| American shad | 8,691 | 1,116 | 9,659 | 1,456 | 3,428 | 1,455 | 2,883 | 1,335 |
| Menhaden | 0 | 0 | 5,110,000 | 212,205 | 797,400 | 31,968 | 1,208,400 | 50,676 |
| CATADROMOUS | | | | | | | | |
| American eel | 580 | 59 | 180 | 42 | 0 | 0 | 2 | 18 |
| SUBTOTAL | 9,271 | 1,175 | 5,119,839 | 213,703 | 800,828 | 33,423 | 1,211,285 | 52,029 |
| UNCLASS. FINFISH | 58,985 | 20,858 | 16,757 | 3,915 | 28,156 | 15,071 | 50,968 | 22,307 |
| CRUSTACEAN | | | | | | | | |
| RESIDENTIAL | | | | | | | | |
| Northern lobster | 5,971,585 | 18,093,903 | 6,635,491 | 20,835,442 | 5,892,163 | 16,615,900 | 6,383,642 | 18,001,870 |
| Shrimp | 134,757 | 140,526 | 6,307 | 5,785 | 5,400 | 5,376 | 39,213 | 27,119 |
| SUBTOTAL | 6,106,342 | 18,234,429 | 6,641,798 | 20,841,227 | 5,897,563 | 16,621,276 | 6,422,855 | 18,028,989 |
| MOLLUSCAN | | | | | | | | |
| RESIDENTIAL | | | | | | | | |
| Soft shell clam | * | 231,409 | * | 146,301 | * | 113,820 | * | 210,704 |
| Quahogs | * | 228,470 | * | 284,676 | * | 66,963 | * | 256,750 |
| Oyster | * | 106,137 | * | 126,000 | * | 0 | * | 104,461 |
| Bay scallop | * | 54,580 | * | 40,951 | * | 5,466 | * | 85,665 |
| Surf clams | * | 65,559 | * | 0 | * | 6,601 | * | 253,680 |
| Mussels | * | 292,390 | * | 61,168 | * | 308,595 | * | 229,922 |
| Conch | * | 32,802 | * | 14,039 | * | 17 | * | 502 |
| Razor clam | * | 5,670 | * | 28,561 | * | 148,410 | * | 215,833 |
| SUBTOTAL | * | 1,017,017 | * | 701,698 | * | 649,872 | * | 1,357,517 |
| MIGRATORY | | | | | | | | |
| Loligo squid | 1,820 | 522 | 2,899 | 890 | 23,305 | 3,955 | 5,341 | 1,218 |
| Unclass. squid | 639 | 184 | 3,160 | 698 | 23,560 | 8,269 | 12,983 | 3,850 |
| Illex squid | 2,080 | 703 | 10,805 | 645 | 135 | 20 | 37 | [illegible] |
| SUBTOTAL | 4,539 | 1,409 | 16,864 | 2,233 | 47,000 | 12,244 | 18,361 | 5,[illegible] |
| MASS. BAYS TOTAL | 31,171,737 | 34,805,847 | 47,774,948 | 39,179,771 | 43,652,042 | 35,769,400 | 70,114,815 | 37,740,474 |
| BOST. HARB. TOTAL | 4,282,859 | 12,901,522 | 4,918,199 | 13,037,402 | 5,280,252 | 14,571,631 | 6,653,593 | 14,991,406 |
| GRAND TOTAL | 35,454,596 | 47,707,369 | 52,693,147 | 52,217,173 | 48,932,294 | 50,341,031 | 76,768,408 | 52,731,880 |

* Shellfish harvest weight values are reported in bushels.

Finfish data from: National Marine Fisheries Service, Northeast Fisheries Center, Conservation & Utilization Division, Fisheries Statistics & Economics Branch, Woods Hole Laboratory, Woods Hole, MA.
Lobster data from: Massachusetts Division of Marine Fisheries, Cat Cove Marine Laboratory, Statistics & Data Processing Project, Salem, MA.
Shellfish data from: Massachusetts Division of Marine Fisheries, Shellfish Sanitation & Management Program, Sandwich and Newburyport, MA.

These values underestimate the total gross benefit of the finfish resources since they do not include the value of any consumer or producer surpluses generated in the marketplace. In the case of producer surplus, this may not be a problem since over-fishing is likely to have eliminated most if not all of the surplus. Some consumer surpluses might be generated in the consumption of Mass Bays caught fish. However, if most species of Mass Bays fish only represent marginal increases in their overall market supply, consumer surplus benefits would be quite small.

The data are calculated from the catch reports of harvesters by the National Marine Fisheries Service. Thus, these data are based on the harvesters' identification of where the fish were caught, and therefore are more accurate than the common practice of reporting the total quantity of finfish landed in Massachusetts Bays ports which include fish caught from far offshore (EPA 1985 and Massachusetts Bays Program 1991). We have categorized the data by whether the fish are demersal or pelagic species and within these broad categories whether they are likely to be residential to the Bays system or migratory, and if migratory, whether they are likely to engage in significant spawning activity while resident in the Bays. It is more likely that residential fish populations will be affected by current water quality conditions and any improvements in water quality than migratory species and that the only significant impact on migratory species would be through the spawning process and development of young fish prior to migration.

Almost $53 million of fish, lobsters and shellfish were harvested from Mass. Bays in 1990, up from $47.7 million in 1987. Finfish accounted for a little over one third of this total or around $18.4 million. Almost all of these were caught outside the Boston Harbor area and bluefin tuna accounted for 40% of the value of the catch with another 50% accounted for by six species groups-- cod, flounder, herring, hake, dogfish, and pollock.

Table 4 reveals that for both 1987 and 1990, around $7 million of the fish harvested (mostly cod, flounder, and hake) were resident to the Massachusetts Bays system. Also the herring and pollock, with a landed value of around $2 million, could also be active spawners in the Massachusetts Bays. Therefore, these finfish species should be the focus of initial studies to determine the impact of Bays water quality on their health and development.

Lobstering and Shellfishing

Unfortunately, the difficulties in linking Bays water quality changes to finfish populations also apply to the lobster population. Yet lobsters are a much more significant species in terms of harvested value. As Tables 2 and 3 indicate, lobsters accounted for almost $31 million or 58% of the total landed value of all species from the Bays system in 1990. Lobsters represent over 85% of the value of the 1990 commercial catch from Boston Harbor alone.

Tables 2 and 3 reveal that commercial shellfish are a much less significant component of total value than lobstering and finfishing. Shellfish accounted for around 6.5% of the value of all fisheries resources harvested from Massachusetts Bay, totalling around $3.4 million in 1990. Boston Harbor area shellfish represented 60% of this value. These shellfish are harvested in a contaminated state and require depuration before being sent to market. Soft shell clams account for the vast majority of the harvest in all areas (Table 7).

The quantity of shellfish harvested in the Bays has fluctuated considerably over the last three years (Tables 5-6). The shellfish catch outside of Boston Harbor fell by almost 50% between 1987 and 1988, while by half as much in the vicinity of Boston Harbor. The 1989 catch was up by over 80% over 1988 levels outside the Harbor area and remained relatively constant within the area. Harvest levels increased in both areas in 1990.

TABLE 4:
LANDED VALUES IN DOLLARS
BY FINFISH TYPE (1987 & 1990)

| FISH TYPE | RESIDENTIAL 1987 | RESIDENTIAL 1990 | MIGRATORY 1987 | MIGRATORY 1990 | MIGRATORY/SPAWNING 1987 | MIGRATORY/SPAWNING 1990 |
|---|---|---|---|---|---|---|
| DEMERSAL | 6,900,656 | 7,290,680 | 520,296 | 1,354,593 | 1,056,339 | 495,907 |
| PELAGIC | 0 | 0 | 6,916,161 | 7,534,547 | 213,972 | 1,561,697 |

Massachusetts Bays & Boston Harbor Area Harvests Combined.

Data from: National Marine Fisheries Service, Northeast Fisheries Center, Conservation & Utilization Division, Fisheries Statistics & Economics Branch, Woods Hole Laboratory, Woods Hole, MA.

TABLE 5:
COMMERCIAL & RECREATIONAL SHELLFISH HARVEST IN BUSHELS
BY TOWN & COUNTY (1987-1990)

| COUNTY/TOWN | COMMERCIAL HARVEST 1987 | 1988 | Change | 1989 | Change | 1990 | Change | RECREATIONAL HARVEST 1987 | 1988 | Change | 1989 | Change | 1990 | Change |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ESSEX COUNTY | | | | | | | | | | | | | | |
| Gloucester | 1,500 | 1,400 | -7% | 1,500 | 7% | 2,020 | 35% | 310 | 400 | 29% | 410 | 3% | 920 | 124% |
| PLYMOUTH COUNTY | | | | | | | | | | | | | | |
| Hull | 0 | 0 | — | 0 | — | 0 | — | 100 | 85 | -15% | 0 | -100% | 0 | — |
| Scituate | 1,600 | 200 | -88% | 0 | -100% | 0 | — | 550 | 475 | -14% | 650 | 37% | 0 | -100% |
| Marshfield | 9,500 | 0 | -100% | 0 | — | 0 | — | 0 | 0 | — | 0 | — | 0 | — |
| Duxbury | 379 | 722 | 91% | 10,472 | 1350% | 21,322 | 104% | 2,729 | 2,722 | -0% | 2,820 | 4% | 3,270 | — |
| Kingston | 0 | 0 | — | 0 | — | 0 | — | 500 | 0 | -100% | 0 | — | 0 | — |
| Plymouth | 6,662 | 5,014 | -25% | 13,976 | 179% | 288 | -98% | 0 | 0 | — | 0 | — | 0 | — |
| BARNSTABLE CTY. | | | | | | | | | | | | | | — |
| Barnstable (.28) * | 1,128 | 1,545 | 37% | 1,173 | -24% | 1,388 | 17% | 255 | 245 | -4% | 118 | -52% | 304 | 158% |
| Yarmouth (.10) | 565 | 210 | -63% | 230 | 100% | 258 | 12% | 58 | 64 | 14% | 38 | -41% | 37 | -3% |
| Dennis (.53) | 740 | 791 | 7% | 943 | 19% | 252 | -73% | 58 | 61 | 9% | 185 | 203% | 149 | -19% |
| Brewster | 0 | 0 | — | 0 | — | 0 | — | 1,838 | 1,406 | -24% | 1,850 | 32% | 1,850 | 0% |
| Orleans (.11) | 386 | 660 | 71% | 973 | 47% | 999 | 3% | 57 | 70 | 23% | 50 | -29% | 57 | 14% |
| Eastham (.24) | 678 | 546 | -19% | 408 | -25% | 480 | 18% | 268 | 173 | -35% | 162 | -6% | 190 | 17% |
| Wellfleet (.69) | 5,428 | 5,557 | 2% | 0 | -100% | 5,615 | 100% | 411 | 537 | 31% | 0 | -100% | 533 | 100% |
| Truro (.19) | 0 | 0 | — | 0 | — | 0 | — | 72 | 93 | 29% | 43 | -54% | 62 | 44% |
| Provincetown | 4,072 | 0 | -100% | 374 | 100% | 10,632 | 2743% | 805 | 756 | -6% | 571 | -24% | 791 | 39% |
| SUBTOTAL | 32,638 | 16,645 | -49% | 30,049 | 81% | 43,233 | 44% | 8,007 | 7,087 | -11% | 6,897 | -3% | 8,163 | 18% |
| DEPURATED SHELLFISH HARVEST | | | | | | | | | | | | | | |
| Revere | 1,555 | 1,964 | 26% | 1,728 | -12% | 0 | -100% | | | | | | | |
| Winthrop | 2,075 | 1,024 | -51% | 0 | -100% | 713 | 100% | | | | | | | |
| Boston | 4,017 | 6,526 | 62% | 5,494 | -16% | 10,159 | 85% | | | | | | | |
| Quincy | 10,300 | 6,978 | -32% | 6,418 | -8% | 9,624 | 50% | | | | | | | |
| Weymouth | 1,832 | 5,018 | 174% | 2,390 | -52% | 0 | -100% | | | | | | | |
| Hingham | 5,902 | 3,635 | -38% | 2,534 | -30% | 3,462 | 37% | | | | | | | |
| Hull | 6,243 | 7,984 | 28% | 3,379 | -58% | 5,583 | 65% | | | | | | | |
| SUBTOTAL | 31,924 | 33,108 | 4% | 21,941 | -34% | 29,520 | 35% | | | | | | | |
| GRAND TOTAL | 64,561 | 49,753 | -23% | 51,990 | 4% | 72,753 | 40% | 8,007 | 7,087 | -11% | 6,897 | -3% | 8,163 | 18% |

From: Massachusetts Division of Marine Fisheries, Shellfish Sanitation & Management Program, Sandwich and Newburyport, MA; & Massachusetts Division of Marine Fisheries, Cat Cove Marine Laboratory, Statistics & Data Processing Project, Salem, MA.

* For some Cape Cod towns, the town landings data compiled by the SSMP include harvest from south cape and outer cape shellfish beds. Therefore, Cape Cod Bay's contributions to town annual landings were estimated by multiplying the town annual landings by the ratio of the town's Cape Cod Bay shellfish area acreage to its total area acreage. The computed town ratios are listed for each town.

TABLE 6:
COMMERICAL & RECREATIONAL HARVEST VALUES IN DOLLARS
BY TOWN & COUNTY (1987-1990)

| COUNTY/TOWN | Commercial Harvest 1987 | 1988 | Change | 1989 | Change | 1990 | Change | Recreational Harvest 1987 | 1988 | Change | 1989 | 1990 | Change |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ESSEX COUNTY | | | | | | | | | | | | | |
| Gloucester | 103,185 | 66,458 | -36% | 19,590 | -71% | 137,852 | 604% | 21,257 | 13,731 | -35% | 15,750 | 42,754 | 171% |
| PLYMOUTH COUNTY | | | | | | | | | | | | | |
| Hull | 0 | 0 | — | 0 | — | 0 | — | 1,610 | 2,028 | 26% | 0 | 0 | — |
| Scituate | 30,992 | 2,632 | -92% | 0 | -100% | 0 | — | 29,931 | 16,646 | -44% | 17,462 | 0 | -100% |
| Marshfield | 184,014 | 0 | -100% | 0 | — | 0 | — | 0 | 0 | — | 0 | 0 | — |
| Duxbury | 12,774 | 32,865 | 157% | 250,511 | 662% | 445,054 | 78% | 164,238 | 154,182 | -6% | 143,924 | 202,604 | 41% |
| Kingston | 0 | 0 | — | 0 | — | 0 | — | 32,358 | 0 | -100% | 0 | 0 | — |
| Plymouth | 103,665 | 70,727 | -32% | 182,527 | — | 3,917 | -98% | 0 | 0 | — | 0 | 0 | — |
| BARNSTABLE CTY. | | | | | | | | | | | | | |
| Barnstable (.28) * | 72,296 | 87,455 | 21% | 65,072 | -26% | 84,980 | 31% | 15,865 | 15,289 | -4% | 6,326 | 18,546 | 193% |
| Yarmouth (.10) | 37,629 | 10,152 | -73% | 13,721 | 35% | 17,228 | 26% | 2,884 | 3,726 | 29% | 1,934 | 2,365 | 22% |
| Dennis (.53) | 49,947 | 38,294 | -23% | 56,973 | 49% | 17,053 | -70% | 5,922 | 6,767 | 14% | 11,676 | 10,908 | -7% |
| Brewster | 0 | 0 | — | 0 | — | 0 | — | 119,112 | 79,187 | -34% | 88,090 | 88,090 | 0% |
| Orleans (.11) | 21,728 | 34,198 | 57% | 34,215 | 0% | 44,329 | 30% | 3,602 | 3,731 | 4% | 2,558 | 3,444 | 35% |
| Eastham (.24) | 37,124 | 31,292 | -16% | 20,662 | -34% | 28,682 | 39% | 12,148 | 8,331 | -31% | 7,739 | 10,901 | 41% |
| Wellfleet (.69) | 298,104 | 327,623 | 10% | 0 | -100% | 324,763 | 100% | 28,047 | 38,536 | 37% | 0 | 33,926 | 100% |
| Truro (.19) | 0 | 0 | — | 0 | — | 0 | — | 3,327 | 4,052 | 22% | 2,207 | 1,479 | -33% |
| Provincetown | 65,559 | 0 | -100% | 6,601 | — | 253,680 | 3743% | 26,976 | 37,724 | 40% | 24,292 | 38,653 | 59% |
| SUBTOTAL | 1,017,017 | 701,698 | -31% | 649,872 | -7% | 1,357,517 | 109% | 467,277 | 383,930 | -18% | 321,958 | 453,670 | 41% |
| DEPURATED SHELLFISH HARVEST | | | | | | | | | | | | | |
| Revere | 213,937 | 93,255 | -56% | 104,816 | 12% | 0 | -100% | | | | | | |
| Winthrop | 142,739 | 48,491 | -66% | 0 | -100% | 49,047 | 100% | | | | | | |
| Boston | 276,295 | 309,765 | 12% | 333,126 | 8% | 698,603 | 110% | | | | | | |
| Quincy | 708,193 | 331,246 | -53% | 389,157 | 17% | 661,986 | 70% | | | | | | |
| Weymouth | 108,968 | 238,181 | 123% | 144,930 | -39% | 0 | -100% | | | | | | |
| Hingham | 405,999 | 172,530 | -58% | 153,682 | -11% | 238,151 | 55% | | | | | | |
| Hull | 429,456 | 378,051 | -12% | 204,872 | -46% | 382,679 | 87% | | | | | | |
| SUBTOTAL | 2,283,587 | 1,571,519 | -31% | 1,330,563 | -15% | 2,030,646 | 53% | | | | | | |
| GRAND TOTAL | 3,300,604 | 2,273,215 | -31% | 1,980,435 | -13% | 3,388,164 | 71% | 467,277 | 383,930 | -18% | 321,958 | 453,670 | 41% |

From: Massachusetts Di vision of Marine Fisheries, Shellfish Sanitation & Management Program, Sandwich and Newburyport, MA; & Massachusetts Division of Marine Fisheries, Cat Cove Marine Laboratory, Statistics & Data Processing Project, Salem, MA.

* For some Cape Cod to wns, the town landings data compiled by the SSMP include harvest from south cape and outer cape shellfish beds. Therefore, Cape Cod Ba y's contributions to town annual landings were estimated by muiltplying the town annual landings by the ratio of the town's Cape Cod Bay shellfish area acreage to its total area acreage. The computed town ratios are listed for each town.

TABLE 7:
COMMERCIAL SHELLFISH HARVEST VALUES BY REGION
AND SPECIES IN DOLLARS (1987-1990)

SOFT SHELL CLAM

| REGION | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| NORTH SHORE | 103,185 | 66,458 | 0 | 137,580 |
| BOSTON HARB. | 2,283,587 | 1,571,509 | 1,330,563 | 2,030,646 |
| SOUTH SHORE | 0 | 332 | 121 | 1,926 |
| CAPE COD | 128,224 | 52,598 | 113,517 | 71,198 |
| TOTAL | 2,514,998 | 1,690,895 | 1,444,201 | 2,241,350 |

QUAHOG

| REGION | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| NORTH SHORE | — | — | — | — |
| BOSTON HARB. | — | — | — | — |
| SOUTH SHORE | 4,402 | 2,499 | 542 | 6,934 |
| CAPE COD | 224,068 | 282,177 | 66,421 | 249,81[illegible] |
| TOTAL | 228,470 | 284,676 | 66,963 | 256,75[illegible] |

OYSTER

| REGION | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| NORTH SHORE | — | — | — | — |
| BOSTON HARB. | — | — | — | — |
| SOUTH SHORE | — | — | — | — |
| CAPE COD | 108,137 | 126,000 | 0 | 104,461 |
| TOTAL | 108,137 | 126,000 | 0 | 104,461 |

BAY SCALLOP

| REGION | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| NORTH SHORE | — | — | — | — |
| BOSTON HARB. | — | — | — | — |
| SOUTH SHORE | — | 1,170 | — | — |
| CAPE COD | 54,580 | 39,781 | 5,466 | 85,66[illegible] |
| TOTAL | 54,580 | 40,951 | 5,466 | 85,66[illegible] |

SURF CLAM

| REGION | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| NORTH SHORE | — | — | — | 4,772 |
| BOSTON HARB. | — | — | — | — |
| SOUTH SHORE | — | — | — | — |
| CAPE COD | 65,559 | — | 6,601 | 253,680 |
| TOTAL | 65,559 | 0 | 6,601 | 258,452 |

MUSSEL

| REGION | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| NORTH SHORE | — | — | 19,590 | 27[illegible] |
| BOSTON HARB. | — | — | — | — |
| SOUTH SHORE | 104,695 | 59,707 | 283,964 | 224,548 |
| CAPE COD | 3,680 | 1,461 | 5,041 | 5,372 |
| TOTAL | 108,375 | 61,168 | 308,595 | 230,19[illegible] |

RAZOR CLAM

| REGION | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| NORTH SHORE | — | — | — | — |
| BOSTON HARB. | — | — | — | — |
| SOUTH SHORE | 5,602 | 28,561 | 148,410 | 215,833 |
| CAPE COD | 68 | — | — | — |
| TOTAL | 5,670 | 28,561 | 148,410 | 215,833 |

TOWNS IN EACH REGION

| NORTH SHORE | BOSTON HARBOR | SOUTH SHORE | CAPE COD |
|---|---|---|---|
| Gloucester | Quincy | Duxbury | Barnstable |
| | Boston | Hingham | Yarmouth |
| | Revere | Hull | Brewster |
| | Winthrop | Kingston | Dennis |
| | Weymouth | Marshfield | Eastham |
| | | Plymouth | Orleans |
| | | Scituate | Wellfleet |
| | | | Provincetown |

Shellfish harvest data from: Massachusetts Division of Marine Fisheries, Shellfish Sanitation & Management Program, Sandwich and Newburyport, MA.

Averaged per bushel monetary values for each species provided by National Marine Fisheries, Northeast Fisheries Center, Conservation & Utilization Division, Fisheries Statistics & Economics Branch, Woods Hole, MA.

Unlike with finfish and lobster, the link between shellfish availability and pollution is much more certain. With the exception of occasional closures because of the presence of natural toxins (i.e. paralytic shellfish poisoning), water quality related closures of shellfish beds are determined by high fecal coliform counts. Therefore, the elimination of the sources of the fecal coliform counts would allow most closed shellfish beds to open. The other main source of shellfish bed closures in Massachusetts is the lack of resources within the Division of Marine Fisheries to allow adequate inspection of existing beds. If inspections cannot be conducted, the beds are closed in what is referred to as an administrative closure. Over half of all shellfish bed closures in Mass Bays is due to administrative closures.

As with finfish and lobsters, estimation of the consumer surplus generated by the Mass Bays shellfish harvest is not possible due to the lack of estimated demand curves for any of the species (EPA 1985). However, the value of harvest estimates represent a minimum value of the total annual benefits of the shellfish resource. It is likely that the consumer surplus is not very significant anyway since, as in the case of finfish, Mass Bays harvested shellfish represent only a small fraction of the total Massachusetts consumption of shellfish.[3]

Shellfish supply curves are also not available, making any estimates of producer surplus impossible. However, in this case also it seems reasonable to assume this would be quite small. Although there are some institutional barriers to entry into the shellfishing industry, such as licenses and record-keeping requirements, there are no rigidly enforced entry restrictions -- licenses are not limited. Consequently, it is likely that, as in the case of finfish, any producer surplus would be competed away by the entry of new diggers. Because of limited enforcement resources, it is also possible that illegal harvesting of shellfish by unlicensed diggers would also reduce this surplus.

TABLE 8:
SHELLFISH AREA CLASSIFICATIONS BY REGION
(As of 4/21/91)

| REGION | TOTAL ACRES | OPEN ACRES | CLOSED ACRES | SEASONAL ACRES | MC ACRES | CR/CA ACRES |
|---|---|---|---|---|---|---|
| NORTH SHORE | 78,647 | 8,208 | 48,749 | 0 | 17,693 | 3,997 |
| BOSTON HARBOR | 2,780 | 0 | 1,385 | 0 | 26 | 1,369 |
| SOUTH SHORE | 77,942 | 50,181 | 17,298 | 666 | 9,798 | 0 |
| CAPE COD | 191,790 | 133,941 | 4,857 | 50 | 52,943 | 0 |
| TOTAL | 351,160 | 192,330 | 72,289 | 716 | 80,460 | 5,366 |
| % OF MASS. BAYS TOTAL | 100% | 55% | 21% | 0.20% | 23% | 1.5% |

Legend:
Open: shellfish digging permitted at all times.
Closed: shellfish digging prohibited at all times.
Seasonal: shellfish digging restricted or prohibited due to seasonal variations in water quality.
MC: (Management Closure) shellfish areas not sufficiently monitored to meet NSSC guidelines.
CR/CA: (Conditionally Approved/ Conditionally Restricted) restricted area shellfish must be depurated. Conditionally Approved areas require detailed water quality monitoring.

Classification data from: Massachusetts Division of Marine Fisheries, Shellfish Sanitation & Management Program, Sandwich and Newburyport, MA.

Table 8 describes the current status of the shellfish beds by region in the Bays.[4] A more detailed table showing the status of each bed as of the end of 1990 is provided in Table I in the Appendix. A little over half of known beds are fully open to harvesting at all times. Of the remaining beds, half are closed because of insufficient monitoring resources and almost all the rest are permanently closed because of severe pollution. The remaining acres require depuration or close monitoring (CA/CR in Table 8), with the latter being subject to temporary closures if fecal coliform counts are found to be high, or are subject to seasonal closures.

The Division of Marine Fisheries has attempted to spread its monitoring resources in such a way that only the least productive beds are closed for administrative reasons. Nevertheless, it would be worth sampling some of these beds to determine if the value they are likely to generate is worth the additional expenditures required to allow DMF to properly monitor them.

With improvements in water quality, especially reductions in fecal coliform inputs, many of the non-administratively closed beds are likely to open and depuration would no longer be required for many of the conditionally restricted beds. However, estimating the value of such a change is difficult both because of the lack of demand and supply functions for the shellfish industry, but more importantly because of the lack of easily accessible data on the likely productivity of the closed beds and the true costs of depuration.

All depuration takes place at a plant in Newburyport which is run by the state. Its operating costs are not separately itemized in the Division of Marine Fisheries budget. Diggers are charged $6 per bushel for depuration, but there is no evidence that this fully covers the costs of operating the plant. If improvements in water quality led to reduced need for depuration, the value of this change would be measured by the savings in depuration costs. This assumes that the resources devoted to the depuration plant could be used readily for some other productive purpose. Assuming the $6/bushel is a minimum estimate of the cost savings from reduced need to depurate, if all currently depurated clams (an average of 29,000 bushels per year over the 1987-1990 period) no longer required depuration this would represent a savings of $174,000 per year.

For the same reasons used in the case of finfishing, opening additional commercial shellfish beds with improved water quality is not likely to substantially increase economic benefits. Since these additional shellfish are unlikely to reduce the price of shellfish because they would represent such a small fraction of the market, gains in consumer surplus are unlikely to result. Likewise, there is no evidence that the shellfish industry is properly managed to avoid over-fishing since shellfish management is primarily oriented toward reduction of public health risks, and thus any producer surplus generated by the opening of new beds might be competed away. Each town is responsible for the management of its beds and thus there is no overall coordination of shellfish management statewide. It may be that highly productive newly reopened beds will simply result in the expansion of resources devoted to harvesting shellfish until these beds are no more productive than existing open beds.

There is no statewide data base on the likely productivity of these closed beds. Instead, the only source of such information is from local shellfish wardens and what they remember about these beds before they were closed. Given this lack of data the only way to grossly approximate the likely yield of these beds is to assume their average productivity will be similar to the productivity of existing beds. Since some of these beds have not been under harvesting pressures in several years, this is likely to underestimate their harvest value. In 1990, there were a total of 192,330 open acres in the Bays system and an additional 3,997 conditionally approved acres (see Table 8).

Assuming all of this acreage was opened to harvesting in 1990 and represented the only source of Mass Bays shellfish during 1990, it yielded a total value of $1,357,517 (see Table 6). This represents an average value per acre of around $7.00. Thus, assuming the closed beds of around 72,000 acres would be at least as productive if opened they would have yielded around $500,000 in additional shellfish annually. Again it is important to keep in mind that if an additional $500,000 is spent in harvesting these shellfish (thus yielding no additional producer surplus) and because shellfish prices are likely to remain unchanged (thus yielding no additional consumer surplus), the economic benefit from the opening of the beds would be zero, since neither consumer nor producer surpluses would be expanded. Thus, the size of economic benefit in this scenario is dependent on the extent of producer surplus generated which could range from none to the full value of the additional shellfish on the market (if no additional resources are spent on their harvest due to excess capacity in the industry).

**SUMMARY OF COMMERCIAL FISHING BENEFIT VALUE ESTIMATES (1990$)**

**Current Resource Values**

**(1) Annual Economic Benefit (Consumer Surplus) .............Insufficient Data**
**(2) Annual Gross Benefit (Minimum Value)....................$53,000,000**

**Potential Net Change in Value**

**Scenario: All Shellfish Beds Reopened Due To Improvements in Water Quality**

**(1) Annual Benefit from Eliminating Depuration (minimum)....$174,000**
**(2) Annual Gross Benefit of Opening All Shellfish Beds (market value of harvest)............................................$500,000**
**(3) Annual Economic Benefit of Opening All Shellfish Beds (changes in consumer and producer surplus)................................$0-$500,000**

**Recreational Fishing**

The lack of data on the linkages between finfish stocks and water quality also makes estimating likely benefit value improvements in recreational finfishing resulting from hypothetical pollution control strategies impossible at this time. While there is more certainty about the relationship between recreational shellfish beds and water quality, data on the demand for these beds by recreational harvesters are quite weak. Before discussing the details of the methodology for measuring benefit value in the case of recreational fishing, some general conceptual differences between the treatment of commercial and recreational fishing need to be clarified.

First, most recreational fishing uses of the Bays system are not traded in the market and thus there are no readily available estimates of the market demand curves for different types of recreational fishing. The private market cannot be relied upon to reveal the recreational fisher's willingness to pay for current recreational activity in which he/she is engaged or for improvements in the quality of this activity that can be linked to improvements in water quality.

Second, given that most access to recreational activity is not controlled by the private market, it is essentially free which means that a large consumer surplus is generated by these activities. There are some entry costs to recreational fishing, such as equipment purchases and time spent harvesting or fees for private charters or party boats. However, using expenditures on these goods to measure the value of recreational fishing is incorrect. Some of these goods, such as boats or lodging during a fishing trip, can yield value in their own right independent of the fishing experience. Even more important, while such expenditures might be representative of the costs of engaging in fishing they are not linked to the willingness to pay to engage in recreational fishing activity. For example, if the price of gasoline were to fall, this would lower the cost of a particular fishing trip, but it would certainly not lower the gross value or willingness to pay for such a trip. Unfortunately, because these expenditure data are relatively easy to acquire, they often have been cited in policy studies as estimates of recreational value.

Third, where improvements in water quality may lead to increased value in commercial fishing by expanding the stock available for harvesting and thus lowering harvesting costs, recreational fishing value is increased in a different way since the fish are not sold. If improvements in water quality were to lead to an expansion of recreational stocks, this would increase the value of recreational activity by causing the recreationist to be willing to pay more to engage in this activity.[5] This assumes that one of the contributors to the value of the recreational fishing experience is the expected number of fish that will be caught on any particular trip. If this increases, the value of the trip increases. Improvements in water quality may also increase the fishers' perception of the quality of the fish or even its edibility which will also increase their willingness to pay for a recreational fishing experience.

Both of these increases in willingness to pay will shift the demand curve AB shown in Figure 10 to the right. The value of this change is then measured by the increase in consumer surplus or the area between the new demand curve and AB that is above the cost of engaging in the fishing activity. If this cost were zero, the entire area between the two demand curves would represent the willingness to pay for (economic benefit from) the water quality improvement that led to the demand change.

Techniques for Estimating Benefit Value

In trying to estimate the current gross value of recreational fishing in the Bays system, only knowledge of the demand curve AB for each particular category of recreational fishing is required. It is not necessary to know how the demand curve would shift in reaction to water quality improvements. However, such demand curves for different recreational experiences are not currently available.

There are two major categories of techniques for calculating demand curves of non-marketed goods, both of which involve the collection of a variety of survey data from recreational users. Such surveys have been conducted in other estuaries (Bockstael, et al.- 1988 and 1989), however none have yet been conducted for the Bays system. The different methodologies for calculating such demand curves are detailed elsewhere (EPA 1990; U.S. EPA 1983; Cummings, et al 1986; Bell and Leeworthy 1990; Hanley 1989; Smith 1989) and thus will only be briefly summarized here.

Hedonic Techniques - Travel Cost. One group of techniques, called indirect or hedonic, relies on the observed behavior of people to infer the relationship between this behavior and some non-marketed good such as recreational fishing. The applicable version of this set of techniques in this case is to find some market variable, such as the travel costs to the recreational fishing site, that can then be related statistically to water quality and the number of trips taken to the site. It is assumed that the willingness to pay for the visit to a recreational fishing site is a function of a number of socioeconomic variables, such as income, age, and family size, and other site-specific variables, such as previous experience at the site, the quality of the experience, and the travel costs involved in getting there.

A survey is then conducted on-site in which visitors are asked their place of residence; frequency of visits to the site and substitute sites; details about the length of their trip, including any other activities conducted enroute to the site; and various socioeconomic information. Concentric zones defined by similar travel costs to the site are then specified and travel costs from each zone are calculated. The survey results are then used to determine the average visitation rate from each of these zones. Statistical analysis is then used to relate these visitation rates to the travel costs from each zone which then allows the construction of a demand curve for recreational visits to the site, where travel costs are used as the equivalence of a market price for the recreational activity. Thus, an increase in travel costs is assumed to be analogous to an increase in the market price of recreational fishing and the resulting demand curve then approximates the willingness to pay for recreational fishing.

There are a number of drawbacks to this approach, including the difficulty in measuring the value of different specific recreational experiences at the site (fishing vs. boating or walking), the assumption that visitors reactions to a marginal change in travel costs is the same as their reactions would be to a marginal change in a hypothetical entrance fee to participate in the activity, and the need to control for the number of alternative activities engaged in during the trip to and back from the site (Clough and Meister 1991; Kaoru 1990).

In the context of the Bays system as a whole, many of these problems would apply, but the technique could still be used for specific sites in the Bays system where the purposes of the visit could be more precisely identified and where a careful analysis could try to counter some of these drawbacks with additional survey information. The travel cost approach can also be used for the estimation of consumer surplus associated with the catching of a particular species of fish, if the survey data are available. For example, one study used a 1980 survey of Maryland hunters and fishermen to estimate an aggregate consumer surplus for striped bass fishing among this group of between $14,852 and $54,196 (Bockstael et al 1988).

Direct Techniques - Contingent Valuation. Direct techniques involve trying to determine the willingness to pay for a non-market good by surveying users and potential users and asking them "directly" to reveal their value of different qualities and/or quantities of the good. Thus, rather than relying on their behavior toward the good to implicitly determine their evaluation of it, this method asks them to explicitly place a value on the good in question. The main advantage of this approach is that it allows managers to get some sense of the value nonusers place on the resource since no direct use of the resource is required to survey the population. This is vital for determining nonuse value of non-marketed Bays systems resources and this is discussed in more detail at the end of this section.

The drawback of this technique is the difficulty in designing a survey to present a hypothetical situation that will elicit true evaluations of the resource from the population. The surveyor has to be careful to clearly describe the resource in question and make this description as applicable to the actual situation as possible. Baseline conditions with respect to the availability of the environmental good and the institutions that will regulate a citizen's access to it must be clearly delineated. If the valuation of a possible change in the quality or quantity of the good is being requested, the change must be defined and described clearly. This may require the use of photographs, charts, diagrams, or even the use of different smells or tastes. The survey must also be clever in the method used to elicit the value of the good from the client so that it mimics a real life market situation as closely as possible.

There is a huge and growing literature on the use of this technique and its application to different resource problems, much of which is summarized in Mitchell and Carson, (1989). The technique has been used in valuing recreational benefits for improvements in Chesapeake Bay water quality (Bockstael, et al 1988 and 1989); in estimating values of water quality improvement from boatable to swimmable (Smith et al 1981); in measuring the value of national improvements in fishing attributable to Federal water pollution control legislation (Russel and Vaughn 1982); and in measuring the value of coastal state parks (Leeworthy, et al 1989) to name a few.

Benefit Estimates for Recreational Fishing in the Bays

Although demand curves for recreational fishing in the Bays derived from the techniques just discussed do not exist, it is possible to use national data survey bases to describe the general use characteristics of the Massachusetts marine finfishing population.

Every five years the U.S. Fish and Wildlife Service conducts a National Survey of Fishing an Hunting which includes state level data. However, even more appropriate for our purposes is the Marine Recreational Fishery Statistics Survey which is conducted annually by the National Marine Fisheries Service (NMFS). Although the survey is restricted to population along the coast, the findings are grossed up to include non-coastal and non-state residents. Essig et al., (1991) contains the latest published survey results covering the years 1987-1989.

Over 12 million fish were caught in Massachusetts coastal waters by marine recreational fishermen during 1989 representing almost 50% of the fish caught in the entire North Atlantic subregion, which includes the coastline from Maine through Connecticut. Three species - winter flounder, Atlantic mackerel, and scup accounted for over 60% of the catch, although within the entire subregion (there is no breakdown by state), the most popular fish sought was bluefish, followed by winter flounder, Atlantic cod and striped bass. In the North Atlantic subregion, almost 60% of the fish were caught in "inland" waters defined as rivers, bays, and sounds; 27% in the ocean within three miles from shore and the rest between 3 and 10 miles from shore. Thus, it is clear that most of the recreational activity takes place in waters heavily influenced by pollutant inputs from onshore activities. Also, boating and shore access to the coastline is obviously crucial to the recreational fishing industry, since relatively little of it takes place on the charter fleet. Almost three-fourths of the fish were caught in private or rented boats, seventeen percent from shore, and the rest on party or charter boats.

In 1989, it is estimated that around 634,000 people engaged in recreational fishing in Massachusetts coastal waters. Two-thirds of these fishers were Massachusetts coastal residents, ten percent were non-coastal Massachusetts residents and the rest were from other states. This group accounted for approximately 2,658,000 recreational marine fishing trips (defined as one day or part of day) during 1989.[6] The average number of trips taken over the 1984-1989 period was 3,699,000. Although these are statewide numbers, it is reasonable to assume that the Mass Bays system accounted for a majority of these trips. If we assume that around two-thirds of these trips took place in the Mass Bays region, this would be a total of around 2.5 million trips.

Although no estimates of the net benefit value or consumer surplus for a day of recreational fishing in Massachusetts Bay exist, there have been a number of other studies of different types of marine recreational fishing experiences, largely using the travel cost methodology, that provide such estimates. These range from $13-$104 per fishing day in 1981 dollars (Rowe, 1985). Inflating these estimates to 1989 dollars ($18-$142) and applying them to the 2.5 million trips yields a net benefit value range of all recreational fishing trips in Mass Bays of $45-$355 million annually.

This estimate is only reliable as an indication of the order of magnitude of the likely net recreational fishing benefits generated by the Bays as the data on number of trips conducted in the Bays system are subject to considerable uncertainty. Also, an heroic assumption is being made that the range of recreational fishing values developed in a variety of different settings for a variety of different species are applicable to the Bays system. The use of fishing day values from other studies to value Mass Bays recreation is subject to all the standard criticisms discussed in the recent literature beginning to analyze benefit transfer methodologies (Brookshire and Neill, 1992; Smith, 1992; Boyle and Bergstrom, 1992).

These include reliance on the statistical qualities of the original studies, application of different water quality changes to the new study site, differences in socioeconomic characteristics and available substitute recreational activities between the old and new sites to name a few. Moreover, the Bays covers a large region with a large variety of recreational fishing opportunities and access. Thus, any single estimate of recreational fishing day value for the entire Bays is subject to the same criticisms. This is why we have chosen to report the entire range of fishing day value estimates in the literature and restricted these estimates to those related to the marine recreational fishing experience.

In order to get a more accurate figure, additional data relevant to Massachusetts Bays need to be collected. Either a separate survey of recreational fishers that asks such information as place of residence, frequency of visits to marine sites, and details about their fishing trip and their socioeconomic status should be conducted or a cheaper alternative, such as expanding the sample and information collected by the annual NMFS survey, should be explored. The state currently supplements the NMFS survey with questions directed at the striped bass fishery, so an ample precedent has been set for such an endeavor. This information could also contribute to a study of the likely changes in consumer surplus that would result from specified improvements in water quality. However, as already discussed, the information requirements for such a study, especially how changes in water quality affect the biota and how these affects translate into changes in fish stocks or other resources likely to be perceived by recreational fishermen, are still not fulfilled for the Bays region.

There is one study which develops a very rough estimate of the additional recreation fishing benefits that would result in the immediate Boston Harbor area from building the MWRA ocean outfall and imposing controls on CSOs as ranging from $299,000 to $7,911,000 annually in 1982 dollars (EPA 1985). This estimated range is based on a series of very restrictive assumptions about the impact of such controls on fish stocks, the user day value associated with recreational fishing in the Harbor, and the number of additional recreational trips that would be taken as a result of the improved water quality. The study does not attempt to measure the increased value of trips to existing recreational users, but instead measures all value as resulting from an increase in the number of recreational trips taken.

The only available data on recreational shellfishing in the Bays are reported in Tables 5 and 6. As with the commercial shellfishing harvest, the recreational shellfish harvest has fluctuated considerably over the 1987-1990 period. The average harvest over the entire period was around 7,500 bushels which has an average market value of around $407,000. There is no recreational shellfishing allowed in the Boston Harbor area.

Although, there are no data on the number of people who engage in recreational shellfishing or the number of days spent shellfishing in Mass Bays, a recent NOAA report provides information on the number of people involved in recreational shellfishing in Massachusetts in 1985 (NOAA, 1991). This is the first nationwide effort to quantify recreational shellfishing activities, so there are no other years of observation with which to compare. In this survey the definition of shellfish included non-molluscan as well as molluscan.

There were almost 127,000 shellfishermen (age 16+) engaged in recreational shellfishing activity in Massachusetts, of which approximately 70% were state residents. This resulted in 1,079,000 shellfish activity days in Massachusetts, which means the average days of shellfishing per person was around 8.5, compared to a national average of 7.3 (NOAA, 1991: 16,18).

Nationally, shellfishermen have higher annual household incomes (62% > $25,000 vs. 48% > $25,000) and are more highly educated (51% vs. 36% with one or more years of college) than the general population. In addition, all shellfishermen surveyed also participated in saltwater fishing. This has two implications if the Mass Bays shellfisherman fits these national profiles: (i) opening recreational shellfish beds clearly benefits a higher income group in the population, and, (ii) "negative impacts from policy changes that increase the relative cost of recreational shellfishing or reduce the quality of recreational shellfishing may be mitigated to some extent if other fishing and hunting activities are substituted" (NOAA, 1991:12). Therefore, should a study of recreational fishing participation be conducted for the Bays it should include these other recreational activities to control for possibilities of substitution.

There are also no estimates of the net benefit associated with a shellfishing day from the Mass Bays system or in the user day value literature and no studies reporting the number of potential Mass Bays recreational shellfishers who would actively participate if particular beds were reopened. Thus, it is currently not possible to calculate the gross value of existing shellfish beds to recreational users or any increases in this value that would result from the opening of shellfish beds. However, given the data on existing recreational shellfish harvest and participation it seems unlikely that this use will compare in magnitude to recreational finfishing benefits.

## SUMMARY OF RECREATIONAL FISHING BENEFIT VALUE ESTIMATES

### Current Resource Values

**(1) Annual Economic Benefit of Finfishing (1989$)..$45,000,000-$355,000,000**
**(2) Annual Economic Benefit of Shellfishing (1989$)....Insufficient Data**

### Potential Net Change in Value

**Scenario: Improvement in Boston Harbor Area Water Quality**

**(1) Annual Economic Benefit of Recreational Fishing**
**(U.S. EPA 1985) (1982$)....................$299,000-$7,911,000.**

**Swimming and Beach Recreation**

One of the most visible and popular uses of the Bays systems is recreating on its many beaches. Determining the benefit value of recreating on Bays beaches is analytically similar to the determination of benefit value for recreational fishing. Like fishing, there is no market for much of the recreational value of beaches as access to most beaches is free or involves a minimal payment. Therefore, there is a lack of information from the private market to aid in valuing recreational beach use. In order to measure the value of beach use, demand curves, such as depicted in Figure 10, need to be derived for each of the recreational beaches. These would be constructed based on the maximum willingness to pay of beach users for different levels of beach recreation.

The methodologies for deriving these demand curves are the same as for recreational fishing - travel cost or contingent valuation. Neither technique has been applied to all Mass Bays beaches in general, although there are a few studies of beach use for smaller areas within the system, most of which focus on Boston Harbor.

Before discussing the valuation of beach resources the size of these resources will first be described. Appendix Table II lists the most recent data on beaches in the Bays system. There are almost 150 beaches in the system varying in size from small beaches of less than 5,000 square feet to large reservations of over 15 million square feet. The beaches are listed by town, size, available parking, level of use, and number of postings in the last three years. Several important points are revealed by the table. First, size data are not available for some of the beaches and parking facilities for many of the beaches are also not readily available. Also, the size data reflect the entire beach area, which in the case of large reservations includes large chunks of upland not associated with regular beach use.

Second, and much more serious, beach attendance data in any form are not available. There is no regular procedure in the state for reporting and collecting data on beach attendance even by season or month, let alone daily. The level of use designations are given by very broad classifications that have no statistical basis, but are essentially based on the impressions of managers who compile the data, and many of these data are not available.

Third, the beach posting data only indicate the number of times a beach was initially posted, not the length of the posting. Therefore, it is not possible to determine how many days in a given season that a beach was posted. Moreover, there is no centralized source of beach posting data, largely because such postings and testing protocol are determined by each town's Board of Health. Exceeding the fecal coliform standard does not require the beach to be closed and only the local Board of Health has the right to close a beach (NRDC 1991). Instead of closures, advisories are usually given in the form of beach postings. The data in the table were gathered by contacting as many local public health departments as possible on the status of the beaches under their jurisdiction.

Almost all of the beach postings in the Bays system occur in the immediate Boston Harbor area. Over the last three years, one or two isolated beach posting incidents were recalled by Scituate and Salem officials, otherwise the Metropolitan District Commission was involved in the rest of the beach postings. Table 9 shows that the number of posting incidents was down in 1991 from the previous two years for all beaches on the South Shore, but more frequent for some of the beaches on the North Shore. However, without knowing the length of the closings or the causes of the increased or decreased coliform counts it is difficult to interpret these trends.

Given this poor database, even the simplest attempts to estimate the value of beach use cannot be conducted. If attendance data were available, existing estimates of the value

TABLE 9:
INCIDENTS OF BEACH POSTINGS AT
METROPOLITAN DISTRICT COMMISSION BEACHES (1988-1991)

| LOCATION | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|
| NORTH SHORE | | | | |
| King's Beach (Swampscott) | 4 | 1 | 1 | 7 |
| King's Beach (Lynn) | 1 | 1 | 1 | 5 |
| Lynn Beach | 2 | 8 | 4 | 2 |
| Nahant Beach | 0 | 1 | 1 | 2 |
| Revere Beach | 1 | 0 | 1 | 3 |
| BOSTON HARBOR | | | | |
| Short Beach | 1 | 1 | 4 | 1 |
| Winthrop Beach | 0 | 2 | 1 | 1 |
| Yirrell Beach | 0 | 0 | 0 | 2 |
| Constitution Beach | 3 | 8 | 2 | 3 |
| Pleasure Bay | 1 | 0 | 1 | 1 |
| Carson Beach | 2 | 2 | 0 | 1 |
| Malibu Beach | 2 | 6 | 7 | 1 |
| Tenean Beach | 2 | 9 | 12 | 7 |
| Wollaston Beach | 14 | 15 | 9 | 8 |
| SOUTH SHORE | | | | |
| Nantasket Beach | 1 | 1 | 0 | 0 |
| TOTAL BEACH POSTINGS | 34 | 55 | 44 | 44 |

Postings based on measurements of water column fecal coliform and enterococcus concentrations. Duration of postings not available.

Data From: Metropolitan District Commission, Engineering Division, Water Resources Section.

of a recreational beach day from the literature could be used to give a rough order of magnitude estimate of net benefit value. Even then, such estimates would suffer from the use of values from non-Mass Bays beaches.

These problems are compounded if measurements of likely changes in value in response to water quality improvements are attempted. In this case, the extra value of beach use for existing users would have to be measured in addition to the value to new beach users. Also, a careful survey would need to be conducted of new beach users to be sure they are not simply moving among beaches in the Bays system. In this case, the increased value of their use of a particular cleaner beach in the system is measured by the savings in travel and other costs incurred by substituting the cleaner beach for the beach they previously visited, not by the consumer surplus generated by the cleaner beach.

The most recent comprehensive study of beach use valuation in the Mass Bays system is an attempt to measure the value of beaches in the Boston Harbor area (EPA 1985). Rather than measuring gross value, the study focussed on the measurement of increases in consumer surplus from beach use likely to be generated by controlling CSO emissions and upgrading the MWRA sewage treatment plant. The sources of such increases in value were identified as increases in recreational use by current users and non-users; increased willingness to pay for recreational use at the now higher quality beaches by all users; and regained recreational use from reduced beach closings. A travel cost model was used as the basis for quantifying the first two sources of net benefits and the last relied on assumptions of increased participation by the neighboring population.

In developing all of these estimates the study was hampered by the lack of accurate beach attendance data and instead relied on "best guesses" of seasonal attendance by MDC personnel and beach capacity measures were based on "best professional judgment" (EPA

EPA 1985, p. 6-19). There also were no good data on the likely impact of improvements in Bays-wide ecological parameters on the perceptions of beach users. The survey sample used for the travel cost analysis was quite small (467) and dated, having been conducted in 1974 in the Boston area. The value of a day at the beach estimated from this analysis was at the high end of the range of national values available, from $1.60-$11.00 in 1982 dollars.

Keeping all of these caveats in mind, the estimates of the annual benefits of increased swimming participation due to improved water quality on Boston Harbor beaches ranged from $1.8 million to $19 million, while the annual benefit estimates that used a travel cost model to try to include the increased valuation of swimming by current beach users ranged from $13.7 million to $20.5 million, all in 1982 dollars. The estimated value of reduced beach closures was based again on the best guess seasonal attendance figures. It was assumed that the percentage of the time water quality exceeded fecal coliform standards was equivalent to the percentage of seasonal attendance affected by the closing. Multiplying this figure by the user day value yielded annual values from reduced closings that ranged from $900,000 to $6,000,000.

Given all the assumptions involved in measuring these data, it is hard to be certain if the order of magnitude can be relied upon with any certainty. However, existing data do not enable any significant improvement on the accuracy of these estimates. Therefore, a high priority in developing the capabilities for deriving such estimates is the expansion of beach attendance collection, possibly through the newly organized Beach Manager's Association, and the conducting of contingent valuation or travel costs studies focussing on the beaches of most important concern to Bays managers.

**SUMMARY OF SWIMMING AND BEACH RECREATION VALUE ESTIMATES**

**Current Resource Values**

**(1) Annual Economic Benefit ........................Insufficient Data**

**Potential Net Change in Value**

**Scenario One: Improving Water Quality at Presently Open Beaches Within the Boston Harbor Area**

**(1) Annual Benefits (U.S. EPA 1985) (1982$)....$1,800,000-$20,500,000**

**Scenario Two: Reduction in Boston Harbor Area Beach Closings**

**(1) Annual Benefits (U.S. EPA 1985) (1982$)....$900,000-$6,000,000**

**Other Recreational Activities**

In addition to beach use and fishing, other recreational uses of the Bays system include hunting, bird and wildlife watching, walking, and boating to name a few. The best approach for estimating the benefit value of many of these activities is through a contingent valuation survey approach that questions the area population about their different recreational uses of the Bays system. Such a survey was successfully conducted for the Chesapeake Bay area and helped to identify the chief recreational uses of the Bay by different socioeconomic groups, as well as the major water quality characteristics, such as floating debris, oil, odors, and presence of seaweed, that affected the use of different Bay resources (Bockstael, et al 1988). Although such information is not yet available for the Bays system, there is some general information on two of these uses, boating and whale watching. In the case of boating, it is estimated that a little over 16% of the Massachusetts population, or around 958,000 people actively engage in boating activities (American Red Cross 1991 p.72). If Massachusetts boaters are typical of the national average, they participate in boating around 24 days per year (American Red Cross 1991 p. 85). Unfortunately, there is no breakdown available on the location of boating activities (inland vs. coastal and if coastal, Bays vs. south Cape or Buzzards Bay) and these data also do not include boating in the Massachusetts Bays systems by non-residents. The other difficulty is determining what type of boating activities are being engaged in to avoid double counting benefits already covered by other uses, such as recreational fishing.

With these caveats in mind, it is possible to develop a gross estimate of the value of boating in the Massachusetts Bays system, by making a number of further assumptions. First, given the extent of coastal waters covered by the Bays, assume that at least 50% of the boating days by Massachusetts residents are spent in Bays system waters. This would mean a total of around 11.5 million boating days per year. Estimates of the user day value of a boating day in the literature vary from $9 to $41 in 1982 dollars (EPA 1990). Thus, correcting for inflation, in 1990 dollars the total benefit value from boating in Mass Bays could range from $138-$472 million annually.

The usefulness of this figure for policy purposes is limited by the number of restrictive assumptions which were required to derive it, the fact that it clearly must involve some double counting of recreational uses, and the fact that it is a static number and does not begin to answer the more interesting question of how the value of boating activity in the Bays might change given alternative pollution control scenarios. There is a potential relationship between levels of human pathogens and floating debris and the quality and/or safety of recreational boating (including wind surfing). However, the precise nature of this relationship has not yet been established. Actual surveys of recreational activity are needed to better address these issues.

Another increasingly popular activity in the Bays system is whale watching. Around 20 companies operate whale watching expeditions in the Bays, carrying around 1.5 million passengers annually. Given an average ticket price of $15 per trip, this represents almost $23 million dollars in revenues generated annually (Terkla 1990). This would be a minimum estimate of the gross value of whale watching since it does not include the consumer surplus generated by this activity. It also does not include the value of the whale's presence to people who have not yet been on whale watching trips or who never intend to participate in this activity. This non-use value has been estimated to be as high as $25 million for the whales in the Bays system (Rumage 1990).

## SUMMARY OF OTHER RECREATIONAL ACTIVITIES BENEFIT VALUE

### Current Resource Value

**(1) Annual Economic Benefit from Boating .........$138,000,000-$472,000,000**
**(2) Gross Annual Benefit from Whale Watching (Minimum) .... $23,000,000**

### Transportation and Port Management

The Bays system is used extensively for transportation of commercial products, waterborne commuting, and of course for recreational fishing and boating and commercial fishing. Commercial product transportation and waterborne commuting are usually not directly linked to Bays water quality, except for the possible presence of corrosive substances in the water that would increase the maintenance costs of vessels, wharfs, and piers. However these services and recreational boating and commercial fishing all require onshore docking support facilities and well maintained navigational channels in order to survive and this inevitably involves considerable amounts of dredging.

It is the link to dredging, more than any other, that ties all of these transportation uses of the harbor to water quality because the quality of the sediments directly influences dredging costs. An estimated 15 million cubic yards of dredged material from marine environments is expected to be generated in Massachusetts over the next fifty years and much of this will be from the Bays system (Dolin and Pederson 1991). To the degree that many of the sediments being dredged are contaminated, the costs of their disposal increases dramatically and may threaten the viability of many of the uses that rely on the Bays system for transportation related services.

Therefore, although it is not possible to put a number on the gross benefit value of the Bays system as a means of transportation, it is important to highlight that management of pollutants that contaminate sediments needs to take account of not only the potential ecosystem impacts of the contaminants, but also the increased future costs these contaminated sediments are likely to impose on dredging. Also, the benefit value of the Bays system as a disposal site for dredged materials is reduced -- which in any particular case would be measured by the cost difference between open water and the required alternative disposal technique -- when materials are too contaminated to qualify for open ocean disposal and require added expenses, such as capping or even upland disposal.

**Public Health**

While the gross benefits of the Massachusetts Bays system would not include benefits to public health, the improvement of Bays system water quality is certain to provide increased health benefits in terms of reduced risk of seafoodborne illness and from direct contact with particular pollutants. Specifying the value in reducing public health risk from Bays system resources relies on the use of analyses characterizing the cost of foodborne disease nationally and then using certain assumptions concerning the relative contribution of Bays resources to such costs in Massachusetts.

Several studies have attempted to estimate both the scope and cost of disease in the United States. For example, the Center for Disease Control (CDC), using a passive reporting system (that is, reported cases of disease made directly to state public health officials who then report to the CDC), have identified approximately 14,000 cases of foodborne disease per year. However, these numbers clearly underrepresent the number of actual case by a significant amount. As noted in a recent report by the Institute of Medicine,"clearly, existing data [from the CDC] reporting the level and source of seafoodborne illness do not represent accurately either the level or source of disease. Data currently available are too limited to lead to fully effective, scientifically valid, risk-based control programs, or even to valid comparisons of the hazards posed . . ." (NAS/IOM 1991).

The Carter Center, using a combination of expert opinion and community-based survey methods has estimated that there are approximately 6.5 million cases of foodborne disease in the United States every year (Bennett et al. 1987). The Canadian National Department of Health and Welfare has estimated the number of cases of foodborne disease in Canada to be 2,159,120 (Todd 1989a). If one assumes that the number of cases in Canada and the U.S. to be roughly equal, correcting the Canadian number for differences in population results in a U.S. estimate of 19,879,612 (Todd 1989b). One strategy in dealing with the variance in estimates identified in these studies is to assume that the median of these estimates provides a useful compromise. Therefore, this strategy, originally proposed by Todd (1989b), suggests that the number of cases of foodborne disease in the United States may be estimated to be approximately 12 million (annual cases).

The cost of foodborne disease has been established by various authors using interviews and surveys of public health professionals and health care insurers (Roberts 1985; Sockett and Stanwell-Smith 1986; Todd 1989c). These studies estimate the average cost of a case of foodborne disease to be $1,000, based on the direct cost of treating, recovering from, and litigation resulting from seafoodborne disease. If one assumes that foodborne risk is distributed equally through the United States one can estimate the number of cases of foodborne disease in Massachusetts to be approximately 300,000. This calculation is based on the fact that 2.4% of the total U.S. population lives in Massachusetts. The Massachusetts Department of Public Health has suggested that approximately 20% of the disease attributable to foodborne agents can be traced to seafood (Ridley, pers. comm. 1992). Therefore, if there are 60,000 cases of seafoodborne disease (300,000 x .2) in the Commonwealth every year, the cost of that disease approximates 60 million dollars (on an annual basis). However, efforts to establish the proportion of this figure that can be attributed to seafood harvested within the Massachusetts Bays will require much better data describing regional seafood consumption patterns.

**Mining**

Another potential resource of the Bays system is its sand and gravel deposits. Although no active mining of sand and gravel is currently taking place in the Bays, the depletion of upland sand and gravel pits in the immediate Boston area is increasingly shifting attention to the Bays as a possible cheaper source of these materials. Total recoverable sand and gravel deposits in Mass Bays are estimated to be around 41 million short tons (Stubblefield and Duane 1986). One recent estimate of the gross value of this resource was $320 million (Terkla 1990). The value of this resource less the costs of mining (including proper environmental safeguards and any impacts that reduce the value of other Bays uses) has not been calculated, since proposals to mine have not yet reached the stage where such cost estimates have been developed by the industry.

**Ecosystem Benefits**

Although we have focused our discussions on direct human uses of the Bays system, there are a variety of ecological processes that contribute to the value of the Bays, but that are not captured by direct benefit estimates of the most obvious human uses of the Bay. For example, where the contribution of wetlands to the expansion of fish stocks is captured in estimates of fishing benefits; and the contribution to flood control or groundwater filtration can be estimated by the cost of replacing these functions with human-made structures; the contribution of wetlands to the expansion of the variety of wildlife in the area or the greater appreciation of natural scenery by people frequenting the area may be inappropriately ignored.

Although such indirect benefits are difficult to quantify for the entire Bays system and are likely to vary from wetland to wetland and among different ecological processes, it is possible to use the techniques of travel cost and contingent valuation to estimate people's willingness to pay for particular areas of the Bays over and above what can be measured through their direct recreational uses or the cost of mitigation. The key information necessary for the success of such techniques is the linkage between the environmental attributes of the resource in question and the rest of the ecosystem and a further linkage to tangible characteristics for which people are able to assign values.

Several such studies have been conducted for wetland areas in other locations, such as Louisiana and Virginia (Batie and Wilson 1978; Bergstrom et al 1990; Farber and Costanza 1987). The Louisiana studies arrived at individual consumer surplus estimates for wetland recreationists in an area in the southeastern part of the state of between \$300 and \$360 per year. When aggregated over all users of the area the benefits were estimated to be around \$27 million per year (Bergstrom et al 1990). Gross expenditures of these users on their recreation activity were estimated at around \$118 million annually yielding a total gross recreational economic value of this wetland area of almost \$150 million annually.

Lacking any estimates of coastal wetland recreational values for Massachusetts, we will apply the Louisiana recreation values to Massachusetts acreage numbers to show how these added recreational values of wetlands can be quantified. Obviously, these estimates need to be interpreted cautiously as the population of users in Louisiana is different from Mass Bays wetland users and the characteristics of Louisiana wetlands are different. More importantly, these estimates only apply to the recreational use of wetlands and none of the other uses of wetlands such as flood control and breeding grounds often cited in the literature are included in this valuation.

The total tidal flat and salt marsh acreage in Mass Bays is around 72,000 acres (Massachusetts Bays Program 1991:II-20). This probably underestimates coastal wetland acreage since it leaves out wetlands off the coast, but within the watershed. (Bergstrom et al. 1990) report an estimate of $8.42 of annual consumer surplus or economic benefit per acre and $44.69 of annual gross benefit per acre. Therefore, if this number is applied to Mass Bays, the annual total economic benefit to recreational users of wetlands would be around $600,000 and the annual gross benefit around $3.2 million. With such large numbers, it would appear worthwhile to make an attempt to measure such recreational values for particular Mass Bays wetlands under the most intense development pressures in order to supplement measures of their other values, such as flood control, linkages to spawning stocks and groundwater filtration.

**Intrinsic Environmental Values or Values of the Bays Systems to Non-Users**

To the extent that the Mass Bays system is thought of as a unique environmental asset, it has a benefit value beyond that measured by the value to direct users of the system. People who are not current users of the Bays system are likely to value particular aspects of the system and their values are not reflected in the use values discussed here. Even current users of the system are likely to be willing to pay more for the continued existence of particular Bays resources than reflected in their willingness to pay for current uses. Economists have ascribed these non-use benefits to several alternative human motivations.

One of these is referred to as option value. This reflects the willingness of people to pay a sum (analogous to an insurance premium) for greater assurance that the Bays system resources will continue into the future for their possible future use. Thus, both users and non-users may attach some option value to Bays resources. Another intrinsic benefit derives from the bequest motive. This is the willingness to pay for resource preservation in order to guarantee that a sustainable ecosystem is passed on to future generations. Finally, it is also felt that the unique Bays system resources carry an existence value. People receive pleasure from the knowledge of their existence or from the satisfaction of knowing that the Bays system is in good ecological health, and are therefore willing to pay some amount to maintain or enhance Bays water quality.

Quantifying these values is quite difficult, but it has been attempted in other studies using contingent valuation techniques. Results from these studies indicate that such values may be quite large. Several studies have found intrinsic benefit values to equal as much as 50% of the direct user benefits (EPA 1990). One study estimated that non-use value accounted for $35 million dollars or 40% of the total value Colorado residents placed on the preservation of an additional ten million acres of wilderness in the state (Walsh, Loomis, and Gillman 1984).

## SECTION THREE

### SUMMARY

It is important to reemphasize the caveat that these estimates of Bays system use values are incomplete and substantially underestimate the total value of the Bays resources. This is not only because of incomplete data, but also because many of the linkages between improvements in ecosystem health and various human uses are not yet understood enough to enable their value to be quantified.

Also, for management policy purposes, it is the change in human use value, rather than the current human use values, resulting from changes in water quality initiated by particular policies that is of greater interest. Each proposed regulatory change will have a unique impact on the Bays ecosystem and thus will require its own individual benefit valuation and thus the estimates discussed in this report cannot serve as general evaluative tools for potential policy changes, but only as a guide to the uses that need more investigation and that are likely to result in the largest value improvements if expanded or enhanced.

We are not presenting a comprehensive number of the total benefit value of the Mass Bays because this would be misleading. All values of the Mass Bays have not been measured because of insufficient data. Also, due to data constraints in some cases economic benefits (consumer surplus or the difference between total benefit value and current expenditures on the resource) are estimated in relation to hypothesized scenarios, while in other cases gross benefits are estimated (usually as a minimum value based on gross expenditures), and in other cases estimation of neither is possible.

In what follows, we summarize our key findings and valuation estimates for each of the major resources identified in Section I, Figure 3 as being limited by environmental contamination in the Mass Bays. The context for this discussion will be the model introduced in Section I and the subsequent valuations of the resources derived from it.

<u>Commercial Fishing</u>

Commercial fishing was divided into two areas: finfishing and lobstering; and shellfishing. This division was necessitated by the inability to quantify one of the linkages in our model (illustrated in Figure 2) for finfish and lobstering. This was the relationship between limiting factors and impacts on the finfish and lobster resources. The knowledge of how specified improvements in water quality affect the primary limiting factors of residual chemicals and natural toxins and how specified changes in these limiting factors impact the stocks of these resources was not available. However, in the case of shellfish, except for the case of natural toxins, we were able to be much more precise about this linkage. A reduction of fecal coliform counts to a point at or below the existing regulatory limit would clearly enable most shellfish beds to legally reopen.

In the case of finfish and lobsters, the absence of the limiting factors/use-resource impacts linkage prevented us from estimating changes in these resource values from likely water quality control scenarios. Instead, we provided market value estimates of these species caught in Mass Bays waters and divided the species into groups to identify those species likely to be of longest residence in the Bays system. This provides a minimum value of the gross benefit of these species of $53 million annually, although as we have shown the additional consumer surplus value produced from any change in water quality is likely to be small because Mass Bays does not appear to contribute a significant enough portion of market supply to influence price. Moreover, additional producer surplus is also likely to be small because of the existence of substantial overfishing. A key point raised here is that if overfishing is allowed to continue, any gains in the value of finfish or lobster stocks through environmental improvements will be substantially lower than in the case of a properly managed finfish industry.

For shellfishing, we estimated the annual benefits from the elimination of depuration due to lower fecal coliform counts to be at least $174,000 annually. The minimum gross benefit - measured by the market value of additional product - from opening currently closed commercial shellfish beds is estimated to be $500,000 annually. As in the case of finfish, the Mass Bays contribution to the overall shellfish market is too small for the opening of these beds to result in any significant impact on shellfish prices. Likewise, there are substantial dangers of overfishing in the shellfish industry due primarily to the fact that shellfish management is focused on health issues and is substantially understaffed at the state level. Further, shellfish management is controlled by the towns and thus there is no overall statewide management of the commercial resources devoted to shellfishing.

**Key Results:**

*** The presence of overfishing in the finfish industry and the likely presence in the shellfishing industry reduces the value of any improvements in these stocks resulting from improvements in Bays water quality.**

*** There is insufficient scientific information available to allow for the quantification of likely improvements in finfish or lobster stocks from specified improvements in Mass Bays water quality parameters.**

*** The contribution of Mass Bays finfish and shellfish to the New England market is too small to substantially impact prices of these seafoods.**

*** Herring and pollock, which may be active spawners in Mass Bays, and cod, flounder, and hake, which are the most highly valued resident species in the Mass Bays should be the focus of initial studies to determine the impact of changes in Bays water quality on their health and development.**

Recreational Fishing

Obviously, the same lack of knowledge of the limiting factors/use-resource impact linkage discussed above constrained this analysis also. Another key missing data set was survey data on the socioeconomic characteristics and fishing habits of Mass Bays recreational marine fishermen. In lieu of these data, we first described the approach Mass Bays managers can use to create the survey database. We then use the Massachusetts sample from national survey data to estimate the average number of recreational finfishing trips conducted in Bays waters over the 1984-1989 period. A different national sample is used to report the number of recreational shellfishing trips conducted in 1985. This same study reveals that recreational shellfishermen readily substitute saltwater fishing for shellfishing and that they tend to be much more highly educated and from households with much higher incomes than the general population.

The range of estimates from many studies from all around the country on the consumer surplus value of a recreational marine fishing day is used to estimate a range of $45-$355 million in annual economic benefit of Mass Bays recreational finfishing. Similar estimates for recreational shellfishing were not calculated because of the lack of recreational shellfishing day value estimates in the literature. The only available scenario from the literature to estimate changes in recreational fishing value (additional annual economic benefits) from assumed changes in water quality from the Boston Harbor cleanup reported a range of $299,000-$7,911,000 in 1982 dollars. However, this study readily acknowledges the lack of scientific basis for the assumed affects of water quality on recreational fish populations and subsequent changes in the behavior of recreational fishermen.

**Key Results/Suggestions for Further Research:**

*** Mass Bays should sponsor, maybe in conjunction with the Division of Marine Fisheries, a survey of recreational fishermen to develop a database on the degree of participation, what influences this participation and the socioeconomic characteristics of this population. Such a survey could probably be conducted relatively cheaply as an attachment to the annual survey conducted by the National Marine Fisheries Service. This could serve as a basis for the calculation of recreational fishing day values for the Mass Bays region.**

*** A similar survey should be conducted for Mass Bays recreational shellfishermen to see if the higher income/higher education profile found nationally applies in Mass Bays and to enable us to understand how fishermen substitute among different Mass Bays recreational activities.**

<u>Swimming and Beach Recreation</u>

As in the case of shellfish, one of the key limiting factor/use-resource impacts is fecal coliform counts. Moreover, debris, oil and floating garbage are also key limiting factors. In this case, the key missing linkage was use-resource impacts/use-resource value. This was because of the lack of beach attendance data to help identify the degree of beach usage. We were able to identify all of the beaches and those beaches that experienced postings in past years, but not the length of time that they were posted. Data on other water quality parameters (such as counts of viral pathogens, debris, oil and floating garbage) that could influence the quality of the beach experience were not available for beaches in the Mass Bays system. Therefore, calculations of the value of beach use were not conducted, but instead estimates of a previous study of the annual benefit value from increased usage of Boston Harbor area beaches resulting from assumed improvements in water quality due to upgrading of primary treatment and treatment of CSOs were reported. However, as discussed, the linkage between improvements in water quality and possible increased beach use was poorly documented and based on very weak data.

**Key Results/Suggestions for Further Research:**

*** The Mass Bays program should strongly encourage the state to implement a procedure for the collection of beach attendance data. This could possibly be organized through the newly created Beach Manager's Association.**

*** A survey of beach users and nonusers should be conducted in the Mass Bays region to develop an up-to-date accurate database on the socioeconomic profile of beach users and nonusers, the influence of different water quality characteristics on beach use, and the valuation these people place on different beach characteristics.**

<u>Other Recreational Activities</u>

The linkages of water quality changes to Bays resources that are likely to affect other activities such as whale watching, other wildlife watching, hiking, and general boating are also not able to be parameterized at this time. In lieu of this data, we did report on two of these activities, for which some participation data were available - general boating and whale watching. However, we were not able to specify precisely how these activities would be changed by different levels of water quality. We estimate the annual economic benefit to recreational boaters of the Bays system to range from $138-$472 million and note that the minimum gross annual benefit from whale watching, based on revenues generated in the industry, is $23 million. One other study has estimated the non-use value of the presence of whales in the Bays system to be an additional $25 million.

**Key Findings/Suggestions for Future Research**

*** We need to develop more specific parameters that relate water quality changes to changes in wildlife stocks and aesthetic characteristics likely to influence participation of boaters, hikers, and other recreationists.**

*** Along with the survey suggested for recreational fishermen, a survey of the Bays population concerning their uses of the Bays and the water quality characteristics that affect these uses, similar to the Chesapeake Bay survey cited, would allow for much more precise specification of use value and potential use conflict.**

<u>Transportation and Port Management</u>

**Key Findings/Suggestions for Future Research**

*** The impact of contaminated sediments on port and harbor development and recreational access is potentially very large and is currently being grossly underestimated. Increased dredging and dredging disposal costs and in some cases prohibition of dredging because of inadequate disposal sites need to be documented in order to boost the case for preventing contaminants from entering the Bays system. While many areas around Boston Harbor are already contaminated, the costs of incurring such contamination in other areas is likely to be substantial. Hopefully, one of the outcomes of the current State Dredging Disposal Task Force will be some estimates of the cost such contaminated sediments impose on ports and harbors.**

<u>Public Health</u>

**Key Findings/Suggestions for Future Research**

*** One of the costs of not improving Bays water quality is the risk to public health both through seafood consumption and viral contamination from water contact. Although the data required to measure both health risks are not available for Mass Bays, we use national data and Massachusetts Department of Public Health data to estimate that the cost of seafoodborne disease in the Commonwealth generally in terms of lost work, medical expenses, and liability claims could be as high as $60 million annually.**

Ecosystem Benefits

The valuation of ecosystem benefits suffers from the same missing linkage in our model present in the case of fisheries. We do not yet know enough about the Mass Bays ecosystem to precisely link specific changes in water quality to specific improvements in characteristics of the ecosystem that can be further linked to direct human uses. However, one component of the ecosystem that has received considerable attention recently is wetlands. Although the precise contribution of Mass Bays wetlands to the Mass Bays ecosystem has not been documented, we illustrate the worthiness of such an undertaking by estimating the potential magnitude of just the recreational benefits such wetlands might generate. We do not attempt to value other benefits of wetlands, such as flood control, fish spawning sites, and groundwater filtration systems.

**Key Results/Suggestions for Future Research**

*** Valuation of Mass Bays ecosystem benefits related to direct human use requires a more precise understanding of the relationship between water quality and characteristics of the ecosystem and these characteristics and human uses of the Bays.**

*** An illustration of the methodology available for measuring one component of this value, the recreational value of wetlands, is illustrated, but because of lack of Mass Bays recreational day value estimates, per acre day value estimates from a recently published study on Louisiana wetlands were used. Applying such values to Mass Bays wetlands yields a recreational value estimate of $600,000 annually in economic benefits and $3.2 million annually in gross economic benefits.**

*** Some of the Mass Bays ecosystem benefits are not captured by their relationship to direct human uses, but have a perceived value among the general population even if direct use is not contemplated. This non-use value (willingness to pay for cleaner Mass Bays waters even if one is not a current user of the system or does not contemplate future use) has been found to be quite substantial in several recently conducted studies looking at a variety of resources in other parts of the country. The Mass Bays program should seriously consider conducting such a study for the Mass Bays system as a whole as this non-use valuation is likely to be sizable and should be used as part of the justification for expenditures on water quality improvements.**

**FOOTNOTES**

1. The theoretically correct measure of consumer surplus is not the area under the ordinary demand curve calculated from market data, but the area under a Hicksian compensated demand curve, where the consumer is compensated for any changes in income that occur from the change in the good being examined. However, data availability and uncertainty usually mean that the measurements of consumer surplus under a normal demand curve are thought to be reasonably accurate. For non-marketed resources, many of the estimation techniques allow for the measurement of the Hicksian demand curve directly. For a detailed discussion of these issues see Mitchell and Carson, 1989.

2. In 1989, the Mass Bays total of all species (finfish and shellfish) represented 8.6% of New England landings and 10% of the total value of New England landings. In 1990, it represented 11% of landings and 10% of value. Landings of Atlantic Cod represented around 4% of New England landings in 1990, Yellowtail Flounder around 5%, Winter Flounder around 10%, and Silver Hake around 11% (Table 3 and Commercial Fisheries News, 1991).

3. In 1980, the Division of Marine Fisheries estimated that 625,000 bushels of shellfish were consumed in the Boston area alone (EPA 1985:8-18).

4. According to officials in the Shellfish Sanitation and Management Program in the Division of Marine Fisheries, these acreage estimates are extremely rough, especially for the North Shore. Moreover, they assume shellfish areas extend offshore 3 miles which is seldom the case. This places an upward bias, particularly on open areas which are often well flushed coastal areas and less likely to have highly productive beds in the 2-3 mile region in contrast to long shallow embayments. It is also the case that administrative closures include acreage located near highly developed urban coastal areas that are also unlikely to include many productive beds.

5. This also assumes that the fish stocks are being properly managed. Over-fishing in the commercial sector can spill over into the recreational sector which might limit the expansion of recreational catch.

6. If a fisher went from boat fishing to shore fishing on the same day, this would be recorded as two trips. However, this probably occurs infrequently enough to allow for the assumption that trips can be interpreted as one fishing day.

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# SUMMARY TABLE 1

## Estimated Value of Selected Bays System Resources
## ('000 Dollars)

| Resource/Use | Annual Economic Benefit | Annual Gross Benefit | Potential Net Value Change | Certainty of Estimate[A] |
|---|---|---|---|---|
| Commercial Fishing | (Insufficient Data) | 53,000 (1990$) | 0-674 (1990$)[1] | 2 |
| (Finfish & Shellfish) | | | | |
| Recreational Fishing | | | 299,000-7,911 (1982$)[2] (Boston Harbor Only) | 3 |
| Finfishing | 45-355,000 (1989$) | (B) | | 3 |
| Shellfishing | (Insufficient Data) | (B) | | 3 |
| Swimming and Beach Recreation | (Insufficient Data) | (B) | 1,800-20,500 (1982$)[3] 900-6000 (1982$)[4] (Boston Harbor Only) | 3 |
| Other Recreational Activities | | | | |
| Boating | 138-472,000 (1990$) | (B) | (Insufficient Data) | 2 |
| Whale Watching | (Insufficient Data) | 23,000 (1990$) | (Insufficient Data) | 1 |

## SUMMARY TABLE 1 (continued)

| Resource/Use | Annual Economic Benefit | Annual Gross Benefit | Potential Net Value Change | Certainty of Estimate[A] |
|---|---|---|---|---|
| Transportation/Port Management | (Insufficient Data) | (Insufficient Data) | (Insufficient Data) | - |
| Public Health | (C) | 60,000 (1990$)[5] | (Insufficient Data) | 3 |
| Ecosystem Benefits | | | | |
| Wetlands Recreation | 600 (1990$) | 3,200 (1990$) | (Insufficient Data) | 3 |

Footnotes:

(A) 1 = Fairly Certain 2 = Uncertain 3 = Highly Uncertain

(B) Because these goods are not traded on the market, there are no readily available data for the approximation of gross benefits.

(C) Not applicable. Value calculated as cost of public health impacts.

(1) Annual Economic Benefit from opening all Mass Bays shellfish beds (including minimum cost savings from eliminating

Footnotes (continued):

(2) Calculated in (EPA, 1985) under highly restrictive assumptions as to the impacts of the MWRA ocean outfall and CSOs on recreational fishing in Boston Harbor.

(3) Calculated in (EPA, 1985) under highly restrictive assumptions as to the impact of the MWRA ocean outfall and CSOs on water quality at Boston Harbor Area beaches and subsequent user response.

(4) Calculated in (EPA, 1985) under highly restrictive assumptions as to the impact of the MWRA ocean outfall and CSOs on the frequency of Boston Harbor Area beach closings and subsequent user response.

(5) Calculations represent the estimated total costs to the Commonwealth of risk exposure to contaminated seafood.

# SUMMARY TABLE 2

## Certainty of the Estimates and Data Needs

<u>Commercial Fishing</u>

**Finfish and Shellfish**

<u>Certainty of the Estimate</u>: Uncertain

<u>Data/Information Needs</u>:

Better estimates would require a more effective understanding of:

1. The relationship between contaminate loads and commercial species diversity, health and reproductive capacity.

2. The potential productivity of presently closed shellfish beds.

3. The importance of viruses/vibrios to shellfish public health concerns.

4. The contribution of non-point inputs to pathogen levels in Bays system shellfish.

5. Ecosystemic and food web transfers of contaminants within the Bays system.

<u>Recreational Fishing</u>

**Finfish and Shellfish**

<u>Certainty of the Estimate</u>: Highly Uncertain

<u>Data/Information Needs</u>:

In addition to the needs listed for commercial fishing, better estimates would require a more effective understanding of:

1. Survey data on recreational finfishing and shellfishing uses of the Bays, such as, the number of recreational harvesters, number of fishing days, income distribution of harvesters and distance traveled to recreational site.

2. Travel cost and/or contingent valuation estimates for the value of a recreational fishing day in the Bays.

**Swimming and Beach Recreation**

Certainty of the Estimate: Highly Uncertain

Data/Information Needs:

Better estimates would require a more effective understanding of:

1. The number of people who attend Bays system beaches on a given day.

2. Travel cost estimates of the value of a beach recreational day.

3. The actual number of days a beach closing is posted.

4. The public health impact of contact with pathogens (and in particular with marine viruses).

**Other Recreational Activities**

| | | |
|---|---|---|
| Certainty of the Estimate: | In General: | Highly Uncertain |
| | Boating: | Uncertain |
| | Whale Watching: | Fairly Certain |

Data Information Needs:

Better estimates would require a more effective understanding of:

In General

1. Contingent valuation estimates for non-market benefits for, inter alia, hunting, bird and wildlife watching, walking and boating.

Boating

2. Total number of recreational boating days spent within the Bays system.

3. The user day value of a boating day within the region.

4. The impact of contaminant loads on user day values.

Whale Watching

5. The influence of contaminant loads on the number and diversity of marine mammals resident or spawning within Bays system waters.

6. Existence value calculations for Commonwealth citizens who do not participate in whale watching activities.

<u>**Transportation and Port Management**</u>

<u>Certainty of the Estimate</u>: No estimate provided

<u>Data/Information Needs</u>:

Better estimates would require a more effective understanding of:

1. Cost of additional assessment and disposal costs of contaminated sediments to new construction and maintenance dredging projects.

<u>**Public Health**</u>

<u>Certainty of the Estimate:</u> Highly Uncertain

<u>Data/Information Needs:</u>

Better estimates would require a more effective understanding of:

1. By use of systemic community based health surveys, the number of individuals who become ill from consuming seafood harvested from the Mass. Bays system.

2. The actual cost of seafoodborne disease, including, <u>inter alia</u>, the direct costs of patient treatment, lost working days and industrial liability insurance and litigation.

<u>**Ecosystem Benefits**</u>

Certainty of the Estimate: Highly Uncertain

<u>Data/Information Needs:</u>

Better estimates would require a more effective understanding of:

1. Direct and site specific estimates of the benefits provided by Bays system wetlands, including, <u>inter alia</u>, the contribution of wetlands to the expansion of fish stocks, the relationship between wetlands extent and flood control and/or groundwater filtration, the role of wetlands in anthropogenic contaminant and nutrient reduction and the contribution of wetlands to the expansion of the variety of wildlife in the area or the greater appreciation of natural scenery by people frequenting the region.

# APPENDIX I

# SHELLFISH AREA CLASSIFICATIONS FOR THE MASSACHUSETTS BAYS REGION

APPENDIX I:
SHELLFISH AREA CLASSIFICATIONS FOR THE MASSACHUSETTS BAYS REGION
(AS OF 4/21/91)

| AREA CODE | TOWN/REGION | NAME OF AREA | SURVEY BY | STATUS | ACRES OPEN | ACRES CLOSED | ACRES SEASONAL | ACRES MC | ACRES CR/CA |
|---|---|---|---|---|---|---|---|---|---|
| | NORTH SHORE | | | | | | | | |
| N8 | Gloucester | Coffins Beach | DEQE[1980] | CA | | | | | 3,648 |
| N9 | Gloucester | Gloucester Harbor | | P | | 1,096 | | | |
| N9.FC | Gloucester | Freshwater Cove | DEQE[1980] | MC | | | | 22 | |
| N9.S | Gloucester | Sandbar | DMF[1989] | CA | | | | | 38 |
| N9.1A | Gloucester | | DMF[1989] | MC | | | | 34 | |
| N9.2 | Gloucester | | DMF[1989] | MC | | | | 21 | |
| N9.3 | Gloucester | Little River | DMF[1989] | P | | 86 | | | |
| N9.4 | Gloucester | | DMF[1989] | CA | | | | | 164 |
| N9.5 | Gloucester | | | P | | 39 | | | |
| N9.5B | Gloucester | | DMF[1989] | CA | | | | | 7 |
| N9.5BC | Gloucester | Beck Creek | DMF[1989] | MC | | | | 14 | |
| N9.5M | Gloucester | Mill River | DMF[1989] | MC | | | | 37 | |
| N9.5LF | Gloucester | Lower Flat | DMF[1989] | CA | | | | | 16 |
| N9.5P | Gloucester | Plummers | DMF[1989] | CA | | | | | 12 |
| N9.5WC | Gloucester | Wheelers Cove | DMF[1989] | MC | | | | 9 | |
| N10 | Gloucester | | | P | | 8,664 | | | |
| N12 | Gloucester | Good Harbor Beach | | MC | | | | 3,192 | |
| N13 | Gloucester | Eastern Point | | MC | | | | 9,348 | |
| N14 | Gloucester | Magnolia Point | | MC | | | | 5,016 | |
| N15 | Manchester | Manchester Harbor | DMF[1989] | P | | 47 | | | |
| N15.1 | Manchester | Manchester Harbor | | P | | 17 | | | |
| N16 | Beverly | | | P | | 9,120 | | | |
| N17 | Bev./Danv./Salem | Danvers River | | P | | 344 | | | |
| N18 | Salem | Salem Harbor | | P | | 38 | | | |
| N18.A | Salem | | | P | | 186 | | | |
| N19 | Marblehead | | | P | | 55 | | | |
| N20 | Marblehead | | | P | | 238 | | | |
| N20.1 | Marblehead | | | P | | 1 | | | |
| N21 | Marblehead | | DMF[1989] | A | 8,208 | | | | |
| N21.1 | Marblehead | Devereaux Beach | DMF[1989] | P | | 912 | | | |
| N22 | Swampscott | | | P | | 6,348 | | | |
| N22.1 | Swampscott | | | P | | 1,139 | | | |
| N23 | Lynn | | | P | | 2,280 | | | |
| N24 | Nahant | | | P | | 9,804 | | | |
| N25 | Nahant | | | P | | 5,700 | | | |
| N26 | Lynn/Revere | Lynn Harbor | | P | | 2,280 | | | |
| N26.1 | Revere | | DEQE[1982] | P | | 102 | | | |
| N26.1A | Revere | Center Bar | DMF[1989] | CR | | | | | 70 |
| N26.1B | Revere | Seaplane Basin | DMF[1989] | CR | | | | | 44 |
| N26.1C | Revere | Gravel Guarties | | P | | 38 | | | |
| N26.2 | Winthrop | | | P | | 33 | | | |
| N27 | Winthrop | | | P | | 126 | | | |
| N28 | Winthrop | | | P | | 55 | | | |
| | N. SHORE SUBTOTAL | | | | 8,208 | 48,749 | 0 | 17,693 | 3,997 |

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SHELLFISH AREA CLASSIFICATIONS FOR THE MASSACHUSETTS BAYS REGION
(AS OF 4/21/91)

| AREA CODE | TOWN/REGION | NAME OF AREA | SURVEY BY | STATUS | ACRES OPEN | ACRES CLOSED | ACRES SEASONAL | ACRES MC | ACRES CR/CA |
|---|---|---|---|---|---|---|---|---|---|
| | BOSTON HARBOR | | | | | | | | |
| BHC | Boston | | DMF[1988] | P | | 9 | | | |
| BHD | Boston | | | P | | 10 | | | |
| BHE | Boston | Constitution Beach | | P | | 11 | | | |
| BH1.S | Winthrop | Snake Island | DMF[1989] | P | | 55 | | | |
| BH1 | Winthrop | Winthrop Shores | | P | | 29 | | | |
| BH1.1 | Winthrop | | | P | | 6 | | | |
| BH2 | Boston/Winthrop | Logan Airport | DMF[1989] | CR | | | | | 119 |
| BH2.1B | Boston | Wood Island | DMF[1988] | CR | | | | | 39 |
| BH3 | Boston | Govenor's Island | DMF[1989] | CR | | | | | 34 |
| BH4 | Boston | Carson Beach | | P | | 86 | | | |
| BH4.A | Boston | Pleasure Bay | | MC | | | | 8 | |
| BH4.1 | Boston | | | P | | 43 | | | |
| BH5 | Quincy | Buckley's Bar | | P | | 50 | | | |
| BH5.A | Quincy | Neponset River | | P | | 209 | | | |
| BH5.B | Quincy | | DMF[1989] | CR | | | | | 90 |
| BH5.C | Quincy | | | P | | 41 | | | |
| BH5.C1 | Quincy | | DMF[1989] | CR | | | | | 106 |
| BH6 | Quincy | | DMF[1989] | CR | | | | | 39 |
| BH6.1 | Quincy | Wollaston Beach | | P | | 111 | | | |
| BH7 | Quincy | | DMF[1989] | CR | | | | | 151 |
| BH7.1 | Quincy | Merrymount | | P | | 144 | | | |
| BH8 | Quincy | | | P | | 47 | | | |
| BH8.A | Quincy | Town River Bay | DMF[1989] | CR | | | | | 59 |
| BH8.A1 | Quincy | | | P | | 16 | | | |
| BH8.A2 | Quincy | | DMF[1989] | P | | 11 | | | |
| BH8.B | Quincy | | DMF[1989] | CR | | | | | 55 |
| BH8.C | Quincy | Rock Island Cove | DMF[1989] | CR | | | | | 106 |
| BH9 | Weymouth | Wessagusset Beach | DMF[1989] | CR | | | | | 81 |
| BH9.A | Hingham | | DMF[1989] | CR | | | | | 30 |
| BH9.A1 | Hingham | | | P | | 17 | | | |
| BH9.B | Weymouth | King's Cove | | CR | | | | | 8 |
| BH9.C | Weymouth | Weymouth Fore River | DMF[1989] | P | | 100 | | | |
| BH9.D | Hingham/Weymouth | | | P | | 114 | | | |
| BH9.E | Hingham/Weymouth | | | P | | 44 | | | |
| BH10 | Weymouth | Slate Island | DMF[1989] | P | | 28 | | | |
| BH11 | Hingham | | | MC | | | | 18 | |
| BH12 | Hingham | Bumpkin Island | DMF[1989] | P | | 47 | | | |
| BH13 | Hull | | DMF[1989] | CR | | | | | 53 |
| BH14 | Hull | Clam Alley | DMF[1989] | CR | | | | | 57 |
| BH14.1 | Hull | | DMF[1989] | CR | | | | | 44 |
| BH15 | Hingham | Weir River | DMF[1989] | CR | | | | | 61 |
| BH15.1 | Hingham | | DMF[1989] | P | | 31 | | | |
| BH16 | Weymouth | | | P | | 77 | | | |
| BH18 | Weymouth | Grape Island | DMF[1989] | P | | 52 | | | |
| BH20 | Hingham | Hingham Harbor | DMF[1989] | CR | | | | | 130 |
| BH21 | Hull | | DMF[1989] | CR | | | | | 107 |
| | BOSTON HARBOR SUBTOTAL | | | | 0 | 1,385 | 0 | 26 | 1,369 |

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SHELLFISH AREA CLASSIFICATIONS FOR THE MASSACHUSETTS BAYS REGION
(AS OF 4/21/91)

| AREA CODE | TOWN/REGION | NAME OF AREA | SURVEY BY | STATUS | ACRES OPEN | ACRES CLOSED | ACRES SEASONAL | ACRES MC | ACRES CR/CA |
|---|---|---|---|---|---|---|---|---|---|
| | SOUTH SHORE | | | | | | | | |
| S1 | Hull | | | P | | 5,244 | | | |
| S2 | Hull | Nantasket Beach | | P | | 10,944 | | | |
| MB1 | Duxbury, Plymouth | Duxbury Beach | DMF[1989] | A | 10,455 | | | | |
| MB2 | Marshfield | Marshfield E. Cstl. | DMF[1989] | A/P | 10,643 | 30 | | | |
| MB3 | Marshfield | Green Harbor | | P | | 193 | | | |
| MB4 | Scituate | Scituate S. Cstl. | DMF[1989] | A | 14,211 | | | | |
| MB5 | Marsh./Scituate | North River | DEQE | S/P | | 177 | 308 | | |
| MB6 | Marsh./Scituate | South River | DMF[1989] | S/P | | 192 | 262 | | |
| MB7 | Scituate | Scituate Harbor | DEQE | S/P | | 177 | 98 | | |
| MB8 | Scituate | Scituate N. Cstl. | DMF[1989] | A | 14,872 | | | | |
| MB9 | Coh./Scituate | Cohasset N. Cstl. | | MC | | | | 9,798 | |
| MB10 | Coh./Scituate | Cohasset Harbor | | P | | 150 | | | |
| MB11 | Cohasset | Little Harbor | | P | | 190 | | | |
| | SOUTH SHORE SUBTOTAL | | | | 50,181 | 17,298 | 666 | 9,798 | 0 |
| | CAPE COD BAY | | | | | | | | |
| CCB1 | Provincetown | Herring Cve/Lng. Pt. | DMF[1989] | A | 19,750 | | | | |
| CCB2 | Provincetown | Hatches Harbor | | P | | 152 | | | |
| CCB3 | P-town/Truro | P-town Otr. Harb. | DMF[1989] | A | 5,499 | | | | |
| CCB4 | P-town/Truro | P-town Inr. Harb. | DEQE | A/P | 1,827 | 223 | | | |
| CCB5 | Provincetown | The Dike | DMF[1989] | A/P | 211 | 4 | | | |
| CCB6 | Truro | Truro West Coastal | DMF[1989] | A | 7,300 | | | | |
| CCB7 | Truro | Pamet Harbor & River, & Little Pamet River | | P | | 109 | | | |
| CCB8 | Wellfleet | Wellfleet W. Cstl. | | MC | | | | 16,580 | |
| CCB9 | Wellf./Eastham | Eastham Coastal Area | DMF[1989] | A | 18,283 | | | | |
| CCB10 | Eastham | Hatches Creek | | P | | 15 | | | |
| CCB11 | Wellfleet | Wellfleet Harbor | DMF[1989] | A | 5,069 | | | | |
| CCB12 | Wellfleet | Herring River | | P | | 252 | | | |
| CCB13 | Wellfleet | Wellfleet In. Hrbr. | DMF[1989] | A/S/P | 192 | 20 | 50 | | |
| CCB14 | Wellfleet | Loagy B./Dummer Cv. & Blackfish Creek | DMF[1989] | A | 582 | | | | |
| CCB15 | Eastham | Herring River | | P | | 42 | | | |
| CCB16 | Eastham | Boat Meadow River | | P | | 32 | | | |
| CCB17 | Orleans | Orleans N. Cstl. | DMF[1989] | A | 2,790 | | | | |
| CCB18 | Eastham, Orleans | Rock Harbor | | P | | 14 | | | |
| CCB19 | Orleans | L. Namskaket Crk. | | P | | 25 | | | |
| CCB20 | Brewster | Brewster N. Cstl. | DMF[1989] | A | 9,055 | | | | |
| CCB21 | Brewster, Orleans | Namskaket Creek | | P | | 55 | | | |
| CCB22 | Brewster | Stony Brook | | P | | 13 | | | |
| CCB23 | Dennis | Dennis N. Cstl. | DMF[1989] | A/P | 11,833 | 92 | | | |
| CCB24 | Brewster, Dennis | Quivett Creek | DEQE | P | | 45 | | | |
| CCB25 | Dennis | Sesuit Harbor | | P | | 46 | | | |
| CCB26 | Yarmouth | Yarmouth N. Cstl. | | MC | | 316 | | 1,618 | |
| CCB27 | Dennis, Yarmouth | Chase Garden Creek | | P | | 218 | | | |
| CCB28 | Yarmouth | Bass/Lone Tree Crks. | | P | | 81 | | | |
| CCB29 | Yarm./Brnstble | Mill Crk./Hallets Pnd. & Short Wharf Creek | | P | | 102 | | | |
| CCB30 | Barnstable | Barnstable N. Cstl. | | MC | | | | 9,757 | |
| CCB31 | Barnstable | Barnstable Harbor | DMF[1989] | A | 1,830 | | | | |

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SHELLFISH AREA CLASSIFICATIONS FOR THE MASSACHUSETTS BAYS REGION
(AS OF 4/21/91)

| AREA CODE | TOWN/REGION | NAME OF AREA | SURVEY BY | STATUS | ACRES OPEN | ACRES CLOSED | ACRES SEASONAL | ACRES MC | ACRES CR/CA |
|---|---|---|---|---|---|---|---|---|---|
| CCB32 | Barnstable | Barnstable In. Hrb. & Marspin Creek | | P/MC | | 31 | | | |
| CCB33 | Barnstable | Barnstable Marshes | DMF[1989] | A/P | 283 | | | | |
| CCB34 | Brnstble/Sand. | Scorton Creek | | MC | | | | 228 | |
| CCB35 | Sandwich | Sandwich N. Cstl. | | MC | | | | 24,710 | |
| CCB36 | Sandwich | Scorton Harbor | | MC | | | | 50 | |
| CCB37 | Sandwich | Sandwich Harbor | | P | | 84 | | | |
| CCB38 | Bourne | Bourne N. Cstl. | DMF[1989] | A | 3,380 | | | | |
| CCB39 | Plymouth | Plymouth S. Cstl. | DMF[1989] | A | 18,071 | | | | |
| CCB40 | Plymouth | Ellisville Harbor | | P | | 22 | | | |
| CCB41 | Plymouth | Plymouth N. Cstl. | DEQE | A | 19,619 | | | | |
| CCB42 | Ply./Kngstn./Dux. | Plym. Hrb./Duxb. Bay | FDA | A/P | 2,391 | 2,076 | | | |
| CCB43 | Kingston, Duxbury | Kingston Bay | FDA | A/P | 844 | 686 | | | |
| CCB44 | Kingston, Duxbury | Jones River | | P | | 27 | | | |
| CCB45 | Duxbury, Plymouth | Duxbury Bay | FDA | A | 4,763 | | | | |
| CCB46 | Duxbury | Bluefish River | | P | | 75 | | | |
| CCB47 | Duxbury, Marshfield | Back River | FDA | A | 368 | | | | |
| | CAPE COD SUBTOTAL | | | | 133,941 | 4,857 | 50 | 52,943 | 0 |

LEGEND
CA=Conditionally Approved
CR=Conditionally Restricted
S=Seasonally Closed
P=Prohibited
R=Remote

| | APPROV. | PROHIB. | SEASON. | MGT. CLS. | CA/CR |
|---|---|---|---|---|---|
| COLUMN TOTALS: | 192,330 | 72,289 | 716 | 80,460 | 5,366 |
| GRAND TOTAL: | 351,160 | | | | |
| PERCENT OF TOTAL SHELLFISH AREAS IN MASS. BAYS: | 55% | 21% | 0.2% | 23% | 1.5% |

Massachusetts Bays region defined to be from Race Point, Provincetown to Emerson Point, Rockport.

Data From: Massachusetts Division of Marine Fisheries, Shellfish Sanitation & Management Program offices in Sandwich and Newburyport, MA.

# APPENDIX II

# PUBLIC SALTWATER BEACHES IN THE MASSACHUSETTS BAYS REGION

## APPENDIX II:
## PUBLIC SALTWATER BEACHES IN THE MASSACHUSETTS BAYS REGION

| REGIONS/BEACHES | OWNERSHIP | SQUARE FT | PARKING SPACES | LEVEL OF USE | BEACH POSTINGS (CLOSURES) 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|---|
| NORTH SHORE | | | | | | | | |
| GLOUCESTER | | | | | | | | |
| Good Harbor | Municipal | NA | 850 | NA | | | | |
| Wingersheek | Municipal | NA | 300 | NA | | | | |
| Kettle Cove | Municipal | NA | NA | NA | | | | |
| Pav.-Cres./Stage Fort | Municipal | NA | 600 | NA | | | | |
| Plum Cove | Municipal | NA | NA | NA | | | | |
| MANCHESTER | | | | | | | | |
| Black Beach | Municipal | 60,984 | 15 | XXX | | | | |
| Singing Beach | Municipal | 531,432 | 135 | XXX | | | | |
| Tuck's Point | Municipal | 235,224 | 50 | XXX | | | | |
| White Beach | Municipal | 74,052 | 20 | XXX | | | | |
| BEVERLY | | | | | | | | |
| Brackenberry Beach | Municipal | 43,560 | NA | XX | | | | |
| Dane Street Park | Municipal | 784,080 | NA | XX | | | | |
| Independence Park | Municipal | 121,968 | NA | XX | | | | |
| Lynch Park | Municipal | 696,960 | NA | XX | | | | |
| Obear Park | Municipal | 348,480 | NA | XX | | | | |
| SALEM | | | | | | | | |
| Forest River Park | Municipal | NA | NA | NA | | | | |
| Glendale Cove Beach | Municipal | NA | NA | NA | | | | |
| Leach St. Ext. | Municipal | NA | NA | NA | | | | |
| Palmer Cove | Municipal | NA | NA | NA | | | | |
| Waikiki/Winter Island | Municipal | NA | NA | NA | | | | |
| Misery Island Reserv. | Private | 3,659,040 | NA | XX | | | | |
| MARBLEHEAD | | | | | | | | |
| Castle Rock Beach | Municipal | 21,780 | 30 | NA | | | | |
| Chandler Hovey Park | Municipal | 174,240 | 55 | NA | | | | |
| Crocker Park | Municipal | NA | NA | NA | | | | |
| Devereux Beach | Municipal | NA | 200 | NA | | | | |
| Fort Beach | Municipal | NA | 12 | NA | | | | |
| Gas House Beach | Municipal | NA | 10 | NA | | | | |
| Grace Oliver Beach | Municipal | 21,780 | 25 | NA | | | | |
| Riverhead Beach | Municipal | NA | NA | NA | | | | |
| Seaside Park | Municipal | NA | NA | NA | | | | |
| Crowninshield Island | Private | 217,800 | NA | X | | | | |
| SWAMPSCOTT | | | | | | | | |
| Blaney Beach | Municipal | 17,424 | 50 | XX | | | | |
| Fishermans Beach | Municipal | 87,120 | 40 | XX | | | | |
| Kings Beach | MDC | 91,476 | 150 | XX | 4 | 1 | 1 | 7 |
| Whales Beach | Municipal | 13,068 | 0 | XX | | | | |
| LYNN | | | | | | | | |
| Lynn Beach | MDC | NA | NA | NA | 2 | 8 | 4 | 2 |
| King's Beach | MDC | NA | NA | NA | 1 | 1 | 1 | 5 |
| NAHANT | | | | | | | | |
| Lynn Shore Res. | MDC | 4,212,252 | 230 | XX | | 1 | 1 | 2 |
| NORTH SHORE SUBTOTAL | | 11,412,720 | 2,772 | | 7 | 11 | 7 | 16 |

## APPENDIX II:
## PUBLIC SALTWATER BEACHES IN THE MASSACHUSETTS BAYS REGION

| REGIONS/BEACHES | OWNERSHIP | SQUARE FT | PARKING SPACES | LEVEL OF USE | BEACH POSTINGS (CLOSURES) 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|---|
| BOSTON HARBOR | | | | | | | | |
| REVERE | | | | | | | | |
| Revere Beach | MDC | NA | 200-300 | NA | 1 | | 1 | 3 |
| Crescent Beach | Municipal | NA | NA | NA | | | | |
| WINTHROP | | | | | | | | |
| Short Beach | MDC | NA | NA | NA | 1 | 1 | 4 | 1 |
| Winthrop Beach | MDC | NA | NA | NA | | 2 | 1 | 1 |
| Donovan Beach | Municipal | NA | NA | NA | | | | |
| Yirrell Beach | MDC | NA | NA | NA | | | | 2 |
| Pekoe Beach | Municipal | NA | NA | NA | | | | |
| BOSTON | | | | | | | | |
| Constitution Beach | MDC | 1,698,840 | 150 | XX | 3 | 8 | 2 | 3 |
| M Street Beach | MDC | 217,800 | NA | XX | | | | |
| Malibu Beach | MDC | 548,856 | NA | XX | 2 | 6 | 7 | 1 |
| Pleasure Bay | MDC | 217,800 | 100 | XX | 1 | | 1 | 1 |
| Carson Beach | MDC | NA | NA | NA | 2 | 2 | | 1 |
| Teanen Beach | MDC | 8,537,760 | 50 | XX | 2 | 9 | 12 | 7 |
| QUINCY | | | | | | | | |
| Wollaston Beach | MDC | NA | 500 | NA | 14 | 15 | 9 | 8 |
| Avalon/Quincy Point | Municipal | 108,900 | 0 | XXX | | | | |
| Baker/General Palmer | Municipal | 161,172 | 25 | XXX | | | | |
| Herron Road Playground | Municipal | 56,628 | 0 | XX | | | | |
| Mount Street Beach | Municipal | 431,244 | 0 | X | | | | |
| Perry Beach | Municipal | 17,424 | 0 | XXX | | | | |
| Rhoda Beach | Municipal | 13,068 | 0 | XXX | | | | |
| Willows/C Street | Municipal | NA | NA | X | | | | |
| Nickerson Beach | Municipal | 47,916 | 0 | XXX | | | | |
| Orchard Beach | Municipal | 47,916 | 0 | XXX | | | | |
| Pawsey Beach | Municipal | 13,068 | 0 | NA | | | | |
| WEYMOUTH | | | | | | | | |
| Wessagussett Beach | Municipal | 174,240 | 200 | XX | | | | |
| HINGHAM | | | | | | | | |
| Bathing Beach | Municipal | 261,360 | 250 | XX | | | | |
| Monument Park | Municipal | 252,648 | 120 | XXX | | | | |
| BOSTON HARBOR SUBTOTAL | | 12,806,640 | 1,395 | | 26 | 43 | 37 | 28 |
| SOUTH SHORE | | | | | | | | |
| HULL | | | | | | | | |
| Nantasket Beach | MDC | 1,306,800 | 1,020 | XX | 1 | 1 | | |
| Gunrock Beach | Municipal | 21,780 | 10 | XX | | | | |
| Hampton Beach | Municipal | 8,712 | 5 | XX | | | | |
| Hull Village/Spring St. | Municipal | 4,356 | 0 | XX | | | | |
| TOTAL MDC BEACH POSTINGS, 1988-1991 | | | | | 34 | 55 | 44 | 44 |

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|---|---|---|---|---|---|---|---|---|
| SCITUATE | | | | | | | | |
| Egypt Beach | Municipal | 87,120 | 150 | XX | | | | |
| Humrock Beach | Municipal | 217,800 | 150 | XXX | | | | |
| Jerico Beach | Municipal | 43,560 | NA | XX | | | | |
| N. Scituate Beach | Municipal | 174,240 | 300 | XX | | | | |
| Peggotty Beach | Municipal | 239,580 | 280 | XX | | | | |
| Sand Hill | Municipal | 130,680 | 30 | XX | | | | |
| MARSHFIELD | | | | | | | | |
| Rexhame Dunes | Municipal | 196,020 | 150 | X | | | | |
| DUXBURY | | | | | | | | |
| Duxbury Beach Res. | Municipal | 13,433,904 | 1,500 | XX | | | | |
| Shipyard Lane | Municipal | 52,272 | NA | XX | | | | |
| KINGSTON | | | | | | | | |
| Grays Bch/Howlands Ln. | Municipal | 283,140 | 100 | XX | | | | |
| PLYMOUTH | | | | | | | | |
| Nelson St. Memorial | Municipal | 169,884 | 60 | XX | | | | |
| Plymouth/Long Beach | Municipal | 252,648 | 150 | XX | | | | |
| Stephens Field | Municipal | 322,344 | 100 | XX | | | | |
| White Horse Beach | Municipal | 104,544 | 100 | XX | | | | |
| Taylor Avenue | Municipal | 47,916 | 30 | XX | | | | |
| SOUTH SHORE SUBTOTAL | | 17,097,300 | 4,135 | | | | | |
| CAPE COD | | | | | | | | |
| BOURNE | | | | | | | | |
| Sagamore Beach/Strand | Municipal | 705,672 | 100 | XXX | | | | |
| SANDWICH | | | | | | | | |
| Boardwalk/Town Neck | Municipal | 566,280 | 50 | XX | | | | |
| East Sandwich Beach | Municipal | 522,720 | 50 | XX | | | | |
| Horizons Beach | Municipal | NA | NA | NA | | | | |
| Phillips Road Beach | Municipal | NA | NA | NA | | | | |
| Scusset Beach | State | 16,552,800 | 600 | XX | | | | |
| BARNSTABLE | | | | | | | | |
| Bodfish Park/Sandy Neck | Municipal | 65,340 | 50 | XXX | | | | |
| Coville Beach | Municipal | 313,632 | 300 | XXX | | | | |
| East Beach | Municipal | NA | NA | XXX | | | | |
| Kalmus Park Beach | Municipal | 2,095,236 | 2,000 | XX | | | | |
| Keyes Memorial Beach | Municipal | 435,600 | 200 | XX | | | | |
| Loop Beach | Municipal | 26,136 | 50 | XXX | | | | |
| Millway Beach | Municipal | 60,984 | 50 | XX | | | | |
| Ropes Beach | Municipal | 47,916 | NA | XXX | | | | |
| YARMOUTH | | | | | | | | |
| Gray's Beach | Municipal | NA | NA | XX | | | | |
| DENNIS | | | | | | | | |
| Chapin Mem. Beach | Municipal | 2,805,264 | 200 | XX | | | | |
| Corporation Beach | Municipal | 627,264 | 110 | NA | | | | |
| Howse Beach | Municipal | 130,680 | 50 | NA | | | | |
| Mayflower Beach | Municipal | 435,600 | 148 | NA | | | | |
| Sea Street | Municipal | 87,120 | 40 | NA | | | | |
| Inman Road Beach | Municipal | 13,068 | 30 | NA | | | | |

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|---|---|---|---|---|---|---|---|---|
| BREWSTER | | | | | | | | |
| Breakwater Beach | Municipal | 174,240 | 63 | XXX | | | | |
| Ellis Landing | Municipal | 43,560 | 19 | XXX | | | | |
| Paine's Creek | Municipal | 435,600 | 19 | XXX | | | | |
| Point of Rock | Municipal | 43,560 | 4 | XXX | | | | |
| Robbins Hill | Municipal | 87,120 | 55 | XXX | | | | |
| Saint's Landing | Municipal | 100,188 | 22 | XXX | | | | |
| ORLEANS | | | | | | | | |
| Rock Harbor Road | Municipal | 217,800 | 160 | XXX | | | | |
| Skaket/Namskaket Road | Municipal | 239,580 | 173 | XX | | | | |
| EASTHAM | | | | | | | | |
| Campground Landing | Municipal | 95,832 | 128 | XX | | | | |
| Cooks Brook Beach | Municipal | 187,308 | 152 | XX | | | | |
| First Encounter Beach | Municipal | 1,481,040 | 186 | XX | | | | |
| S. Sunken Meadow | Municipal | 43,560 | 40 | XX | | | | |
| Kingston Beach | Municipal | NA | NA | NA | | | | |
| Thumpertown Beach | Municipal | 43,560 | 30 | XX | | | | |
| WELLFLEET | | | | | | | | |
| Bound Brook Isle Rd. | Municipal | 4,356 | 5 | XXX | | | | |
| Mayo Beach | Municipal | 4,573,800 | 42 | XX | | | | |
| Duck Harbor | Municipal | 435,600 | 40 | XXX | | | | |
| Indian Neck | Municipal | 261,360 | 70 | XX | | | | |
| Powers Landing | Municipal | 21,780 | 25 | XX | | | | |
| The Gut | Municipal | 522,720 | 30 | XX | | | | |
| Jeremy Pt. to Great Island | Municipal | NA | 0 | NA | | | | |
| TRURO | | | | | | | | |
| Highhead Conservation | Municipal | 121,968 | 25 | XX | | | | |
| Cornhill Beach | Municipal | 827,640 | 146 | XX | | | | |
| Ryder Beach | Municipal | 43,560 | 20 | XX | | | | |
| Fisher Beach | Municipal | NA | 8 | NA | | | | |
| Great Hollow Beach | Municipal | NA | 20 | NA | | | | |
| PROVINCETOWN | | | | | | | | |
| Herring Cove N. | Federal | NA | 232 | NA | | | | |
| Herring Cove S. | Federal | NA | 525 | NA | | | | |
| CAPE COD SUBTOTAL | | 35,497,044 | 6,267 | | | | | |

LEGEND
X - Underutilized
XX - Optimally Utilized
XXX - Overutilized
NA - Not Available
Use Levels Assessed in SCORP.

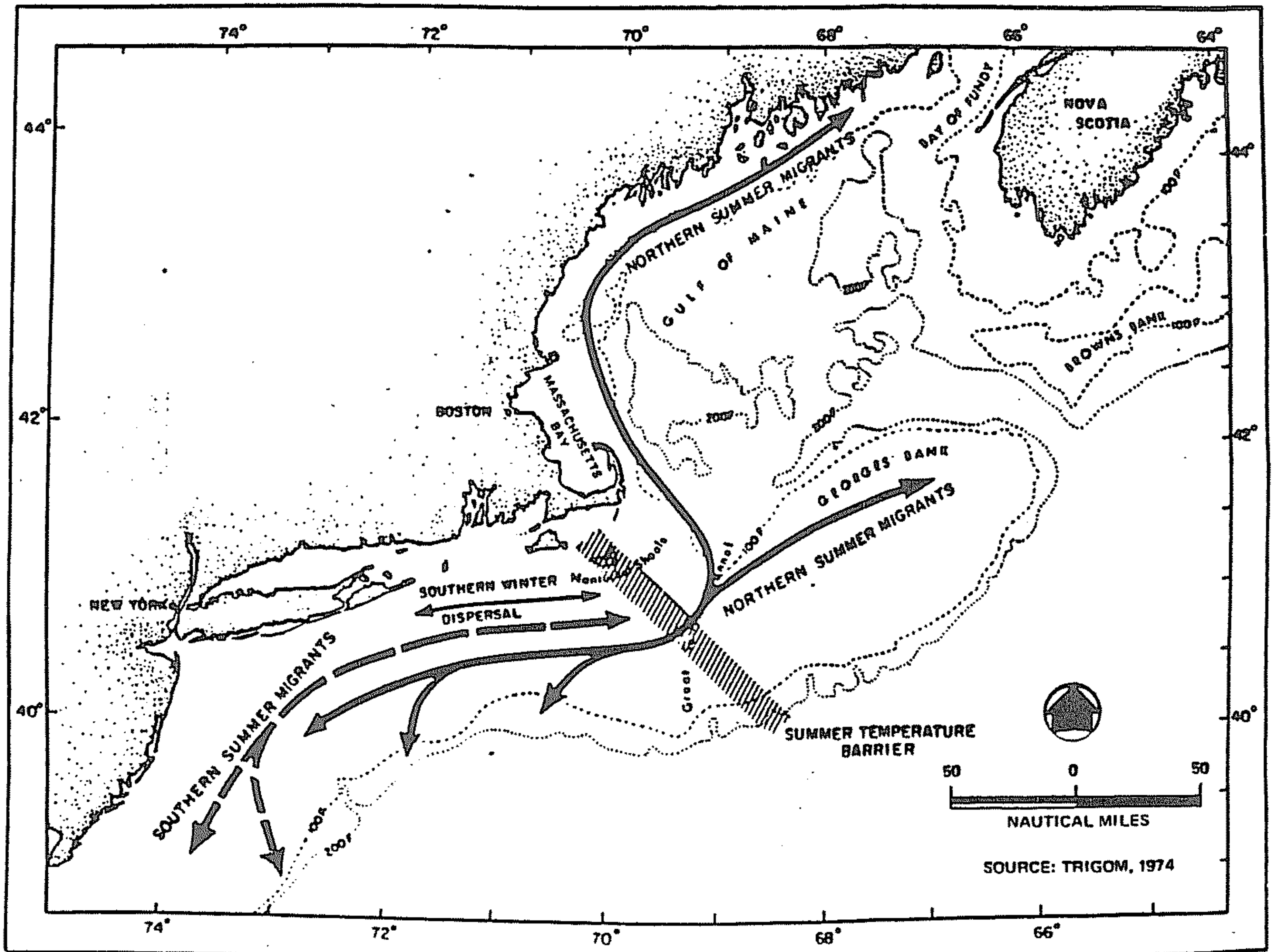
Massachusetts Bays region defined to be from Race Point, Provincetown, to Emerson Point, Rockport.

Data from: Massachusetts Department of Environmental Management, "The Coastal Property Inventory"; Massachusetts Executive Office of Environmental Affairs, "The 1988 Statewide Comprehensive Outdoor Recreation Plan (SCORP); "The Ultimate Beach Guide," Boston Magazine, June, 1990.

# APPENDIX III

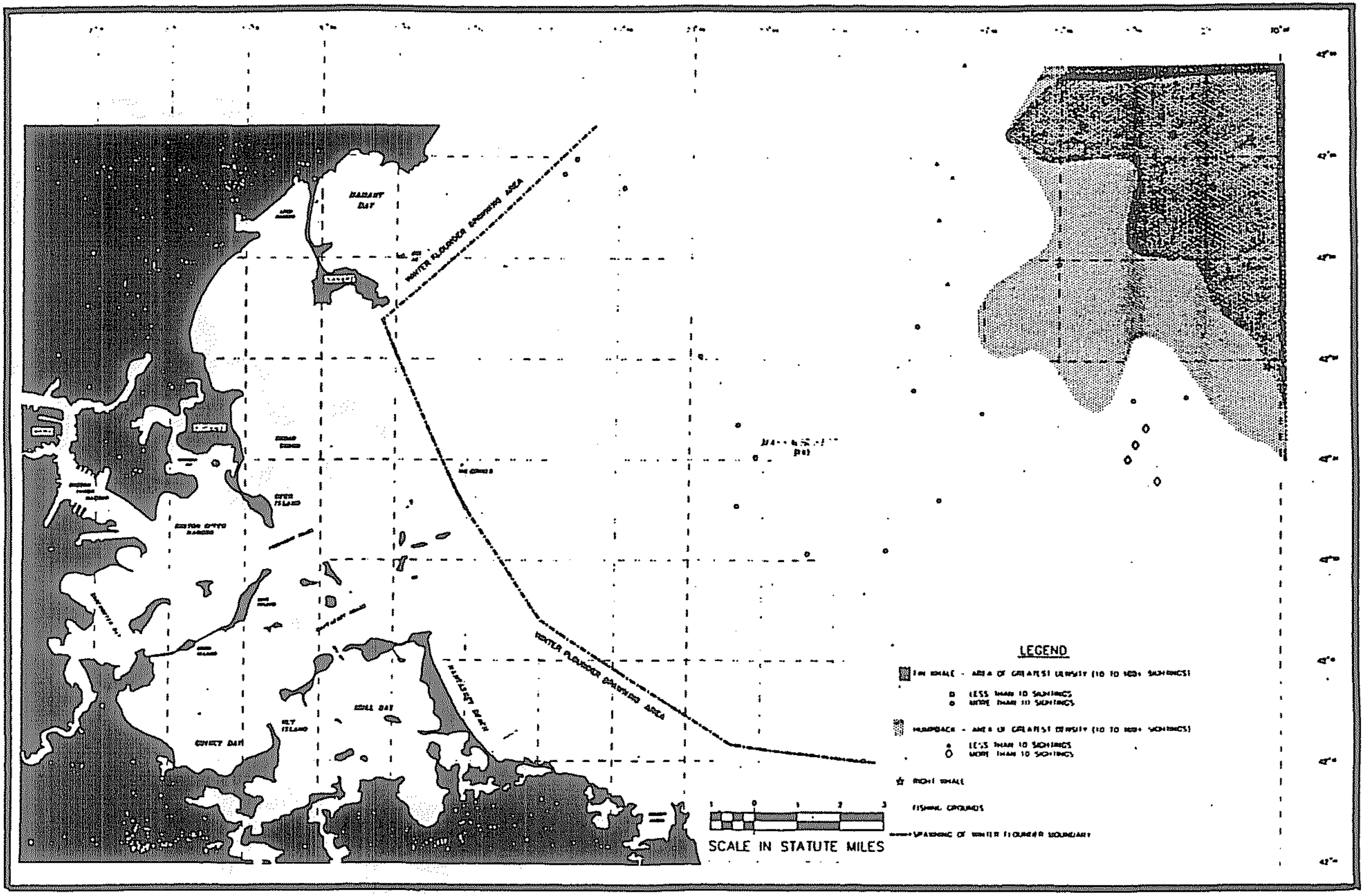
# RESOURCE/USE MAPS

# Fish and Shellfish Resources



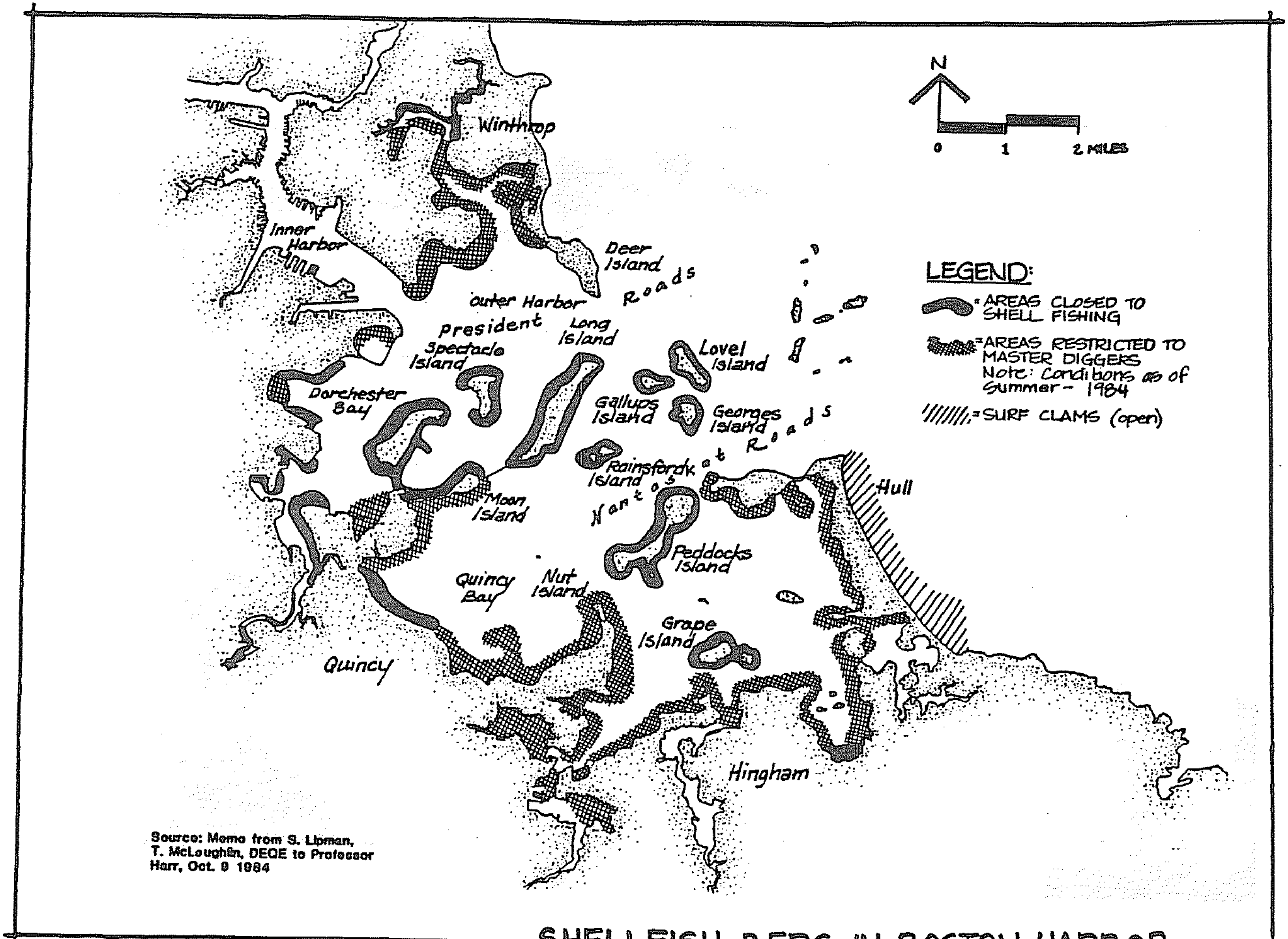

General movement of migratory fish species in the northwestern Atlantic Ocean.

Source: EPA, 1988.




Endangered species and fishing grounds.

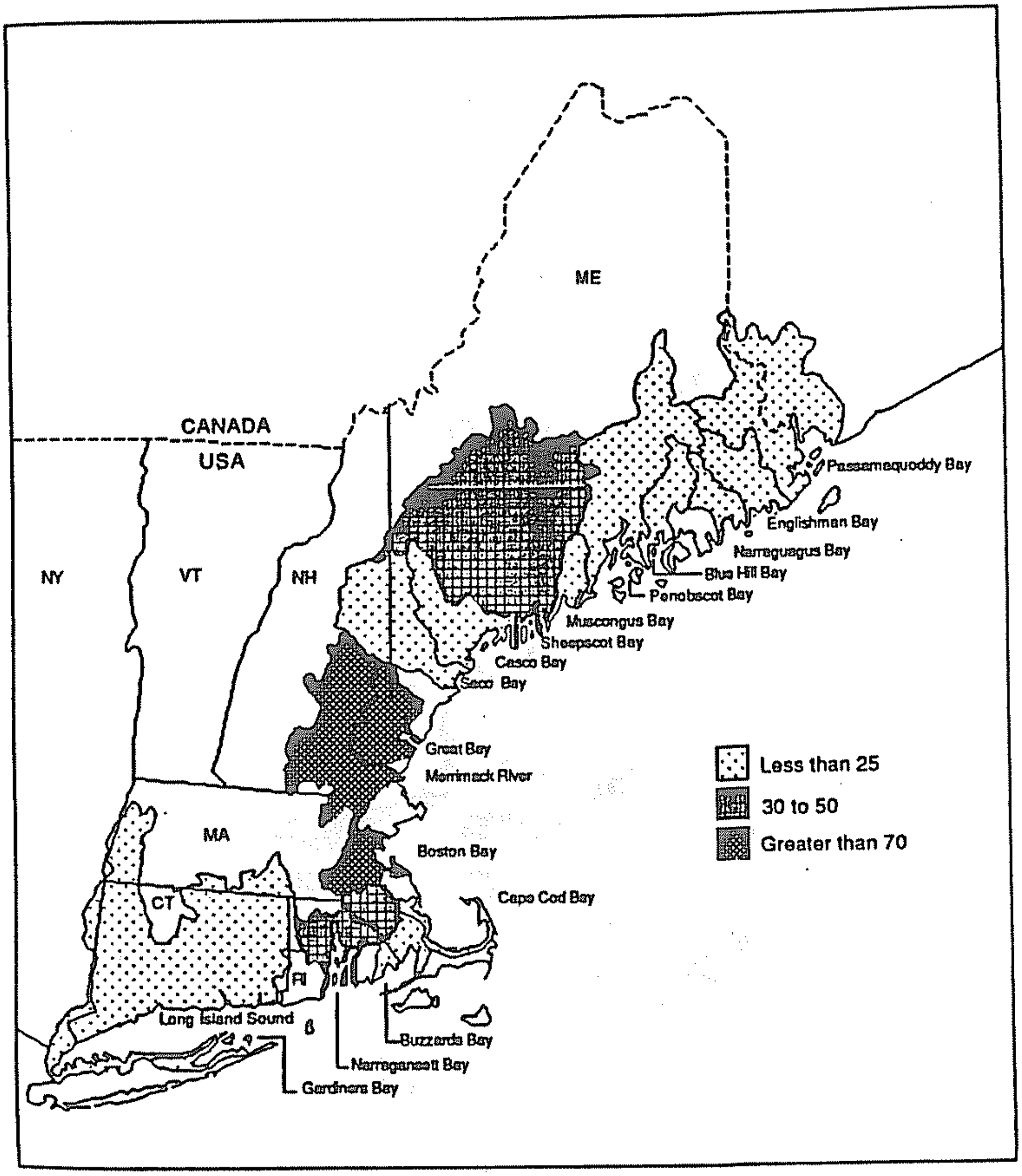
Source: MWRA, 1987.




SHELLFISH BEDS IN BOSTON HARBOR

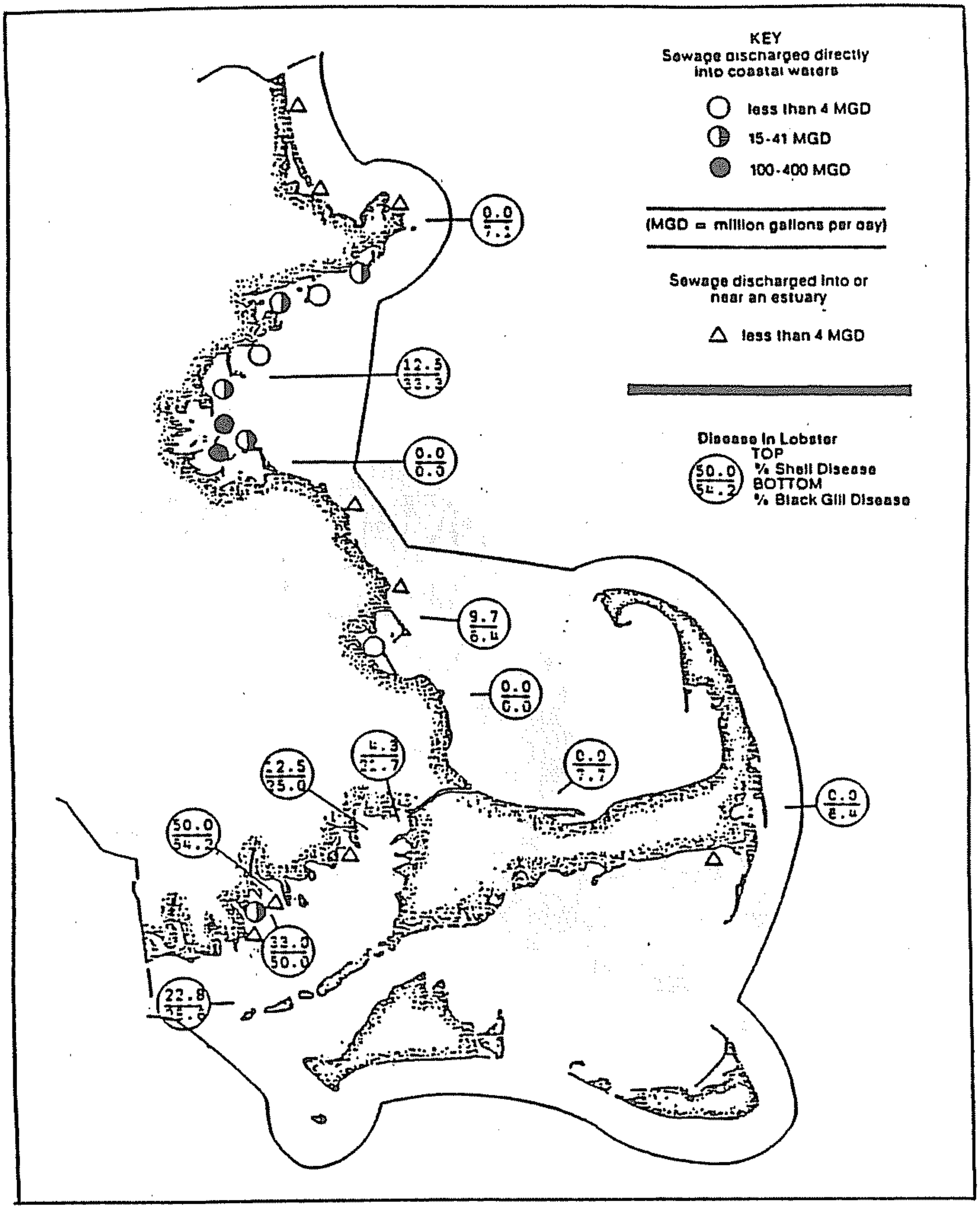
c.e. maguire, inc.

Source: EPA, 1985.




Percent of shellfish waters by estuary that are harvested limited.

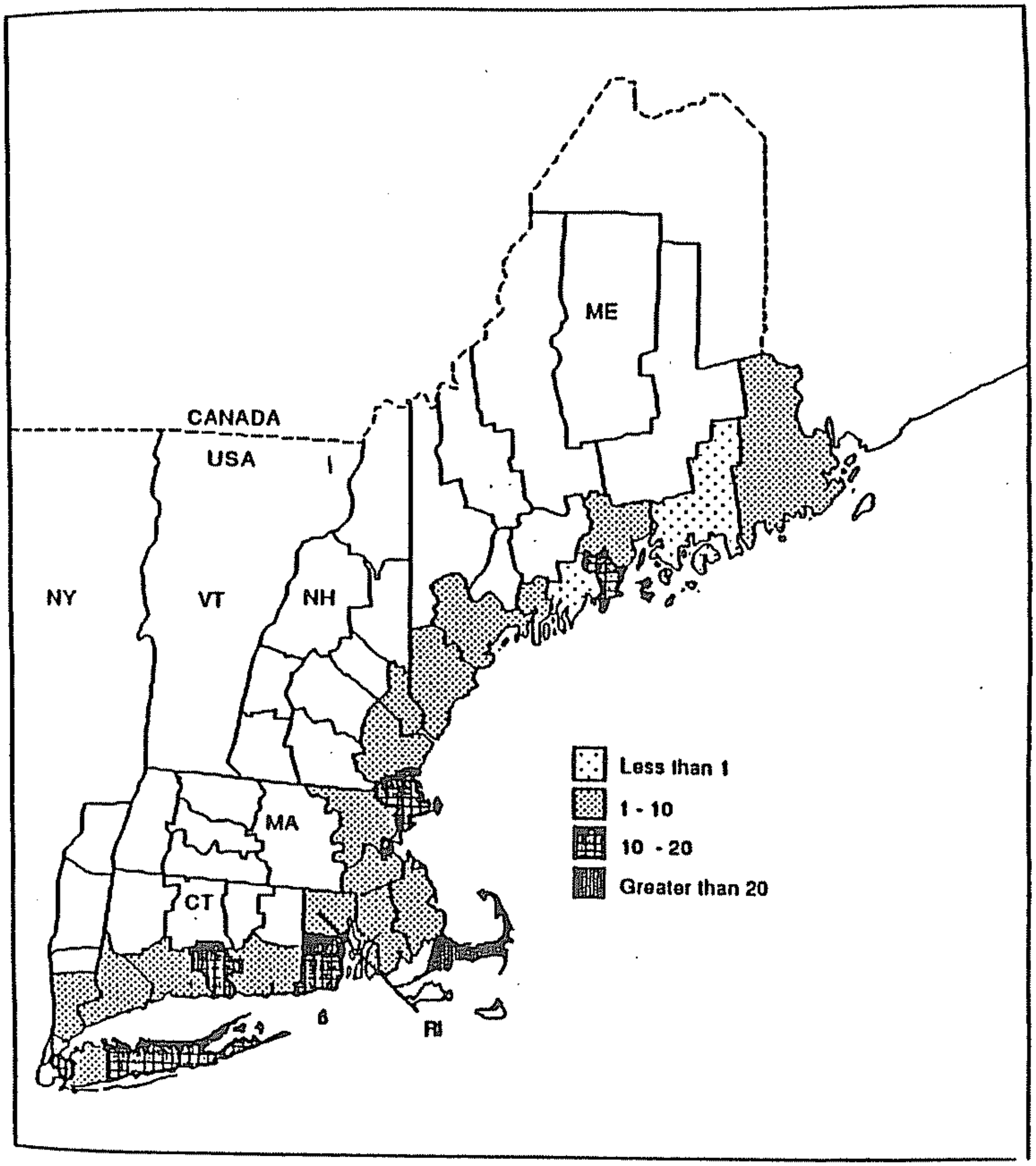
Source: EPA/NOAA, 1987.




Percent incidence of two diseases in lobster - 1983 and 1984.
Locations of major sewage outfalls.

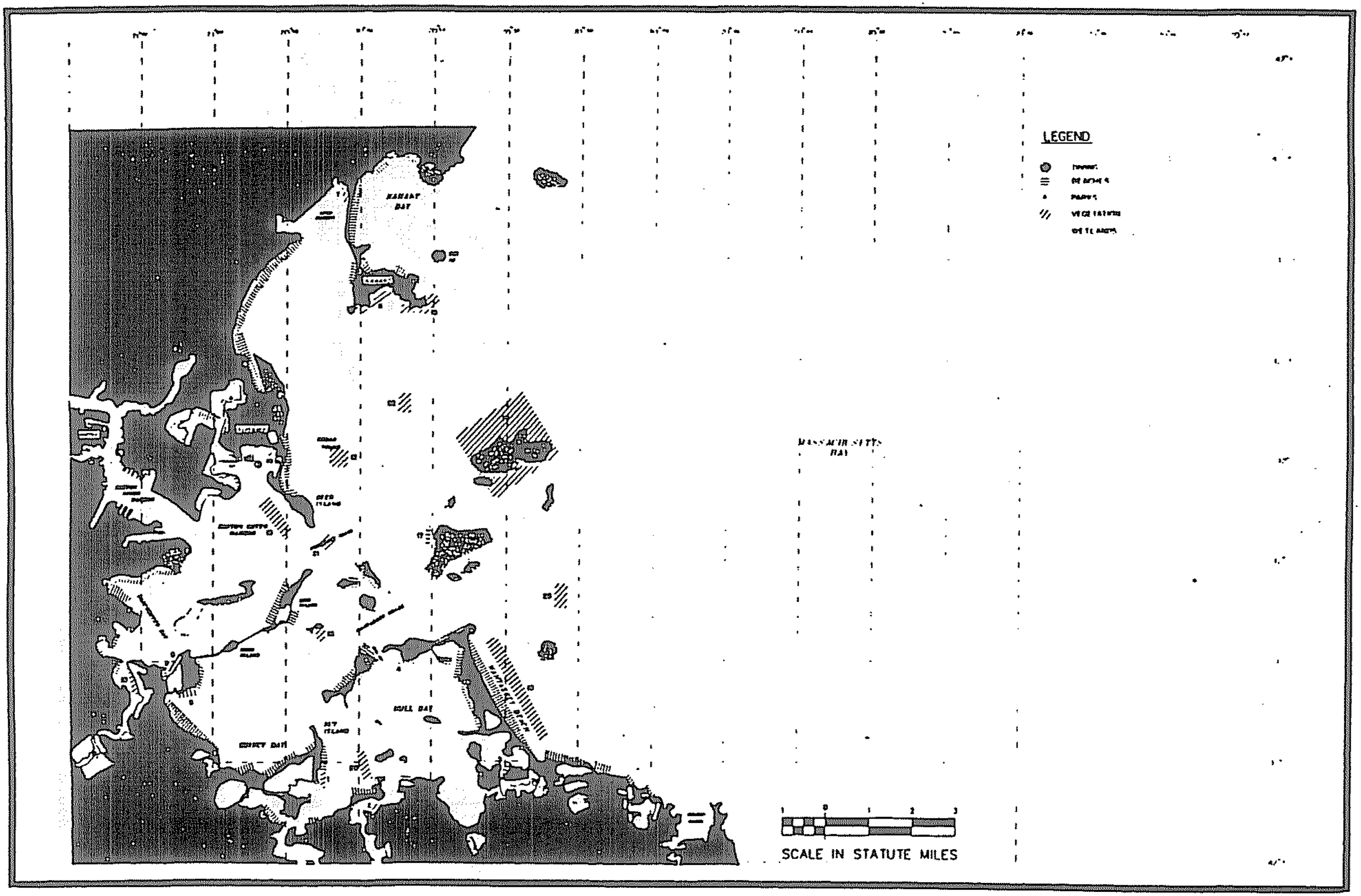
Source: Div. Marine Fisheries, 1985.

## Coastal Recreation



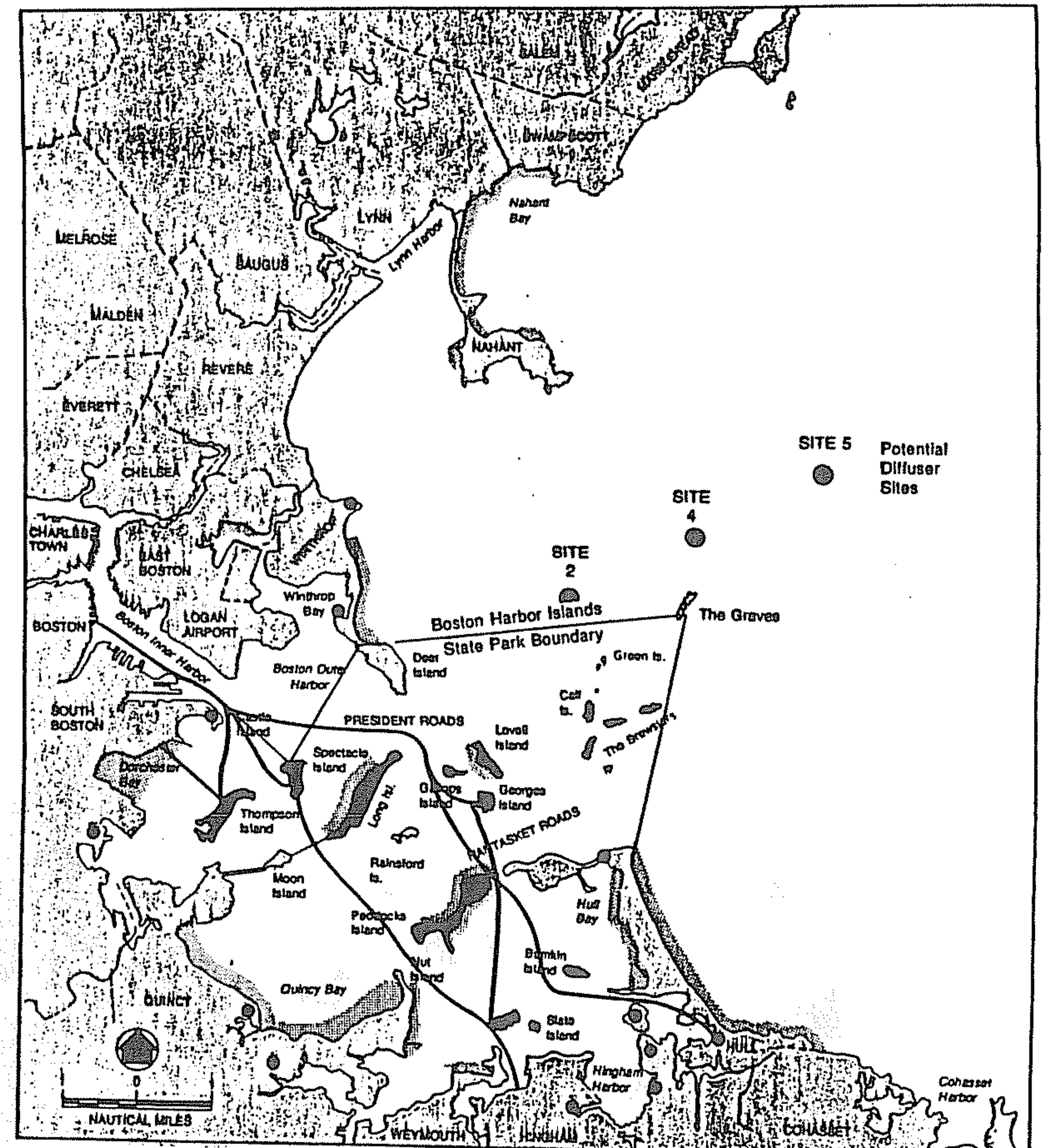

Percent of county land dedicated to public outdoor recreational areas.

Source: EPA/NOAA, 1987.




Recreational areas, submerged vegetation and wetlands.

Source: MWRA, 1987.




LEGEND

Recreational Beaches

Boston Harbor Island State Park

Other Parks

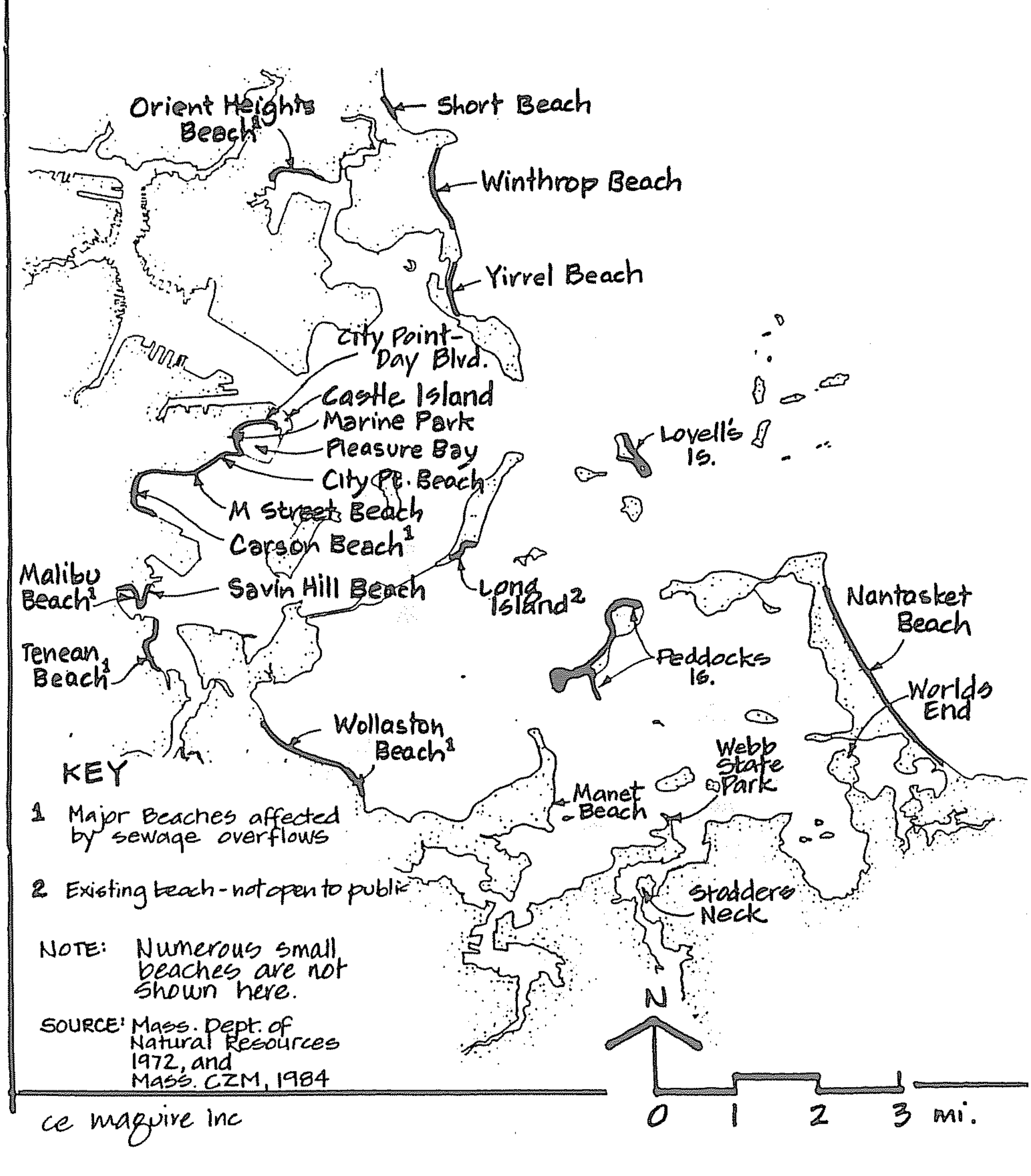
Harbor Islands Ferries (Proposed)

Source: Boston Harbor Islands State Park
1986 Master Plan – Mass. Dem
MDC, 1984
MWRA, VOL. V, App. L, 1987

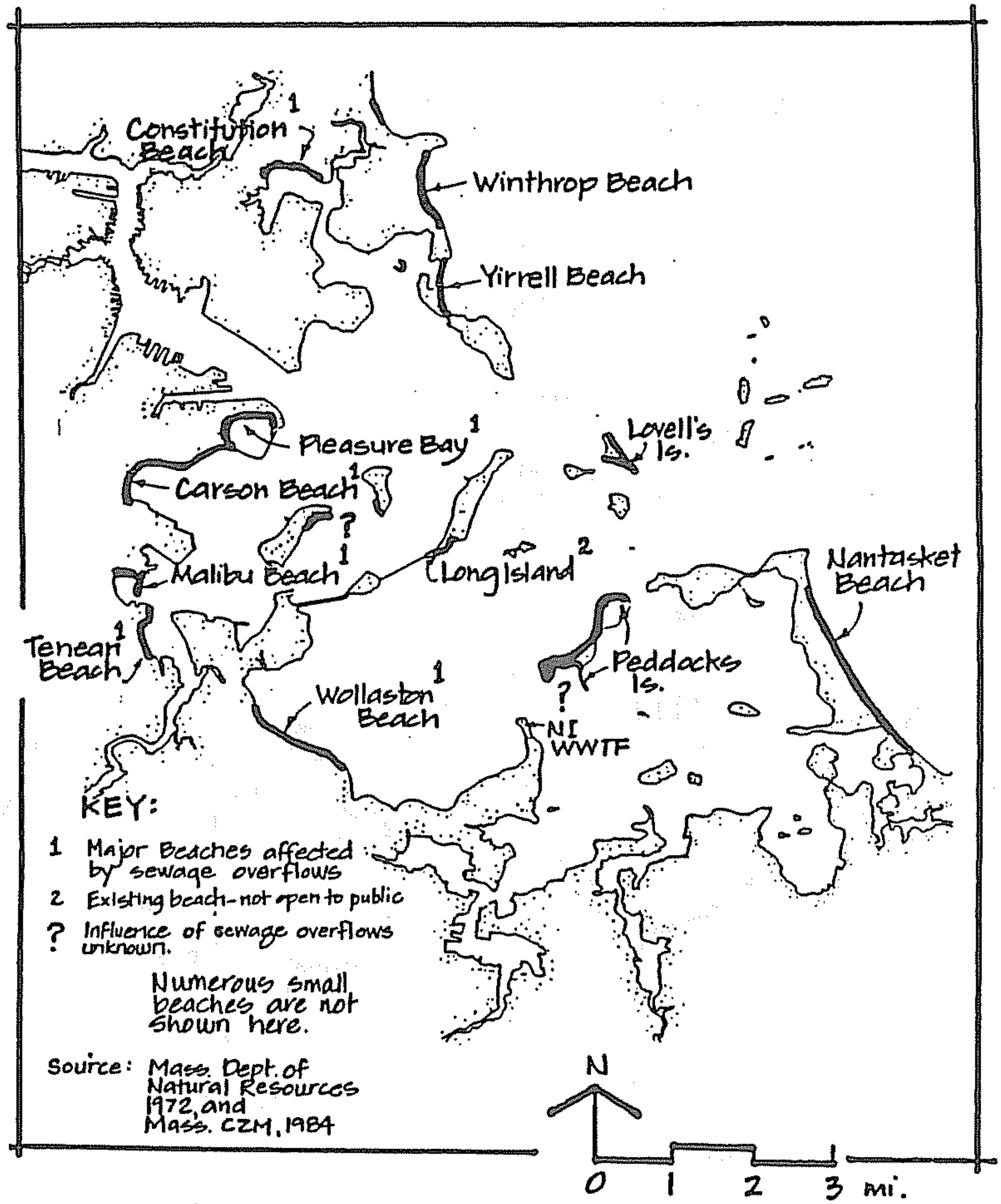
Beaches, shoreline parks, and island parks.

Source: EPA, 1988

## Location map: Shoreline recreational areas

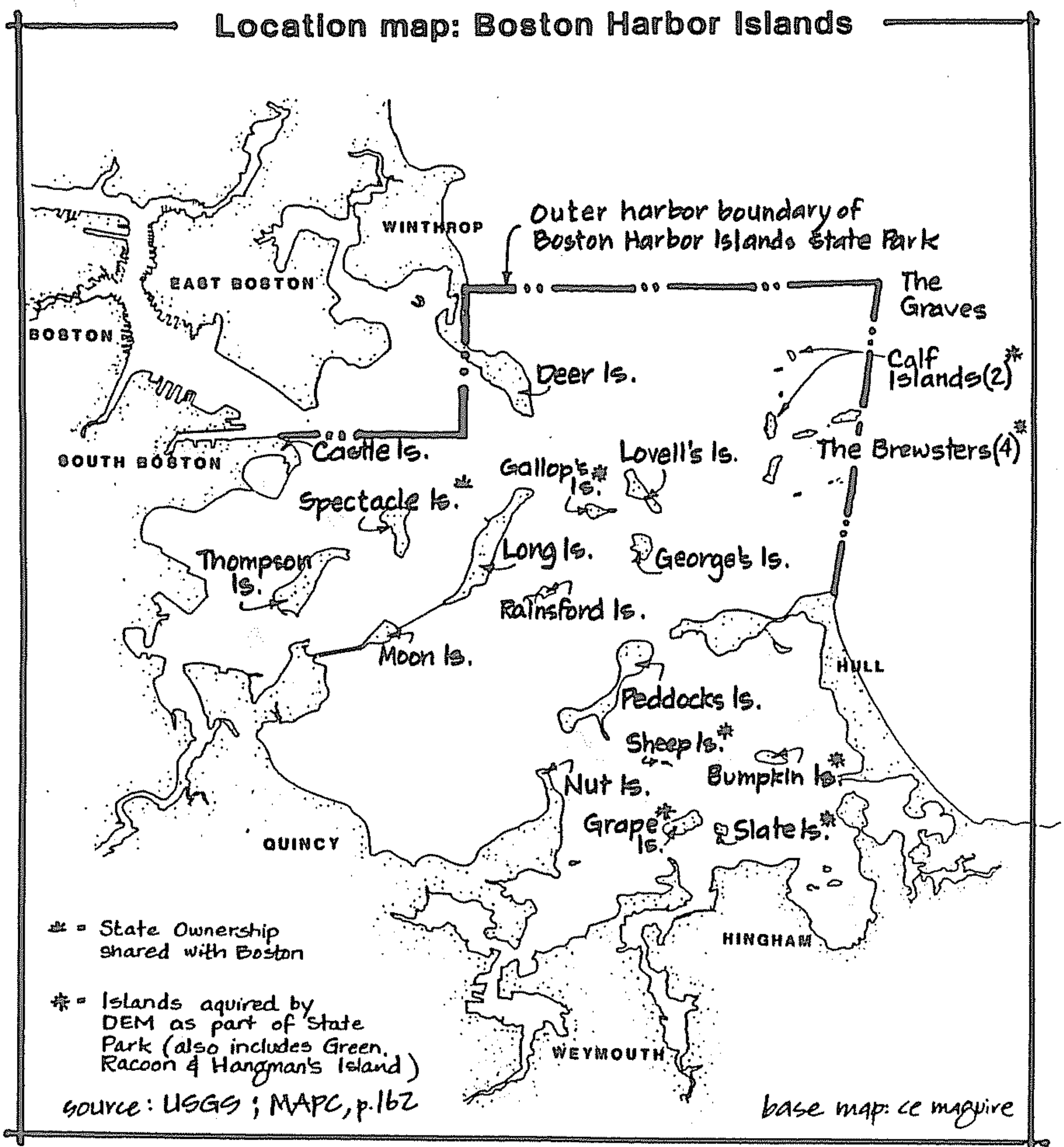



Source: EPA, 1985.



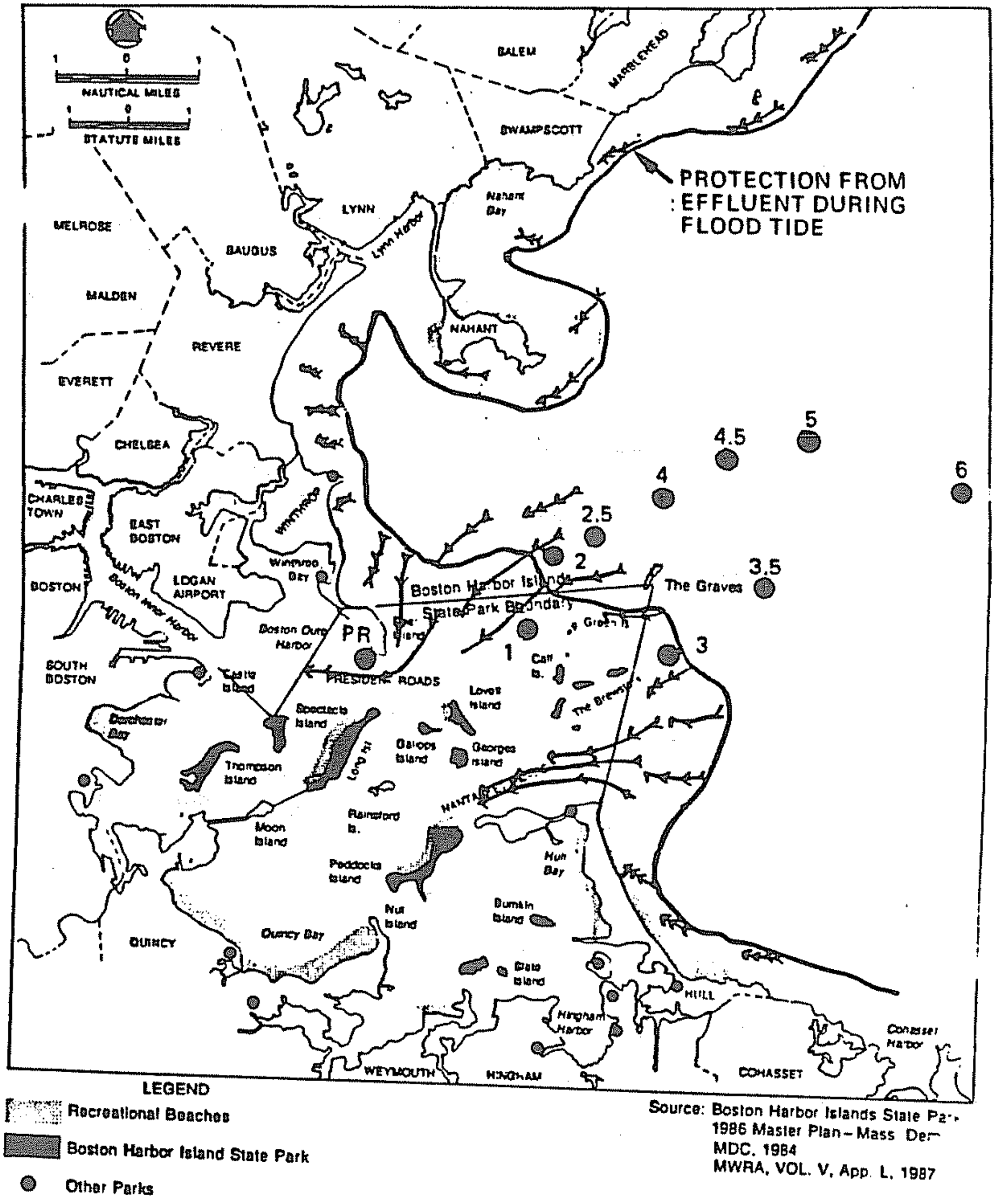

Major beaches of Boston Harbor.

Source: NOAA, 1987.




ce maguire Inc.

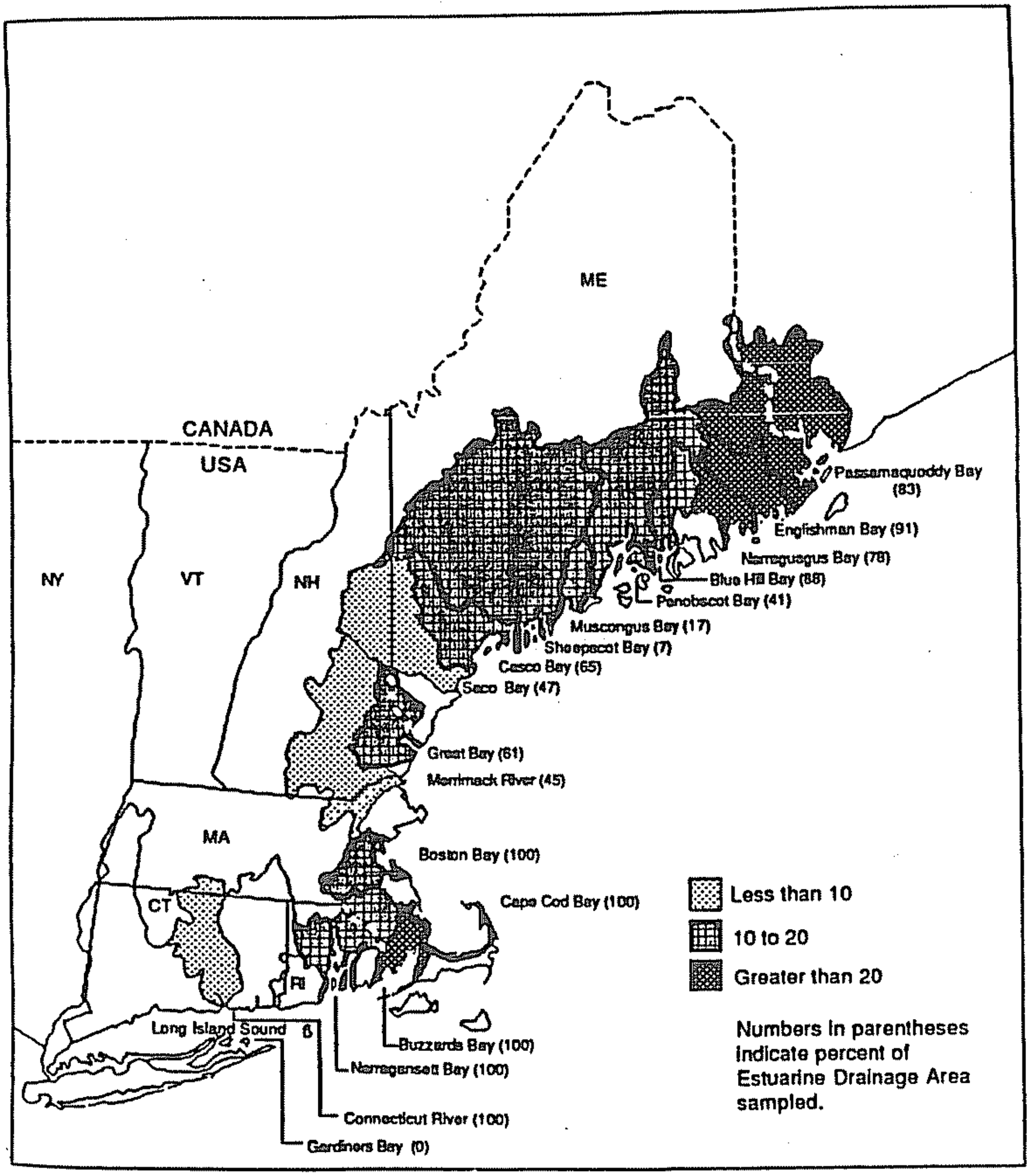
Source: EPA, 1985.




Fate of effluent particles during the flood portion of a tidal cycle and beaches, shoreline, parks and island parks.

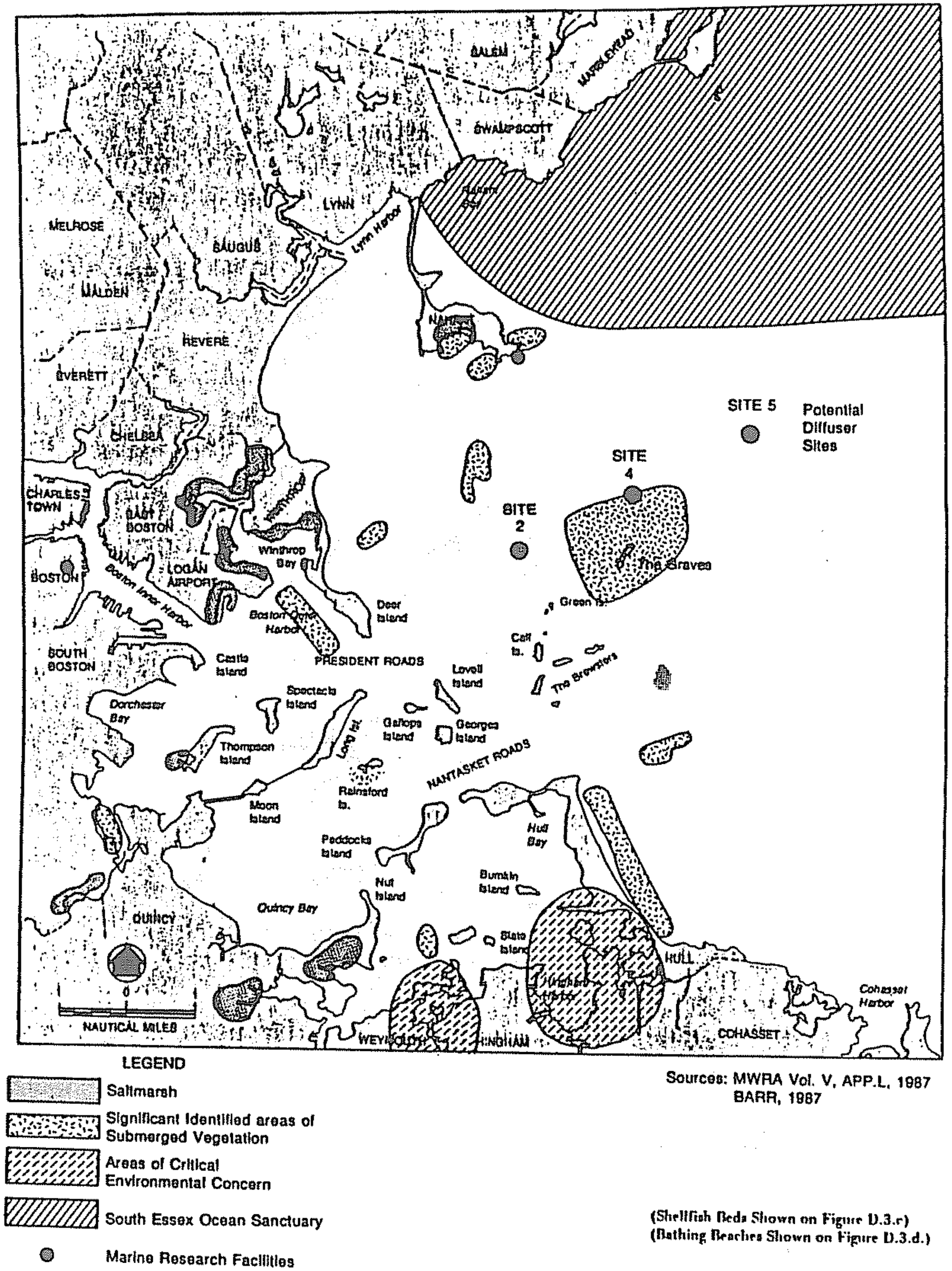
Source: EPA, 1988.

# Wetlands and Other Sensitive Areas



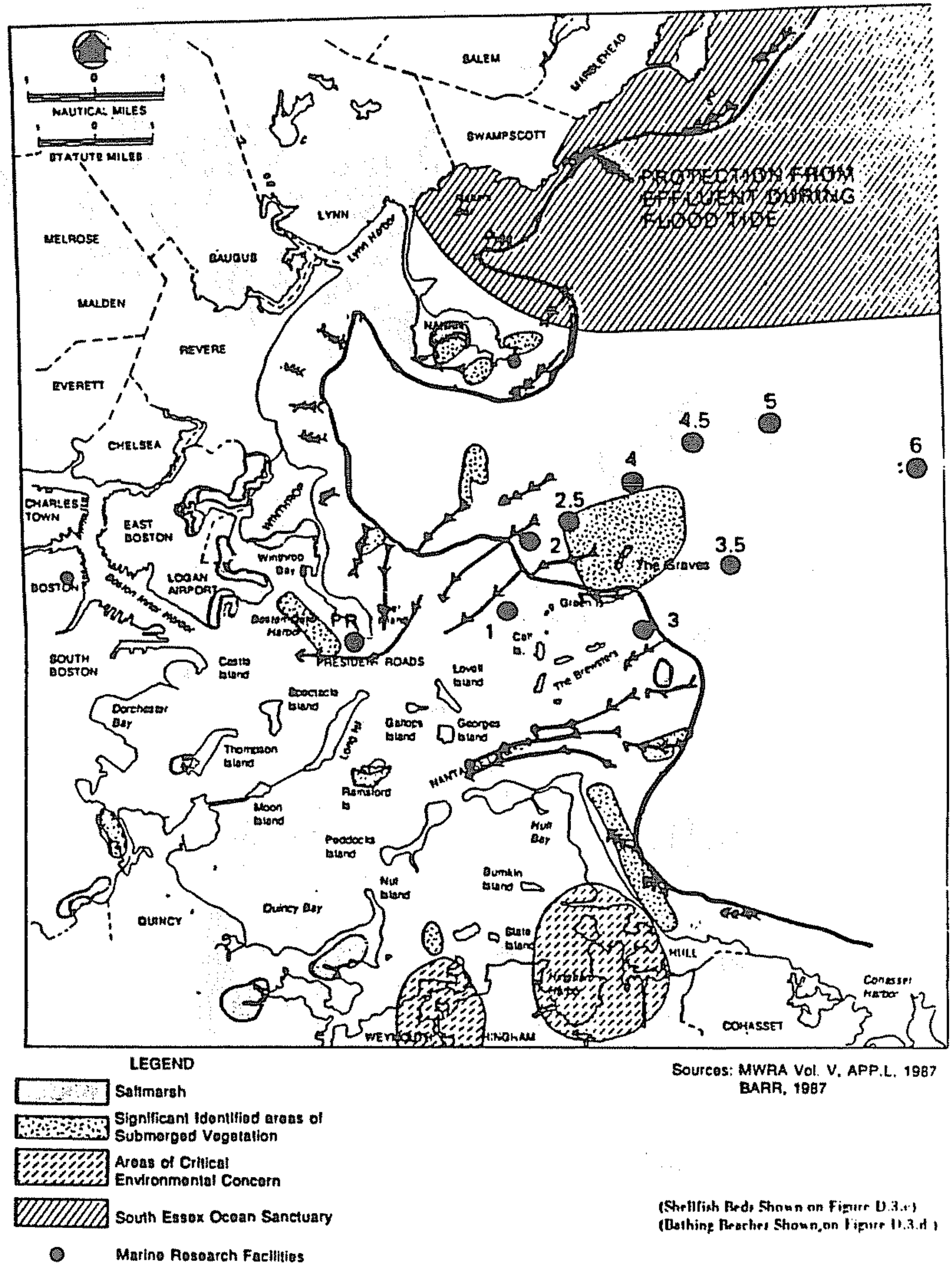

Percent of estuarine drainage area lands sampled that are wetlands.

Source: EPA/NOAA, 1987




Sensitive Harbor resources.

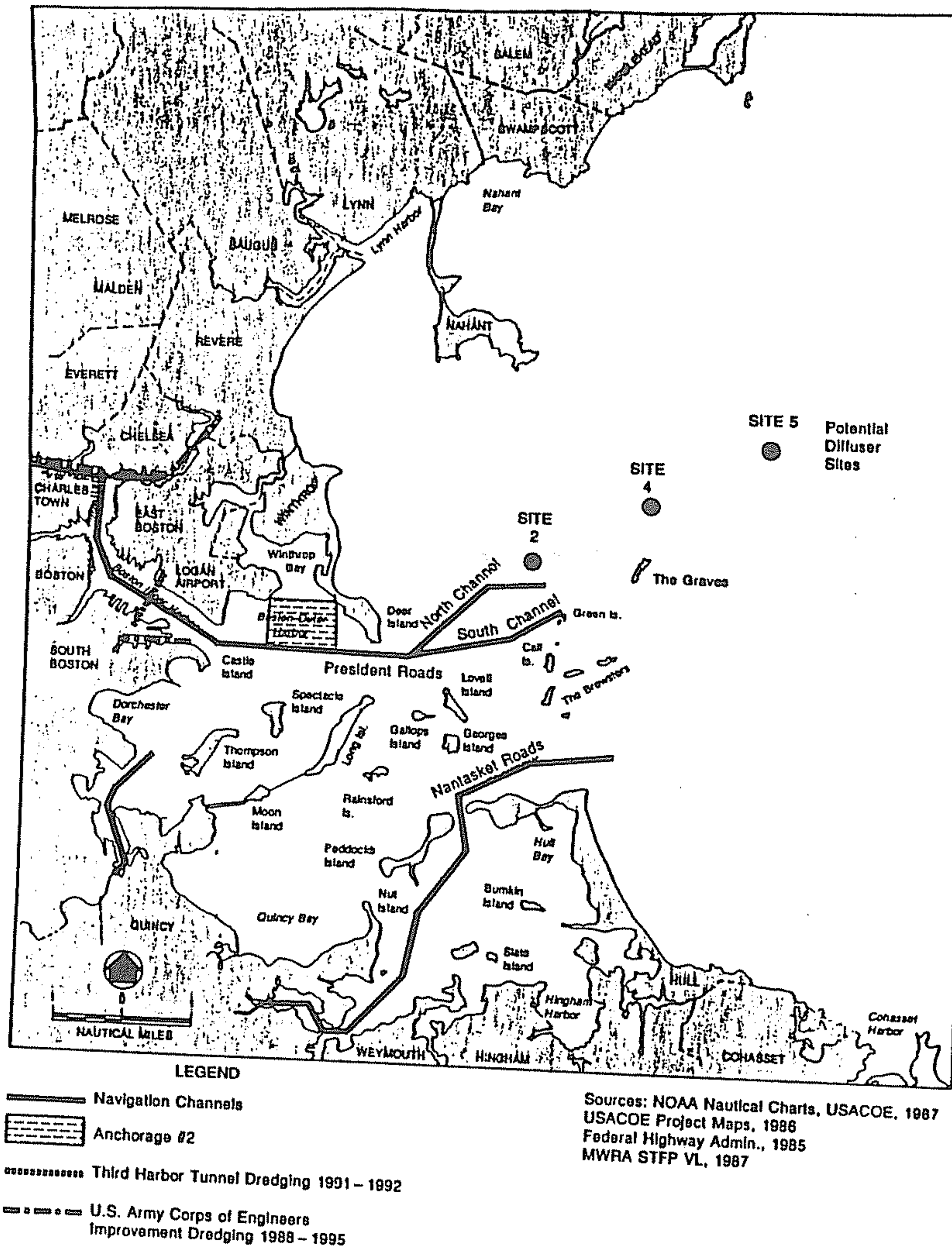
Source: EPA, 1988.




Fate of effluent particles during the flow portion of a tidal cycle and sensitive Harbor resources.

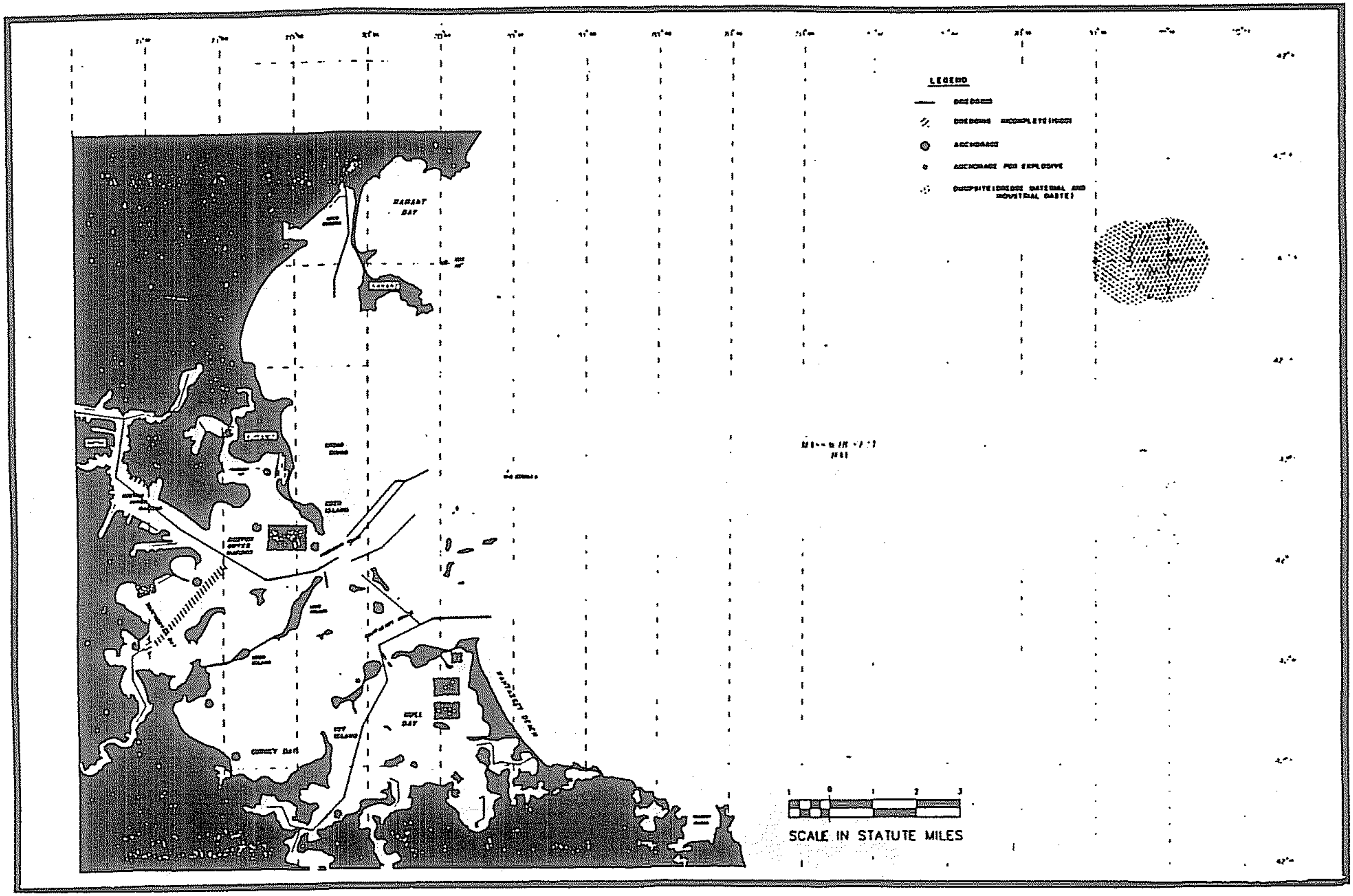
Source: EPA, 1988.

# Ports, Harbors and Transportation



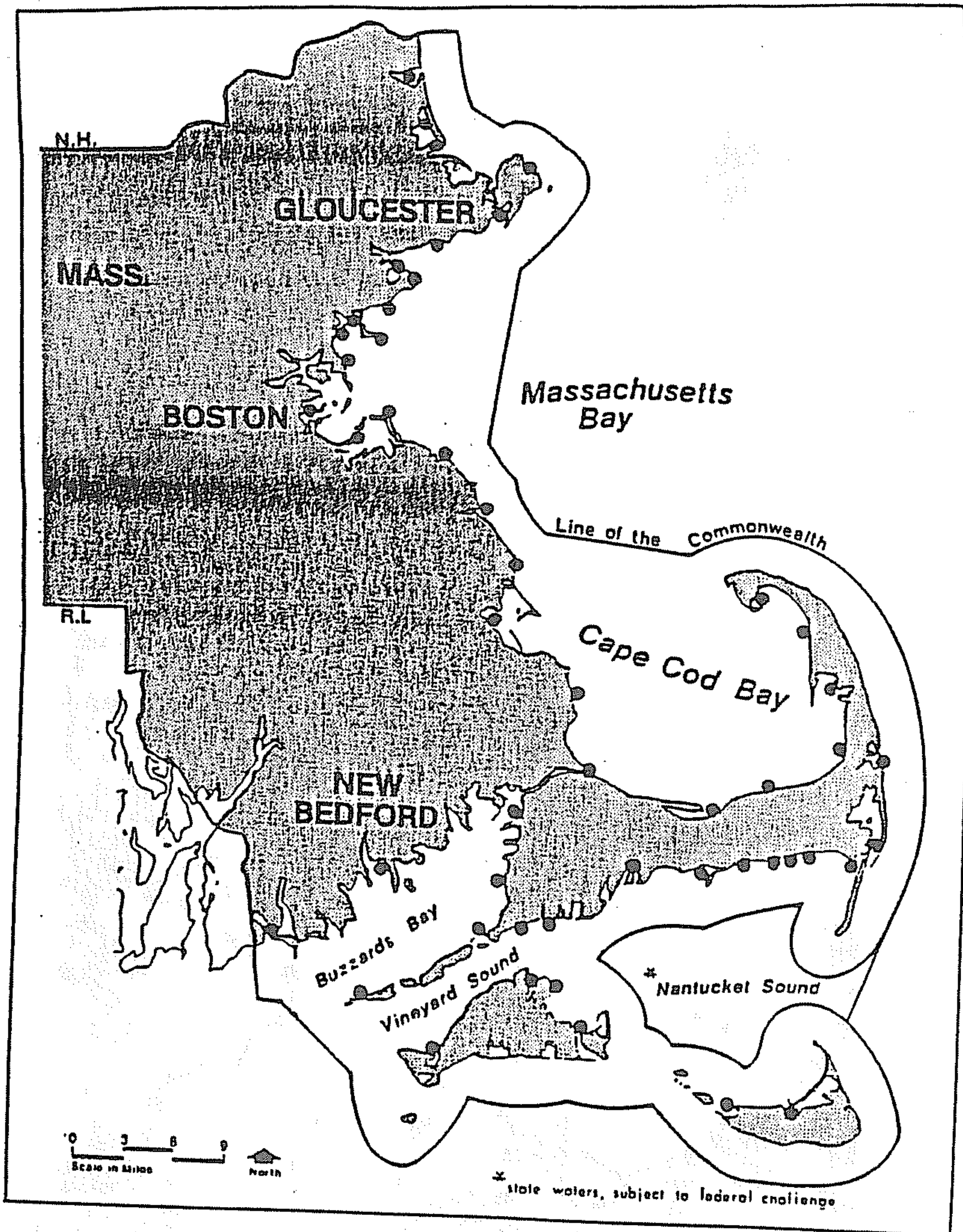

Commercial navigational resources.

Source: EPA, 1988.



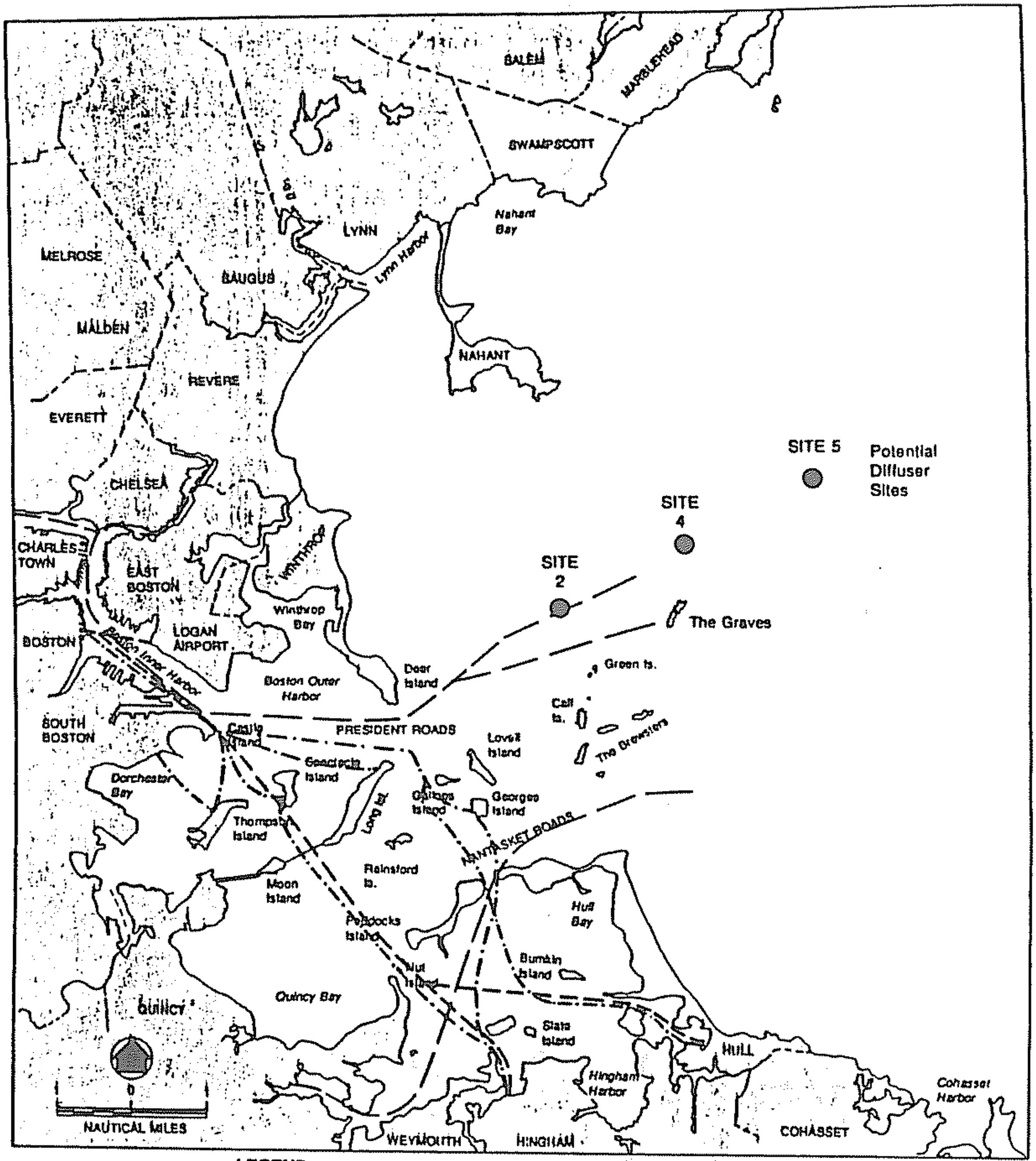

Navigational channels, anchorage sites, routine dredging sites, and disposal sites.

Source: MWRA, 1987.




Massachusetts territorial waters and commercially important ports and harbors.

Source: Div. of Marine Fisheries, 1985.




**LEGEND**

Commercial Vessels

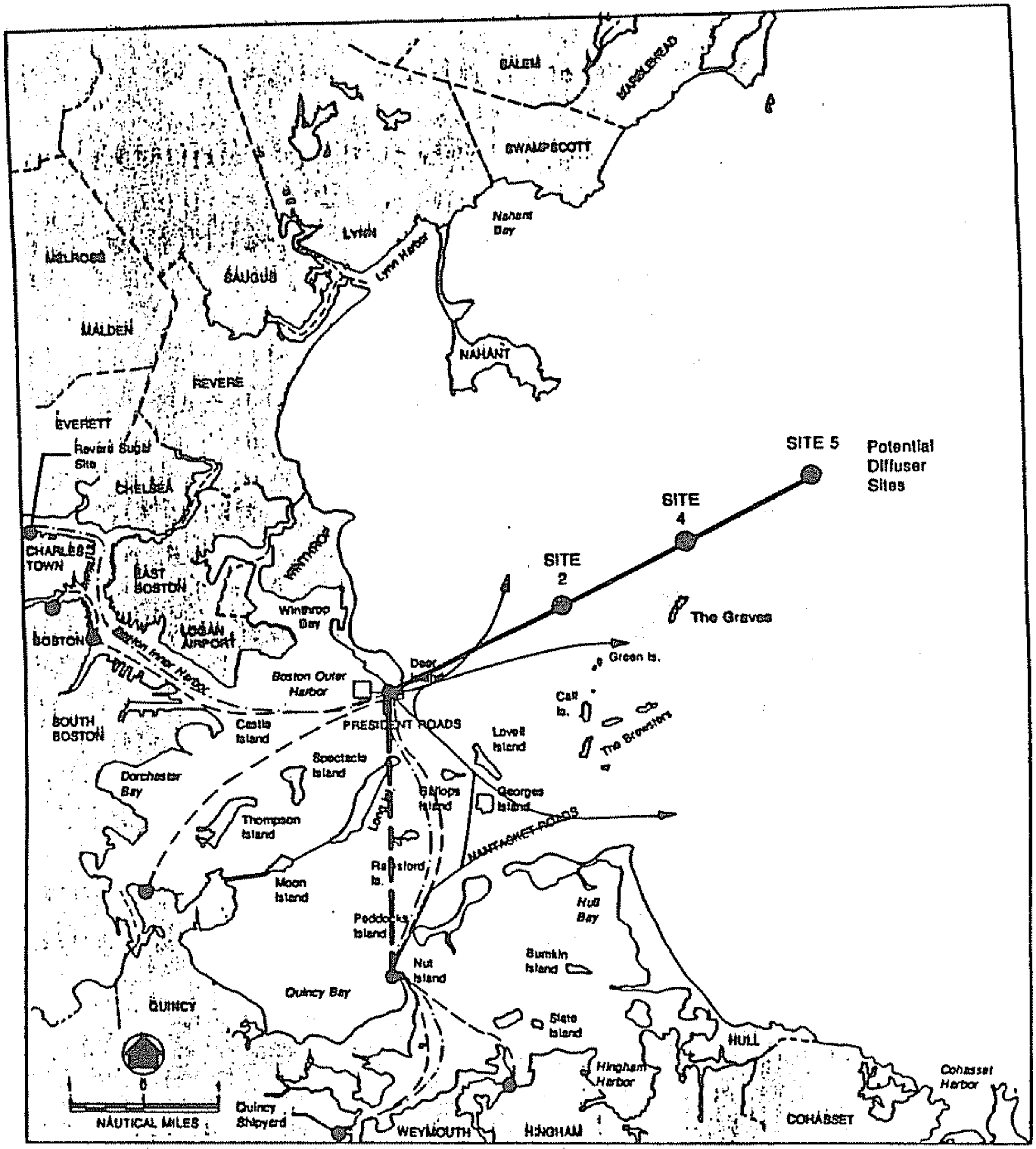
Boston Harbor Island State Park Ferries (Projected and Existing)

Commuter Service and Logan Shuttle

Source: Boston Harbor Islands State Park 1986 Master Plan, Mass Dept. of Environmental Management Massport, 1987 B, Boston Shipping Association, 1986

Typical commercial and passenger ship routes.

Source: EPA, 1988.

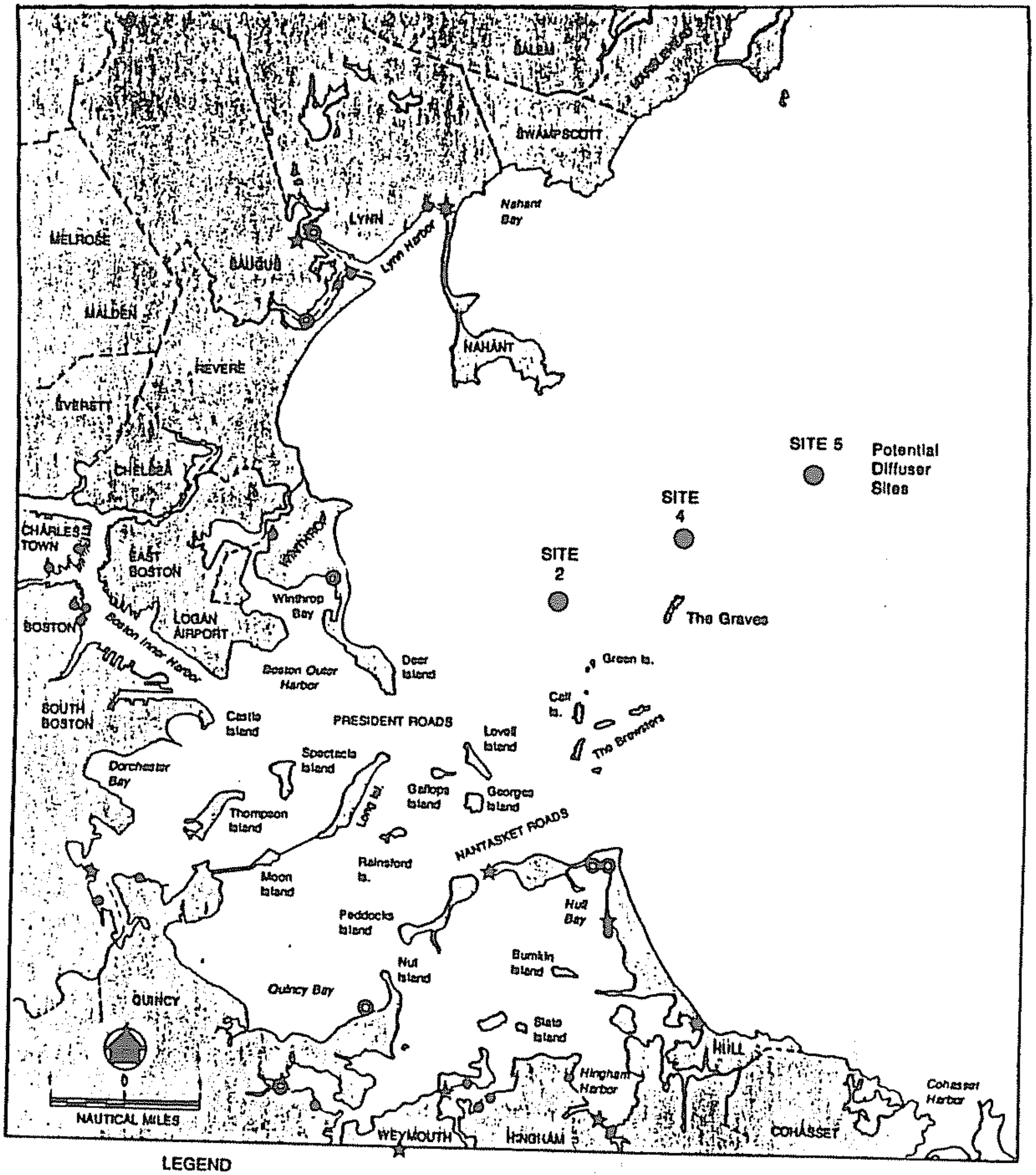



| CARGO | TYPICAL VESSELS | ROUTE SYMBOLS | OTHER SYMBOLS |
|---|---|---|---|
| Bulk Sand, Gravel, Cement | 600 Or 3000 Ton Barges | | Piers |
| Construction and Operations Equipment and Supplies, Excavated Materials | RO/RO 42 Truck Barge<br>RO/RO 12 Truck Ferry<br>RO/RO 6 Truck Supply Boat | | Barge Mooring Area<br>Inter-Island Conveyance |
| Personnel | 150 Person Ferry<br>55 Person Ferry | | Effluent Outfall |

Sources: MWRA STFP Vol. VGG, Vol. VII, Vol. IIIK, 1987.
MWRA Revere, 1987.
MWRA WTFP Vol. 1, Vol. 9, 1987.

Water transports for wastewater treatment related facilities construction/ operation, 1990-1995.

Source: EPA, 1988.



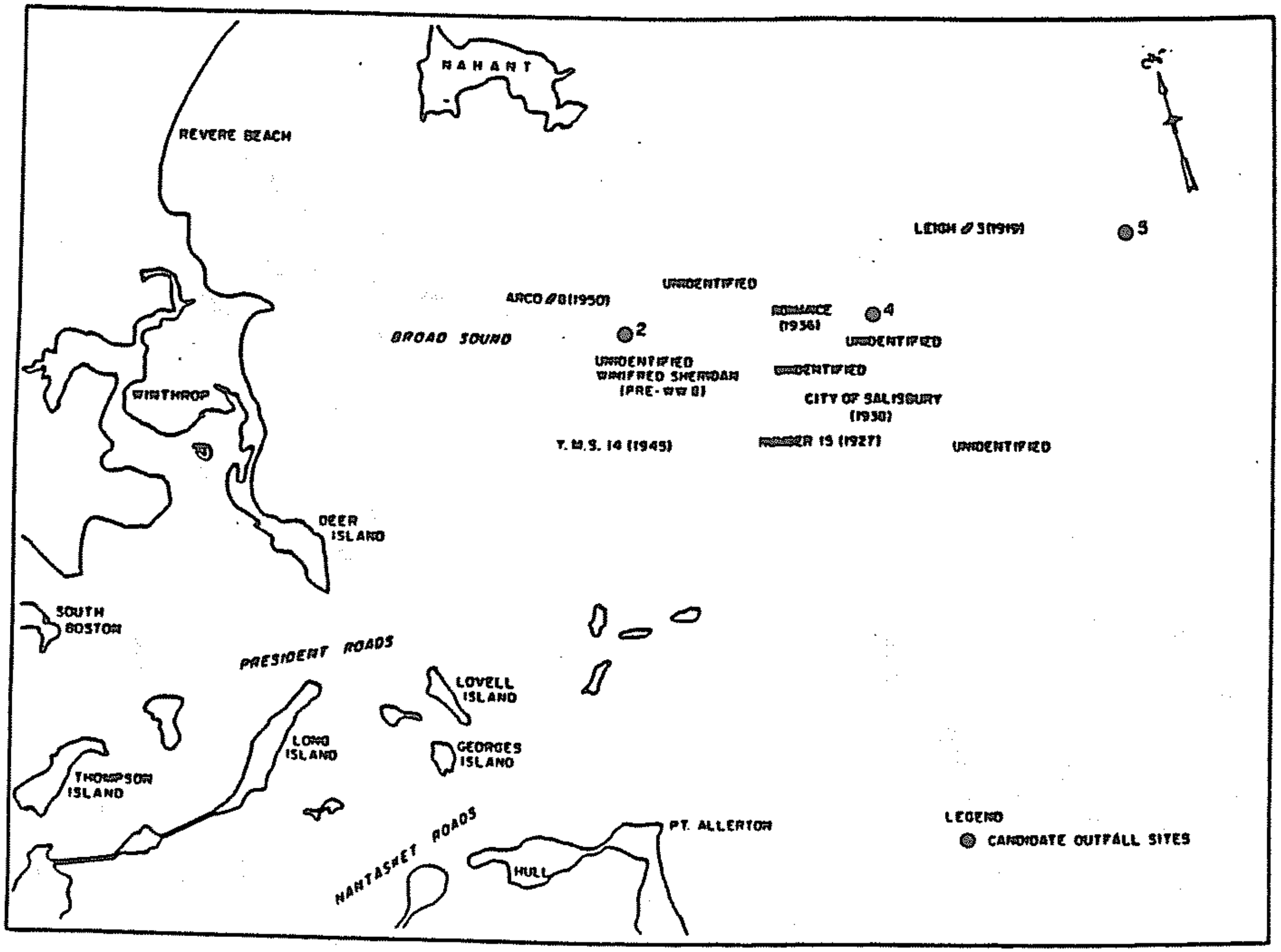

LEGEND

- Marinas w/more than 50 Slips or Moorings
- ☆ Boat Ramps
- Facilities w/more than 50 Slips or Moorings and Boat Ramps

Source: Boating Almanac 1986

Major boating public access point.

Source: EPA, 1988.




Shipwrecks within 1.5 miles of candidate outfall sites
(Ship names indicate approximate locations).

Source: EPA, 1988.

Appendix III: References


DMF (Massachusetts Division of Marine Fisheries), 1985. Massachusetts Marine Fisheries: Assessment at Mid-Decade; Economic, Environmental and Management Problems Facing Massachusetts' Commercial and Recreational Marine Fisheries. Boston, MA.

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