Living resources of Buzzards Bay: Synthesis reports produced for the 1991 Comprehensive Conservation and Management Plan, 2013 Redux

Joseph E. Costa, editor

Buzzards Bay National Estuary Program Technical Report

Massachusetts Coastal Zone Management

October 18, 2013

Acknowledgements

Vicki Gibson helped edit the original reports in 1990. Joseph E. Costa reedited, and combined the reports into this redux volume with a consistent format and layout. Additional text editing by Tracy Warncke and Sarah Williams.

Foreword

Between 1989 and 1990, the Buzzards Bay National Estuary Program (then the Buzzards Bay Project), hired scientists to prepare reports synthesizing the then current knowledge of the state of living resources in Buzzards Bay. We received these living resources reports before we released the draft 1991 Buzzards Bay Comprehensive Conservation and Management Plan (CCMP).

The Buzzards Bay National Estuary Program accepted these reports, and information contained in them was included in the CCMP, however they were never publicly distributed. The original documents were submitted in manuscript form with appended figures and tables. At the time, our intent to consolidate them into a combined report in an easy-to-read layout. This effort was undertaken but not completed because of more pressing needs at the time.

With the 2013 update of the Buzzards Bay CCMP, the Buzzards Bay National Estuary Program decided to re-issue the documents and make them publicly available online because of the useful information, data, and references contained in the reports. Some of the reports contain data or information not previously published, or presented in a way to make them still relevant today.

This redux volume includes the six original reports with editing for spelling, grammar, and style. They were laid out in a consistent format, and a few graphics were redrawn or added. We made no effort to update the information. Thus, these documents stand as the authors understanding of the living resources of Buzzards Bay, and the threats they faced, as characterized in 1989-1990.

Joseph E. Costa, PhD
Executive Director
Buzzards Bay National Estuary Program

Suggested Citation

To avoid confusion about the date of these publications, we suggest the following citation format should they be cited, as in Poole (1990/2013), and listed as follows:

Giblin, A., and K. Foreman. 1990. The Habitats of Buzzards Bay. In J. E. Costa [ed.], Living Resources of Buzzards Bay: Synthesis reports produced for the 1991 Comprehensive Conservation and Management Plan, 2013 Redux, Buzzards Bay National Estuary Program Technical Report, Massachusetts Coastal Zone Management, October 18, 2013. 98 pp.

Grice, F. 1990. The Buzzards Bay Lobster Resource and Fishery. In J. E. Costa [ed.], Living Resources of Buzzards Bay: Synthesis reports produced for the 1991 Comprehensive Conservation and Management Plan, 2013 Redux, Buzzards Bay National Estuary Program Technical Report, Massachusetts Coastal Zone Management, October 18, 2013. 98 pp.

Grice, F. 1990. The Buzzards Bay Shellfish Resource and Fishery. In J. E. Costa [ed.], Living Resources of Buzzards Bay: Synthesis reports produced for the 1991 Comprehensive Conservation Management Plan, 2013 Redux, Buzzards Bay National Estuary Program Technical Report, Massachusetts Coastal Zone Management, October 18, 2013. 98 pp.

Grice, F. 1990. The Finfish Resources of Buzzards Bay. In J. E. Costa [ed.], Living Resources of Buzzards Bay: Synthesis reports produced for the 1991 Comprehensive Conservation and Management Plan, 2013 Redux, Buzzards Bay National Estuary Program Technical Report, Massachusetts Coastal Zone Management, October 18, 2013. 98 pp.

Payne, P. M., C. Coogan, F. Wenzel, M. A. Buehler, and A. L. Hankin. 1991. Status and Assessment of the Marine Mammal and Marine Turtle Species of Buzzards Bay, Massachusetts: An Historical and Present Overview. In J. E. Costa [ed.], Living Resources of Buzzards Bay: Synthesis reports produced for the 1991 Comprehensive Conservation and Management Plan, 2013 Redux, Buzzards Bay National Estuary Program Technical Report, Massachusetts Coastal Zone Management, October 18, 2013. 98 pp.

Poole. A. 1990. Waterbirds of Buzzards Bay. In J. E. Costa [ed.], Living Resources of Buzzards Bay: Synthesis reports produced for the 1991 Comprehensive Conservation and Management Plan, 2013 Redux, Buzzards Bay National Estuary Program Technical Report, Massachusetts Coastal Zone Management, October 18, 2013. 98 pp.

Table of Contents

List of Figures

List of Tables

1. Habitats of Buzzards Bay

By Anne Giblin[1] and Ken Foreman[2]

Introduction

Habitats and Communities Defined

In this report, we will describe the major habitats found in the marine and estuarine waters of Buzzards Bay, Massachusetts, and where possible, compare those habitats to similar habitats found in other bays and estuaries. In this report, we make a clear distinction between the terms habitat and community. The habitat is the physical environment in which the organism lives. Specific temperature, salinity, hydrographic, or sedimentary regimes may characterize these habitats. The assemblage of species found within a given habitat constitutes the community. Together, the biotic community and the physical habitat comprise the "ecosystem." While these may seem obvious definitions, attempts by ecologists to delineate precisely the bounds of ecosystems and habitats, and the properties of communities have engendered considerable debate (May, 1984; O'Neill et al., 1986; Schoener, 1986).

The distinction between habitat and community is further blurred by the tendency of ecologists to name habitats after the dominant species usually present (e.g. eelgrass community) or, conversely, to name communities by the habitat which they occupy (e.g. "rocky intertidal" community). Why should managers care about these semantic nuances? Naming communities after habitats and vice-versa gives the misleading impression that particular communities of organisms are fixed in space and time; somehow permanently associated with a given habitat. In fact, the same habitat may support very different communities due to subtle changes in physical/chemical factors, pollution, disease, or species introductions. For example, the seagrass, *Zostera marina*, which has traditionally been the predominant species in shallow embayments along the shore of Buzzards Bay, Vineyard and Nantucket Sound, nearly disappeared in the 1930s due to an epidemic. As a result, the seagrass community was temporarily replaced by a community more typical of shallow unvegetated sediments.

Because all ecosystems are really made up of a complex mosaic of subhabitats, each grading into the other, it is difficult to precisely define distinct habitats. For example, salt marshes include 1) upland areas colonized by a suite of terrestrial shrubs; 2) an intermittently flooded zone in which different halophytic plants grow depending on tidal elevation; and 3) unvegetated mud or sand bottom creeks and pools occupied by fauna and flora of tidal flats. Bearing in mind that no classification will be perfect, we have attempted to divide the habitats of Buzzards Bay using physical criteria of location, substrate characteristics and tidal regime (Figure 1-1).

Overview of Buzzards Bay Habitats

First, we distinguish nearshore habitats, defined as the areas shallower than 3 meters, from those found in the open bay. In addition to the actual shoreline along the open bay, nearshore environments include tidal rivers, coastal ponds, and embayments that fringe the coast. Separate habitats within each of these environments can be classified by bottom type (rock, mud, sand, or peat) and tidal regime. These include rocky shores, barrier beaches, salt marshes, tidal mud and sand flats, and eelgrass beds. Only a small area of Buzzards Bay is covered by rocky shores. Barrier beaches and dunes, on the other hand, are widespread. They form as sandy sediments accumulate above the high tide line at the entrance to embayments and at the seaward edge of salt marshes. We define salt marshes as intermittently flooded, intertidal sandy or peaty areas that support luxuriant growth of *Spartina* and other halophytic plants. Eelgrass beds are found in shallow subtidal habitats where adequate light penetrates the water column to the bottom. Barrier beaches, salt marshes, tidal flats, and eelgrass beds are frequently found together in tidal rivers and coastal embayments. We have boxed them in Figure 1-1 to emphasize this.

Water column and subtidal benthic habitats occur within the open bay. The water column is, in terms of volume, the largest habitat in the bay and supports a diverse plankton community. In the subtidal benthic habitats, the nature of the bottom (i.e. whether it is composed mainly of silt and clay, sand or gravel) is the basic characteristic of these habitats that determines the type of community present. Silt-clay (<62 pm grain size) sediments support an assemblage of species dominated by small molluscs and polychaete worms (the so-called *Nephthys-Nucula* community). Coarser, sandy sediments support a community composed mainly of amphipods (the *Ampelsicid* community). The gravel community has not been as well studied but is dominated by filter feeding molluscs.

We will present a brief review of the areal extent, physical, and chemical characteristics of each of these habitats, and discuss the major species present in the communities that typically occupy them. Whenever possible we also present

---

[1] Ecosystem Center, Marine Biological Laboratory. Accepted September 26, 1990.

[2] Boston University Marine Program, Marine Biological Laboratory

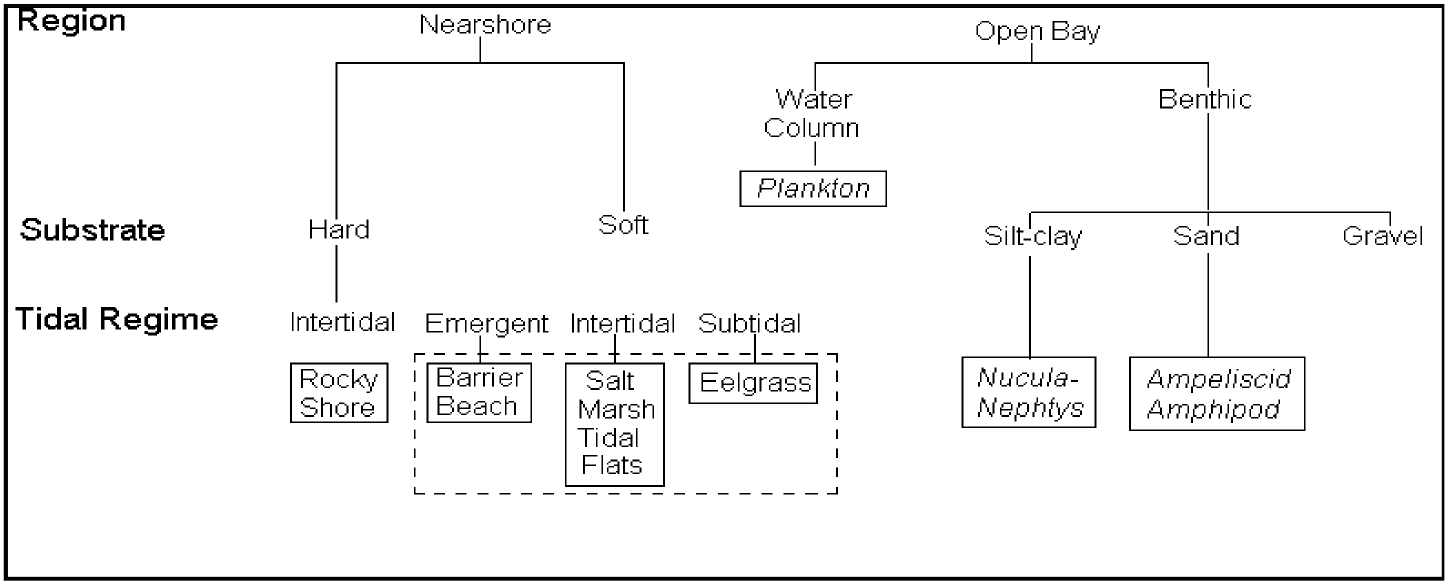


Figure 1-1. Classification of biological communities in Buzzards Bay.

The soft substrate communities in the nearshore region are boxed to signify that all may be found within coastal embayments and tidal rivers.

data on historical change. The most important factors affecting habitat quality will be reviewed.

Many species names will be referred to in our discussion of the biotic resources of Buzzards Bay. To find out more about particular species ("what is it?"), we recommend several general references on invertebrates, plants, and algae. These included in the beautifully illustrated *Encyclopedia of Marine Life,* by George and George (1979), *Gosner's* (1971, 1978) *Keys to the Marine and Estuarine Invertebrates of the East Coast*, Moul's (1973) and Petry and Normans' (1968) guide, *Salt Marsh and Dune Plants*, Taylor's (1957) *Key to the Marine Macroalgae*, and several guides to phyto- and zooplankton in coastal waters (Griffith, 1961; Smith, 1977; Wood and Lutes, 1967).

General Features of Buzzards Bay

Buzzards Bay is located in southeastern Massachusetts extending southwestward from the west end of the Cape Cod Canal to Rhode Island Sound. It is bordered on the northwest by the southeastern coast of the Massachusetts mainland and on the southeast by Cape Cod and the Elizabeth Islands (Figure 1-2, top and bottom). The bay opens into Rhode Island Sound to the southwest and communicates with Cape Cod Bay via the Cape Cod Canal and with Vineyard Sound through a series of passages between the Elizabeth Islands.

Buzzards Bay is approximately 40 km long and varies in width from 10 km at the mouth to a maximum of 20 km at New Bedford, with a total surface area of 550 km^2 (Signell, 1987). It is quite shallow, with a mean depth of 11 m at mean low water (Signell, 1987), and contains 6 x 109 m^3 of water (Farrington and Capuzzo, 1989). In general, the deepest water is found along the central axis. There are 2 deep holes in the bay which reach 43 meters, but the maximum depth over most of the bay is approximately 20 meters.

The watershed of Buzzards Bay is small in comparison to the size of the bay itself. Estimates of land drainage area surrounding the bay range from 780 km^2 (Signell, 1987) to 1492 km^2 (NOAA, 1988, Figure 1-2 top). Although residential and commercial areas have grown rapidly in the last 25 years, about 60% of the watershed is still forested (for a review of land use changes see SRPEDD, 1989). Freshwater inputs from the drainage basin have been estimated to be about 15.4 m^3 sec^{-1} (Signell, 1987) to 34 m^3 sec^{-1} (NOAA, 1988). Due to the low freshwater inputs, the salinity of the main portion of the bay is relatively high and constant ranging from 28-32%. Lower and more variable salinities are common in the marshes, tidal rivers, and coastal ponds around the shore. The tidal range is 1.2 meters (Anraku, 1964a).

Cape Cod, Massachusetts forms an important zoogeographic boundary (Anraku, 1964a; Gosner, 1971). Coastal habitats to the north of Cape Cod differ from southern areas in terms of climate, physiography, and hydrography. Consequently, boreal fauna comprise the majority of species in areas north of Cape Cod, while temperate fauna of the Virginian biogeographic province dominate in Buzzards Bay and areas south of Cape Cod to Cape Hatteras (Gosner, 1971). This boundary was altered in 1914 when the Cape Cod Canal was

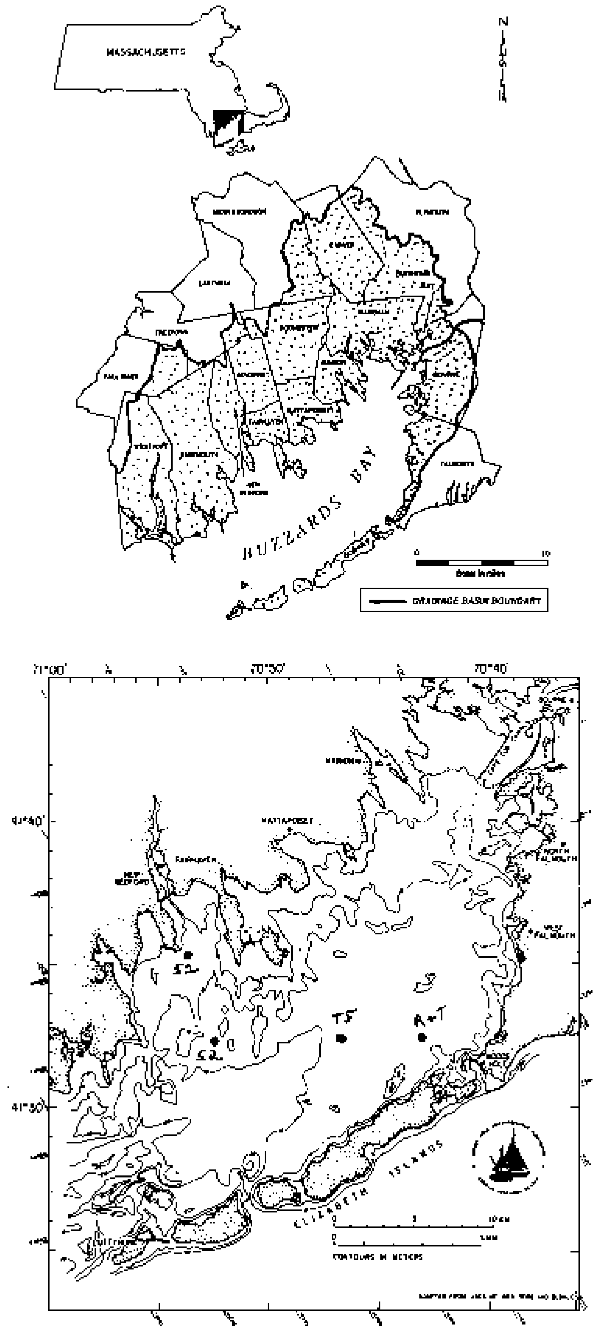


Figure 1-2. Locus map and watershed boundary (top) and bathymetric contour map (bottom) of Buzzards Bay.

From Tripp 1985 Stippled area denotes the drainage basin (from the 1988-1989 Buzzards Bay Project Annual Report).). Four water column stations are shown R&T was used by Roman and Tenore (1978) and Rhodes et al. (1985), T5 denotes station 5 sampled by Turner et al. (1989), and S1 and S2 are station 1 and 2 sampled by Smayda (1989).

opened. The presence of the canal has allowed for some movement of species between Buzzards Bay and Cape Cod Bay which may not have occurred before the canal was built. However, in general, Buzzards Bay fauna is more similar to the fauna of Narragansett Bay and Long Island Sound than to fauna of the Gulf of Maine.

The Open Bay

The Pelagic Zone of Buzzards Bay

Introduction

The pelagic zone of Buzzards Bay has not been as well studied as many of its other habitats. Much of the earlier work on water column nutrients, chlorophyll, carbon, and primary production was done at a single station (Figure 1-2 bottom, station R+T) near the Woods Hole passage (Rhodes et al., 1975; Roman and Tenore, 1978; Roman, 1978; Roman, 1980). Studies on the phytoplankton and zooplankton were largely carried out in stations around Vineyard Sound, although stations in the bay were sampled occasionally, and Anraku (1964a) compared copepod distributions in Buzzards Bay, the Cape Cod Canal, and Cape Cod Bay. A comprehensive bay wide survey of nutrients, phytoplankton, and zooplankton is being carried out by Turner et al. with funding from Massachusetts Department of Environmental Protection. A draft report has been produced (Turner et al., 1989) but data collection and analysis from this study is still proceeding. In addition to this study, a great deal of work is being done in conjunction with a study of the New Bedford outfall (e.g. Smayda, 1989), but again only preliminary data are available.

Physical Characteristics

The salinity of the open waters of Buzzards Bay ranges from 28-32% and seldom varies more than 1% in a given year (Anraku, 1964a; Turner et al., 1989; Signell, 1987). There is a 1-2% gradient in salinity at the surface with the more saline waters found near the opening to Rhode Island Sound (Signell, 1987). The water column of Buzzards Bay is well mixed from October through February (Anraku, 1964a; Signell, 1987, Turner et al., 1989). Weak salinity stratification develops during spring runoff, and there is some thermal stratification in summer (Signell, 1987; Turner et al., 1989). For most of the year, the euphotic zone reaches to within 2 to 3 meters of the bottom (Turner et al., 1989).

Water temperatures in Buzzards Bay normally range from a low of -2 to 0ºC in January to a high of 23-25ºC in July or August. During severe winters, the waters of the open bay may freeze for short periods. This is an infrequent event (see Costa, 1988 for a history of ice accumulation in the bay).

Currents driven by density differences are important in many estuaries, but because Buzzards Bay is only weakly stratified, circulation is dominated by tidal and wind forcing

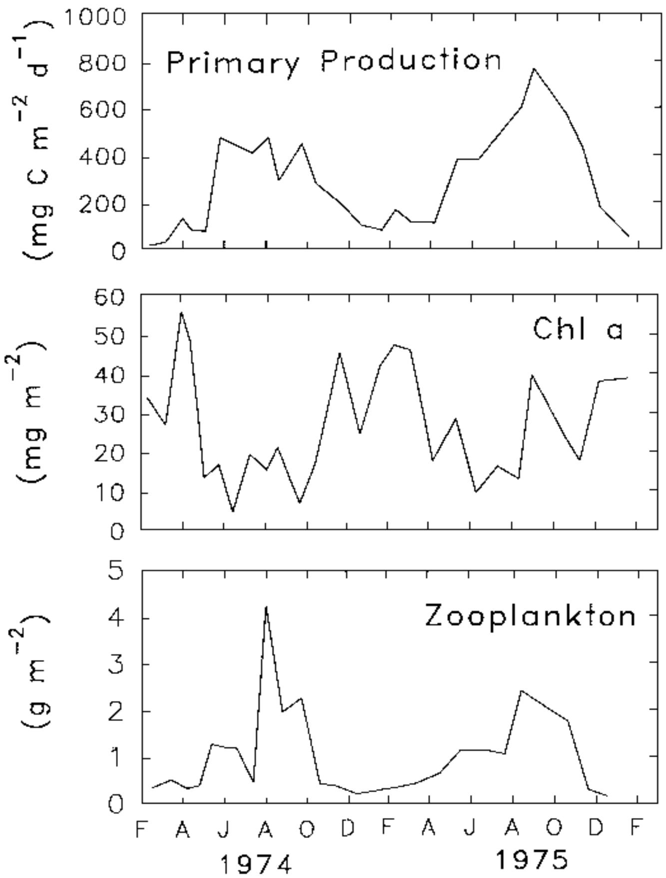


Figure 1-3.Seasonal cycles of zooplankton biomass in Buzzards Bay.

(see Signell, 1987). Tidal currents in some regions, such as the passages through the Elizabeth Islands and the Cape Cod Canal, can be quite high, exceeding 150 cm sec^{--1}. Tidal currents in the rest of the bay are considerably less, averaging from less than 10 cm sec^{-1} near the head of the bay to 50 cm sec^{-1} at the bay mouth. In the upper bay, wind transport is more important than tidal circulation and results in a downwind transport of water in shallower regions of the upper bay.

Chemical Characteristics

Dissolved nutrient concentrations in Buzzards Bay are low. In the central bay, the seasonal average concentration of dissolved inorganic nitrogen (DIN) is about 2.5 µM while dissolved inorganic phosphorus (DIP) averages approximately 1 µM (Turner et al., 1989; Figure 1-2 bottom, central bay station T5). These DIN concentrations are somewhat lower than those reported for a number of other estuaries such as Long Island Sound, Narragansett Bay, the Pamlico and the mid Patuxent (see review by Nixon and Pilson, 1983). They are much lower than values obtained from highly loaded systems such as the upper reaches of the Hudson, Chesapeake, and Delaware Rivers. Nutrient concentrations are not uniform throughout the bay, and higher concentrations are found near the New Bedford sewage outfall and in the New Bedford Harbor area (Turner et al., 1989; Howes as quoted by Smayda, 1989).

The DIN:DIP ratio in Buzzards Bay ranges from 1 to 8 and is apparently nearly always lower than the optimum ratio of 16 needed for phytoplankton growth (Redfield, 1934). These low N:P ratios are typical for most marine coastal waters and suggest phytoplankton growth is limited by nitrogen supply (Valiela, 1984; Howarth, 1988). It appears that in Buzzards Bay, like many other coastal bays and estuaries (Boynton et al., 1982), nitrogen, rather than phosphorus is the primary element limiting primary production.

While nitrogen (N) appears to regulate production, species composition may be influenced by the availability of silica. The increase in diatom abundance, beginning in the late summer and early fall may lower silica concentrations and keep them low throughout the winter and spring. Silica was the only nutrient to show a clear seasonal pattern during Turner et al. (1989) 1987-88 survey. Silica concentrations were generally less than 2 µM from late October through April. However, silica concentrations increased from May to late July before dropping back down. A similar pattern was observed by Smayda (1989).

The present day dissolved nutrient concentrations in the bay reported by Turner et al. (1989) average about 550 mg N m^{-2}, and are higher than the concentrations measured in 1974 by Roman (1980) (discussed by Kelly et al., 1990). Roman (1980) found that total dissolved inorganic nitrogen at station R+T (Figure 1-2 bottom) ranged over the season from 50 to 637 mg N m^{-2}. The majority of the values at this station were below 300 mg N m^{-2}.

Plankton Species Composition

In general, the phytoplankton community consists of species typical of New England coastal waters, although Smayda (1989) found the successional sequence and bloom patterns differed from those observed elsewhere. There are major taxonomic differences among stations and over the year. Diatoms (especially *Skeletonema costatum, Chaetoceros* spp., and *Asterionella glacialis*) dominate the assemblage much of the year (Turner et al., 1989). The diatom *Leptocylindrus danicus* was also abundant in stations near the canal and may reflect the presence of water from Cape Cod Bay (Turner et al., 1989) although Smayda (1989) also reports this species is present in New Bedford harbor. The diatom *Cerataulina pelagica* and the flagellate *Chroomonas* spp. are abundant at stations in and around New Bedford harbor (Turner et al., 1989). Dinoflagellates are reported to reach maximum abundance in the summer but numbers are low and major blooms of toxic species have not been reported in Buzzards Bay.

Microflagellates and other nanoplankton make up a high percentage of the total community at some times of the year. Smayda (1989) found that in summer, when diatom abundance was low, nanoplankton (plankton passing through <64 μ mesh net) made up a large part of the total chlorophyll, but nanoplankton were relatively less important the rest of the year. This is similar to the finding of Roman (1978) that nanoplankton dominate the phytoplankton during May, June and July, but make up less than 20% of the total chlorophyll the rest of the year.

Zooplankton species composition was first in detail by Anraku (1964a and b), who investigated the influence of the canal on copepod distributions in Buzzards Bay. Dominant copepod species in Buzzards Bay included *Pseudocalanus minutus, Acartia clausi, A. tonsa, Centropages hamatus, Paracalanus crassirostris, Oithona similis, and O. brevicornis*. A few colder water species, such as *Calanus finmarchicus*, are carried into Buzzards Bay via the Cape Cod Canal but do not appear to be able to reproduce in the bay. For most of the year copepods dominate the zooplankton community although during August, September, and October large blooms of ctenophore *Mnemiopsis leidyi* may occur (Roman and Tenore, 1978). Zooplankton biomass shows a distinct seasonal cycle with the highest biomass present in the late summer and early fall with minimum values in the winter (Figure 1-2 , bottom; Roman and Tenore, 1978). A detailed analysis of the zooplankton community is currently in progress (Turner et al., 1989), but the data is not yet available.

The abundance of icthyoplankton peak in the early summer between mid-May and late June (Collings et al., 1981). The icthyoplankton eggs of Buzzards Bay are dominated by two groups which make up over 75% of the eggs found in the samples; the cunner-tautog-yellow tail flounder group and the scup-weakfish-silver hake group. Cunner, tautog, sand lance, and anchovies make up over 75% of the icthyoplankton larvae. Collings et al. (1981) found that there were some significant differences in the icthyoplankton composition of Cape Cod Bay, the canal and Buzzards Bay.

Although not a major component of the plankton, lobster larvae are considerably more abundant in the waters of Buzzards Bay than in Cape Cod Bay or Block Island Sound (Collings et al., 1983). About 10 million lobster larvae per year may be discharged from Buzzards Bay through the canal, and contribute substantially to lobster recruitment in Cape Cod Bay.

Standing stocks of Chlorophyll *a* and Primary Productivity

Chlorophyll *a* is a measure of the standing stock of phytoplankton biomass and has been shown to be related to nutrient inputs (Nixon and Pilson, 1983). The annual average chlorophyll *a* concentration measured by Turner et al. (1989) in the central bay (station T5, Figure 1-2 bottom) was 6 mg m^{-3} in 1987-88, equivalent to a depth-integrated value of 95 mg m^2. These chlorophyll concentrations are similar to those reported for Narragansett Bay and Long Island Sound, but are somewhat lower than those reported for Delaware Bay, the Mid-Chesapeake, or the Patuxent and Pamlico estuaries (data compiled in Nixon and Pilson, 1983). The values reported by Turner (1989) are approximately twice those reported by Rhodes et al. (1975) and Roman and Tenore (1978) for a station nearby (discussed in Kelly et al., 1990).

New England coastal waters are normally characterized by a late winter-early spring phytoplankton bloom. The chlorophyll data of Turner et al. (1989), Rhodes et al. (1975), and Roman and Tenore (1978) indicate that there are two periods of maximum chlorophyll *a* in the bay, one during late summer and the other in early winter (Figure 1-3, middle). The winter "bloom" appears to be less predictable and is absent in some years and at some locations (Smayda, 1989).

Two recent studies of phytoplankton production in Buzzards Bay yield contrasting results, which may be due to site differences, or to temporal variation. Roman and Tenore (1978) sampled the open bay during 1975 and 1975, recording the highest rates of primary production during the summer and fall (Figure 1-2 top). During the two years studied, production averaged 106 $\pm$ 17 g C m^{-2} y^{-1}. Smayda (1989) recently measured primary production at two sites near New Bedford (stations S1 and S2, Figure 1-2 , bottom) and found a similar seasonal peak in production during summer and fall. However, Smayda's production values were 3 to 7 time higher than Roman and Tenore's (1978), ranging from 354 g C m^{-2} y^{-1} at the mouth of New Bedford Harbor to 832 g C m^{-2} y^{-1} near the present New Bedford outfall site. Possible reasons for this difference will be discussed in detail below.

Possibility of Historical Change

There appear to be consistent increases in DIN, Chlorophyll *a*, and primary production measured in the late 1980s compared with data taken in the 1970s (aspects of this question are discussed in Kelly et al., 1990). The quality of all these datasets is believed to be good, raising the possibility that over the past 15 years, the bay has become more eutrophic. While suggestive, these data are not conclusive. There are at least three possible explanations for these differences. First, there may be spatial variation between stations recently sampled by Turner and Smayda, and those sampled in the mid-70s by Roman and Tenore (1978) and Rhodes et al. (1975). Second, normal inter-annual variation may account for the increase. Turner et al. is still collecting data so this possibility can be evaluated shortly. Third, chlorophyll *a* concentrations and primary production in the bay may have actually doubled due to increases in nutrient inputs during the last 15 years.

It is quite possible that much of the difference between the data collected in the 1970s and the late 1980s is due to spatial differences within Buzzards Bay. The station used by Rhodes et al. (1975) and Roman and Tenore (1978) was chosen to investigate sediment resuspension and is located opposite Woods Hole Passage (Figure 1-2 , bottom). Tidal currents in this area are considerably stronger than in most of the rest of the bay and the site undoubtedly receives more water from Vineyard Sound than Turner's mid-bay station. Although the stations sampled are close to Turner et al.'s (1989) station (Figure 1-2 bottom, station T5), Roman's (1980) site may be more influenced by low nutrient Vineyard Sound water transported into Buzzards Bay through the Woods Hole Passage, and thus not be as representative of the whole bay. Smayda's site near New Bedford may be higher in primary production than Roman and Tenore's (1978) site because it is influenced by nutrients coming from New Bedford Harbor and the Clark's Point sewage outfall. Turner et al.'s (1989) survey indicates that nutrient concentrations are higher in this area than in the central portion of the bay, so their findings may indicate a local, rather than general increase in water column production.

Subtidal Benthos

Introduction

In most areas of the open bay below about 3 m, too little light reaches the bottom to sustain growth of macrophytes. Nonetheless, dense assemblages of invertebrates colonize many areas of the bottom. For food, these organisms rely on plankton produced in the overlying water column and on organic matter exported from wetlands or terrestrial environments within the watershed.

Physical-Chemical Environment

In the deeper regions of the bay where currents are low, a rain of organic matter (dead phytoplankton and other decaying organic matter), so-called "detritus", settles to the bottom and fine silt-clay muds accumulate (Moore, 1963). Approximately 182 km^2 (33%) of the open bay is covered by these sediments (Figure 1-4, top). Organic detritus deposited in these zones supplies food to the community of "deposit" feeding invertebrates that live at the surface of or buried in the sediments. Although these muds are rich in

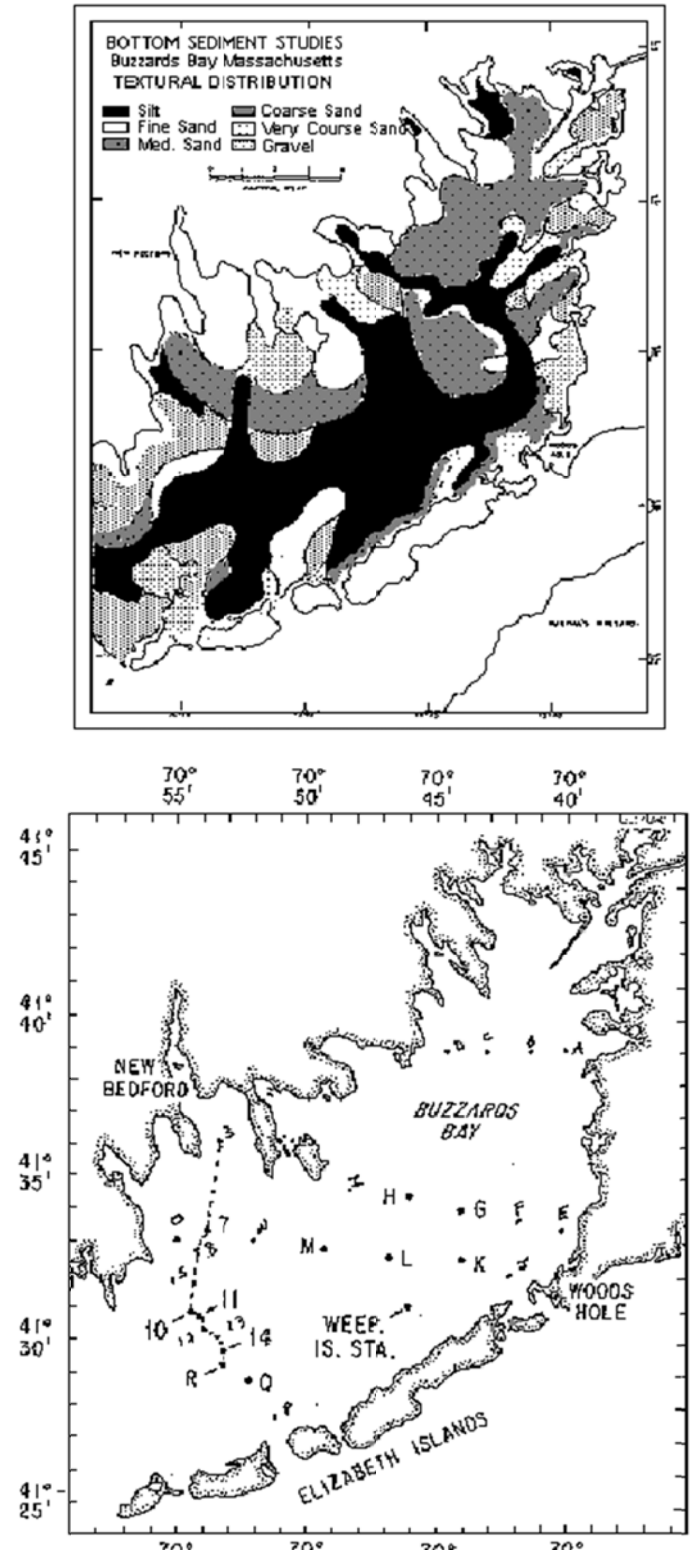


Figure 1-4. Sediment distribution map of Buzzards Bay (top) and map showing Sanders (1960) stations (bottom)

Sediment map from Moore 1963. The station letters show the New Bedford to Station R transect set up by Hampson and Rhodes and the Weepecket site sampled by Banta et al. (1990; Weepecket Is.).

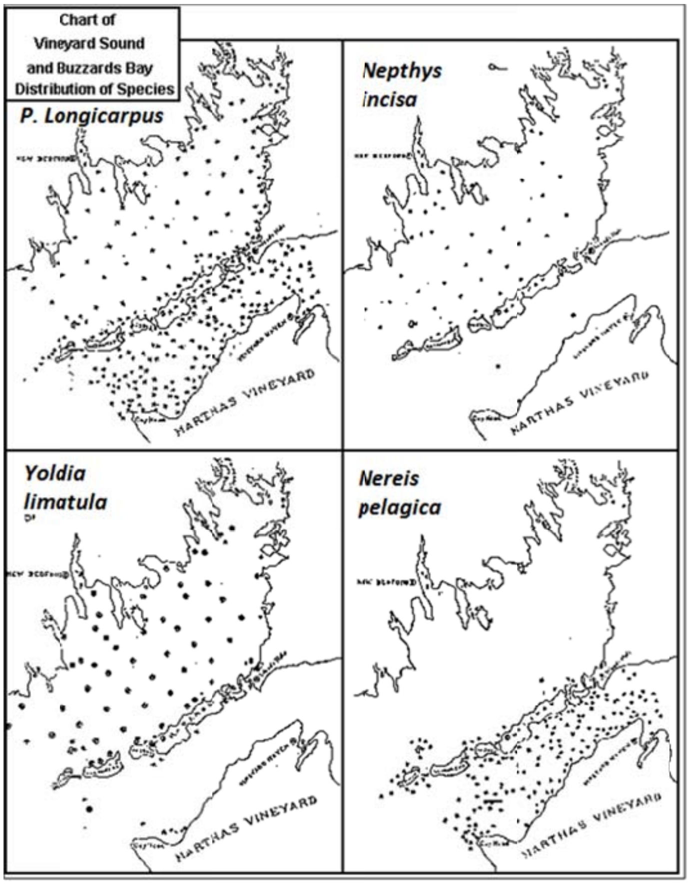


Figure 1-5. Species distributions of *P. longicarpus, Nephthys incisa*, *Yoldia limatula*, and *Nereis pelagica* from survey of Sumner et al., 1911.

organic matter compared with coarser, sandy sediments, they contain only about 1.5-3% organic carbon and about 0.2-0.4% organic nitrogen (Henrichs and Farrington, 1987; McNichol, 1988; Banta et al., 1990; Hampson, 1990). Both benthic metabolism and growth of infauna are rapidly stimulated by deposition of high quality organic matter following phytoplankton blooms (Hargrave, 1980; Christensen and Kanneworff, 1985; Banta, 1992).

In areas where strong tide and wave-induced currents sweep the bottom, fine silts, clays, and light detrital particles are resuspended and sandier sediments are found (Moore, 1963). Medium to fine sand covers about 179 km^2 (33%) of the bay (Figure 1-4, bottom). These sediments contain about one-fifth the organic carbon and nitrogen of muddy sediments (Driscoll, 1975; Hampson, 1990). A very different community dominated by suspension feeding amphipods predominates in this habitat. Finally, about 108 km^2 (20%) of Buzzards Bay is characterized by course sand or gravel bottoms. Assemblages of filter feeding molluscs are abundant on these bottoms (Driscoll and Brandon, 1973). Each of the bottom types provides a habitat suitable for different types of benthic communities.

Subtidal benthic habitats are the ultimate repository for both organic matter and many of the pollutants entering marine ecosystems. Changes in bottom fauna have been used as sensitive indicators of the cumulative impact of human activities in nearshore environments (Stirn et al., 1973; Pearson and Rosenberg, 1978; Gray, 1980; Pearson et al., 1983; Weston, 1990). Thanks to its proximity to major fisheries, oceanographic and marine biological research institutes, the benthos of Buzzards Bay is probably one of the best-studied coastal marine habitats in North America (Figure 1-4, bottom). Because shifts in the benthos over time may reflect the effects of eutrophication or pollution, we will spend a little time examining the history of the study of benthic communities in Buzzards Bay.

Major Species

The first comprehensive survey of benthic fauna in Buzzards Bay was made during the summer of 1871 by A. E. Verrill and his colleagues under the auspices of the U. S. Fish Commission (Verrill and Smith, 1873). Over 600 species were described and cataloged from muddy, sandy and rocky shores and bottoms. This study was purely descriptive, and provides little more than a baseline species list. Forty years later, Sumner et al. (1911) contrasted the subtidal communities within Vineyard Sound and Buzzards Bay. Their work was based on dredge samples collected from 458 stations during 1903-1919. It revealed clear differences between communities of Buzzards Bay and the sound. Most of these differences were associated with the type of bottom sediment (sand and gravel vs. mud, Table 1-1). While some species such as *Nassarius trivittatus* (New England dog whelk) were found throughout Buzzards Bay and Vineyard Sound, others such as the bivalves *Mulinia lateralis*, *Yoldia limatula* and the polychaete *Nephthys incisa* occurred predominantly at muddy stations in Buzzards Bay, and were virtually absent from Vineyard Sound (Figure 1-5). Still other species such as the polychaete *Nereis pelagica* were found almost exclusively in sandy or gravelly sediments in Vineyard sound.

The early collections of Verrill and Sumner were made with crude dredge rakes or trawls, and were not quantitative. Many small or rare species may have been missed entirely; for example, the capitellid polychaete, *Mediomastus ambiseta*, which has been found in high abundance in silt-clay sediments in all recent studies, was not reported at all. Furthermore, it was not possible to estimate the abundance of the species that were found. In fact, Sumner et al. (1911) emphasized, "No attempt has been made by us, here or elsewhere to count the number of individual organisms taken in a single haul or dredge. Such figures are so entirely dependent upon the character and size of the dredge employed, and the duration of the haul, that we do not believe that the value of any results of this sort would have been commensurate with the labor involved in counting.

Table 1-1. List of species taken at 25% or more of stations from gravelly, sandy and muddy bottoms of Buzzards Bay and Vineyard Sound.

The number and percent of stations at which each species was observed is indicated ("X" indicates the species was found at less than one-fourth of the stations). Data compiled from tables VI, VII and VIII of Summer et al., 1911.

Habitat	**Gravel**	**Sandy**	**Muddy**
Number of stations dredged	**168**	**172**	**112**
Sponges			
Cliona celata	91 (54%)	49 (28%)	31 (28%)
Hydrozoa			
Hydractinia echinata	43 (26%)	46 (27%)	x
Eudendrium ramosum	43 (26%)	x	x
Tubularia	44 (26%)	x	x
Thuiaria argentea	47 (28%)	x	x
Zoantheria			
Astrangia danae (solitary coral)	98 (58%)	x	28 (25%)
Bryozoa			
Crisia eburnea	97 (58%)	74 (43%)	30 (27%)
Bugula turrita	99 (59%)	107 (62%)	49 (44%)
Schizoporella unicornis	96 (57%)	63 (37%)	35 (31%)
Parasmittina nitida	90 (54%)	44 (26%)	29 (26%)
Amphipod crustaceans			
Uniciola irrorata	46 (27%)	x	32 (29%)
Leptocheirus pinguis	x	x	41 (37%)
Cirripedia (barnacles)			
Balanus eburneus	63(38%)	51 (30%)	46 (41%
Asteroidea (starfish)			
Henricia sanguinolenta	82 (49%)	x	
Asterias vulgaris	x	56 (33%)	x
Asterias forbesi	83 (49%)	71	48 (43%)
Echinoidea (urchins & sand dollars)			
Arbacia punctulata	80 (48%)	48 (28%)	x
Echinarachnius parma	x	101 (59%)	
Polychaete worms			
Pseudopotamilla oculifera	42 (25%)	x	x
Lepidonotus squamatus	87 (52%)	54 (31%)	x
Nereis pelagica	93 (55%)	72 (42%)	x
Hydroides dianthus	118 (70%)	61 (35%)	
Harmothoe imbricata	80 (48%)	72 (42%)	35 (31%)
Diopatra cuprea	72 (42%)	72 (42%)	54 (48%)
Nephthys incisa	x	x	43 (38%)
Clymenella torquata	x	x	36 (32%)
Ninoe nigripes	x	x	35 (31%)
Cistenides gouldii	x	x	32 (29%)
Pelecypod molluscs (clams)			
Modiolus modiolus	69 (41%)	x	x
Cumingia tellinoides	59 (35%)	x	x
Mytilus edulis	74 (44%)		113 (66%)
Crassinella mactracea	78 (46%)	72 (42%)	x

(CONTINUED)			
Corbula contracta	55 (33%)	46 (27%)	x
Anomia simplex	83 (49%)	97 (56%)	66 (59%)
Pecten gibbus borealis	51 (30%)	52 (30%)	57 (51%)
Arca transversa	81 (48%)	105 (61%)	78 (70%)
Nucula proxima	69 (41%)	62 (36%)	74 (66%)
Cardium pinnulatum	55 (33%)	83 (48%)	79 (71%)
Ensis directus	86 (51%)	84 (49%)	64 (57%)
Spisula solidissima	84 (50%)	109 (63%)	29 (26%)
Clidiophora gouldiana	66 (39%)	88 (51%)	80 (71%)
Astarte undata	x	44 (26%)	x
Astarte castanea	x	59 (34%)	x
Callocardia morrhuana	x	78 (45%)	80 (71%)
Tellina tenera	x	96 (56%)	63 (56%)
Yoldia limatula	x	x	66 (59%)
Laevicardium mortoni	x	x	45 (40%)
Mercenaria mercenaria	x	x	52 (46%)
Macoma tenta	x	x	30 (27%)
Mulinia lateralis	x	x	60 (54%)
Gastropod molluscs (snails)			
Littorina littorea	42 (25%)	x	x
Polynices heras	59 (35%)	80 (47%)	x
Nassarius trivittata	117 (70%)	142 (83%)	108 (96%)
Anachis avara	127 (76%)	95 (55%)	67 (60%)
Astyris lunata	103 (61%)	94 (55%)	48 (43%)
Urosalpinx cinerea	79 (47%)	46 (27%)	29 (26%)
Crepidula fornicata	113 (67%)	124 (72%)	84 (75%)
Crepidula plana	103 (61%)	111 (65%)	74 (66%)
Polynices triseriata	48 (29%)	51 (30%)	41 (37%)
Polynices duplicata	x	x	35 (31%)
Eupleura caudata	x	x	48 (43%)
Busycon canaliculatum	x	x	43 (38%)
Decapod crustaceans			
Pagurus pollicaris	47 (28%)	x	x
Ovalipes ocellatus	x	43 (25%)	x
Pagurus longicarpus	106 (63%)	101 (59%)	83 (74%)
Pagurus annulipes	93 (55%)	59 (34%)	44 (39%)
Libinia emarginata	69 (41%)	62 (36%)	57 (51%)
Cancer irroratus	71 (42%)	92 (53%)	43 (38%)
Crangon septemspinosa	x	80 (47%)	50 (45%)
Neopanope texana sayi	64 (38%)	x	43 (38%)

Quantitative measurements of benthic faunal abundance in Buzzards Bay were first carried out by Sanders (1958) using a modified anchor dredge (Forester, 1953). Nineteen stations, lettered A-S, were sampled in fall of 1955 (Figure 1-4, bottom). Like, Sumner et al. (1911), Sanders found different communities of animals inhabiting sandy and muddy regions of the bay. The most common and abundant species present in finer, predominantly silt-clay (particle size of <62µ) sediments were the deposit feeding clam, *Nucula annulata* (identified as *N. Proxima* in the original paper), the polychaete worms, *Nephthys incisa*, *Scolelepis* sp. (identified as *Nerinides* sp). *Ninoe nigripes*, the gastropods, *Turbonilla* sp., *Retusa caniculata, Cylichna oryza, Nassarius trivittatus,* and the amphipod *Unciola irrorata*. Sanders called this the *Nephthys-Nucula* community, after the numerical dominants (Figure 1-6). Coarser sandy sediments were characterized primarily by the amphipods *Ampelisca abdita* (identified as *A. spinipes*), *Byblis serrata*, *A. macrocephala, Leptocheirus pinguis*, the polychaetes, *Glycera americana*, *Nephthys bucera*, *Lumbrinereis tenuis*, and the clams, *Tellina tenera* and *Cerastoderma pinnulatum* (Figure 1-7). This community is termed an *Ampelisca* community. Although sandy sediments cover one-third of the bottom (Figure 1-4, top), beyond Sanders (1958) initial survey, little additional work has been done on the community occupying coarser, sandy substrates of Buzzards Bay. One exception is the work of Driscoll and Brandon (1973) who surveyed 54 stations (48 in sandy-gravelly sediments) in northwestern Buzzards Bay; unfortunately, they only analyzed the molluscan fauna in detail. Considerable effort, however, has been directed toward the silt-clay habitat.

Species found in muds feed mainly by ingesting sediment deposits (see Lopez and Levinton, 1987 for review of deposit feeding), while those found in sands filter suspended material from the water column (see Jorgensen, 1975; 1983 for reviews of suspension feeding). With a few exceptions, such as the suspension feeding tellinid bivalves (e.g. *Macoma tenta*), there is clear spatial separation of suspension and deposit feeding species related to the percent silt-clay content of the sediments at each station (Figure 1-8).

The difference in species composition between communities inhabiting sandy and muddy substrates is clearly related to sediment grain size, but it may be caused in part by biological interactions between deposit feeding and suspension feeding organisms. Deposit feeders ingest sediment either at the surface or at depth (so-called head down feeding) and rapidly repackage and eject the sediment in the form of fecal pellets (Figure 1-6). Because the food resource of deposit feeders, silt-clay sediment, has low nutritional value (Buzzards Bay silt-clays contain <8% organic matter by weight), deposit feeders must process a lot

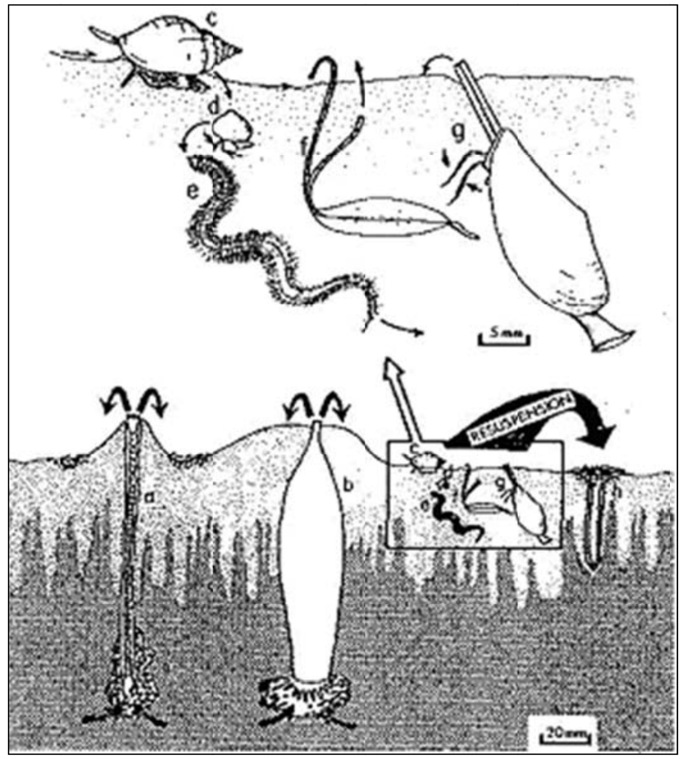


Figure 1-6. Some representative New England mudflat benthic invertebrates.

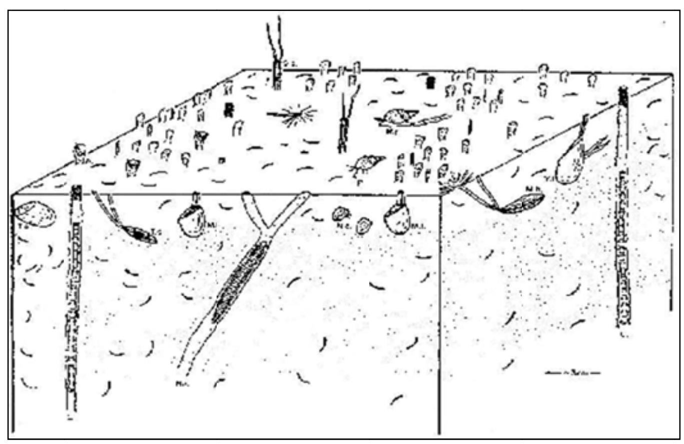


Figure 1-7. Some representative New England sand flat benthic invertebrates including general life habitats.

of it, rapidly. Deposit feeders typically consume the equivalent of 1 body weight's worth of sediment daily (Lopez and Levinton, 1987). The mixing and pelletization which results from deposit feeding destabilizes the sediments and increases resuspension (Rhoads and Young, 1970; Rhoads and Boyer, 1982). Twenty to 30% of the surface (0-2 cm) sediment at station R (Figure 1-4, bottom),

Table 1-2. Comparison of benthic faunal abundance among studies sampling Buzzards Bay (BB), Long Island Sound (LIS), and Narragansett (NB), and Cape Cod (CBB) bays.

Study	**Site & Date**	**Sampling gear (areal sample size)**	**No. Samples**	**Smallest Screen Size (mm)**	**Sediment Type**	**Numerically Dominant Species**	**Dominant as percent total No.**	**Total Density No. m^{-2}**	**Biomass g m^{-2}**
Grassle et al. (1985)	NB (mid bay, 76-80)	corer (35 cm^{-2})	>190	0.3	silty-sand	*M. ambiseta*	46%	76,000	nd
Sanders (1956)	LIS (8 stns, 53-54)	anchor dredge (11.9 m^{-2})	36	0.3	sand & silt	*N. annulata*	nd	16,446	16.3
Reid, R. N. (1979)	LIS (72)	Smith McIntyre grab (0.1 m^{-2})	43	1. 0	silt-clay	*M. lateralis*	75%	10,400	nd
Reid, R. N. (1979)	LIS (73-78)	Smith-McIntyre grab (0.1 m^{-2})	10-16/y	1. 0	silt-clay	co-dominants*	33% ea	1,446	nd
Young & Rhoads (1971)	CCB (69)	Smith McIntyre grab (0.1 m^{-2})	14	1. 0	sandy	*M. ambiseta***	27%	19,113	12.5
Young & Rhoads (1971)	CCB (C9)	Smith-McIntyre grab (0.1 m^{-2})	14	1. 0	silt-clay	*E. incolor*	46%	12,535	13.3
Sanders (1958)	BB (55)	anchor dredge (0.09 m^{-2})	9	0.5	silt-clay	*N. annulata*	24%	4,403	nd
Sanders (1958)	BB (55)	anchor dredge (0.09 m^{-2})	10	0.5	sands	*Ampelisca* spp.	25%	4,449	nd
Sanders (1958)	BB (55)	anchor dredge (0.09 m^{2})	25	0.5	silt-clay	*N. annulata*	76%	8.985	12.2
Whitlach (1979 unpub.)	BB(Stn R,75)	Van Veen grab (. 04 m^{-2})	18	0.3	silt-clay	*N. annulata*	59%	62,350	nd
Banta et al. (1990)	BB(WEEP stn, 89)	SCUBA cores (33 cm^{-2})	33	0.3	silt-clay	*N. annulata*	45%	41,743	nd
Hampson (1990)	BB (7stns, Aug 87)	Van Veen grab (0.4 m^{-2})	16	0.3	silt-clay	*N. annulata*	47%	23,673	nd

**N. annulata* and *M. lateralis*
**initially identified as *C. capitata*

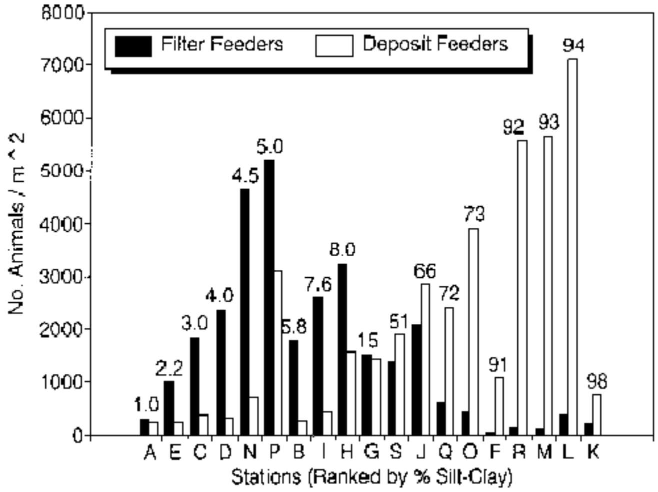


Figure 1-8. Distribution of filter vs. deposit feeders ranked by % silt-clay in the sediments.

which typifies the silt-clay habitat in Buzzards Bay, is composed of fecal pellets (Rhoads, 1967; Young, 1971). The deposit feeding infauna at station R completely processes all the sediment in the top 2-3 cm annually (Rhoads, 1967). Rhoads and Young (1970) argued that disturbance and resuspension caused by deposit feeders inhibits successful recruitment and survival of suspension feeding species and termed the active exclusion of suspension feeding organisms by deposit feeders as "trophic-amensalism" (amensalism is an interaction between two species in which one is inhibited while another is unaffected).

Sanders (1960) examined species composition and seasonal dynamics of the macrofauna at the silt-clay station R in Buzzards Bay in detail (25 samples collected over a 2 year span were analyzed). Total density and biomass averaged 8,985 animals m^{-2} and 12.2 gdw m^{-2}, respectively (Table 1-2). 95% of the biomass was accounted for by 13 of the 19 species found. *Nucula annulata* (originally listed as *N. Proxima*) and *Nephthys incisa* made up, on average, 43% of the biomass and 76% of the individuals in the community. No strong seasonal pattern in abundance was reported. Banta et al. (1990) have recently sampled the *Nucula-Nephthys* community near station R at the Weepecket Islands site (WEEP, Figure 1-4, bottom). They reported much higher faunal abundances than Sanders (1960) found at station R. Densities averaged about 42,400 individuals m^{-2}, and there was a slight seasonal pattern with maximum abundance approaching 60,000 individuals m^{-2} in March-April declining during summer to minimum abundance in July-September of 25,600-31,000 individuals m^{-2}.

Historical Changes - Do They Indicate Eutrophication?

Sanders' station R site has been revisited a number of times by other investigators in the past 30 years (Banta et al., 1990; Hampson, 1990; Whitlach et al., unpublished manuscript). The results of Sanders can be compared with these later studies in an attempt to evaluate whether any long-term changes in the bay have occurred. All the more recent studies found much higher total abundances of benthic fauna than reported by Sanders (1960), and found high densities (4000-28,000 individuals m^{-2}) of the capitellid polychaete, *Mediomastus ambiseta. M. ambiseta* was first reported in high densities in the bay by Grassle and Grassle (1974). It is often found at densities exceeding 10,000 m^{-2} in silt-clay to sandy-silt substrates. At station R, it now makes up 6-20% of the community, and is the second most abundant species after *Nucula annulata* (Banta et al., 1990; Whitlach et al., unpublished manuscript). In contrast, *Mediomastus* ranked 22nd in abundance among all species collected at Station R by Sanders (1960) and comprised only 0.15% of the fauna (Sanders listed it as an unidentified capitellid polychaete and identification was confirmed by examining preserved specimens from his original samples, Whitlach, et al., unpublished).

Mediomastus ambiseta appears to be a good indicator of eutrophication. It responded with dramatic increases in population growth and abundance in experimentally enriched "mesocosms" (1.8 m x 5.5 m cylindrical tanks at the University of Rhode Island's Marine Ecosystem Research Lab - Grassle and Grassle, 1984). In Buzzards Bay, samples collected from a series of stations along a transect extending from station R toward the Clarks Point sewage outfall serving New Bedford show increasing *Mediomastus* densities approaching the outfall site (Figure 1-9). At the station closest to the outfall, *Mediomastus* is the numerical dominant, making up more than 70% of the

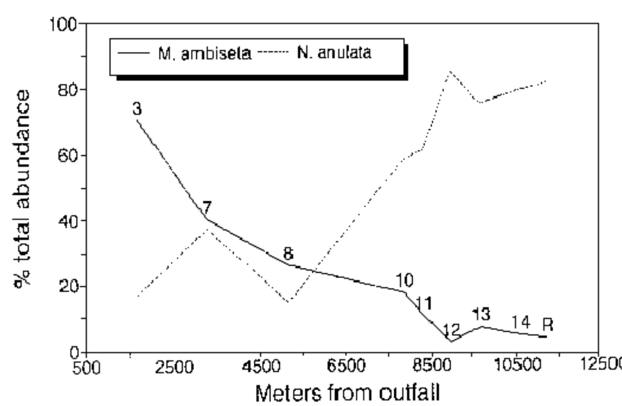


Figure 1-9. Distribution of a filter feeder and deposit feeder relative to the distance of an outfall.

benthic macrofauna. This is consistent with Smayda's (1989) observation of elevated phytoplankton production near the outfall (see previous section), and shows that the outfall has had a local impact on the benthic community.

While it is clear that *Mediomastus* is an indicator of eutrophication, it would probably be wrong to conclude that the apparent increase in *Mediomastus* reported in recent years proves Buzzards Bay has been eutrophied since Sanders early studies. Much of this increase may merely be due to use of improved sampling and sorting techniques. Although differences in sampling efficiency alone cannot explain all of the increase in faunal abundance observed in modern studies, Van Veen grabs, box or SCUBA collected cores do collect 10-20% more individuals than the anchor dredge (Gage, 1975). Perhaps more importantly, improved sample processing (application of stains to make animals easier to see, use of dissecting microscope to pick samples, and use of 0.3 vs. 1. 0 or 0.5 mm sieves to retain specific size fractions of animals and sediments) make it likely that recent studies would find higher abundances of small, inconspicuous species such as *Mediomastus*. Whitlach et al. (unpublished) compared present day sorting methods to those used by Sanders (1960) by counting fauna in identical samples collected at station R, first using Sanders' method (picking unstained samples using a 6X hand lens), and then staining and sorting under a dissecting microscope (Table 1-2). He found about twice as many total animals, and 9 times as many polychaetes using present day methods.

Comparison to Other Temperate Bays

With a few species substitutions, benthic faunas similar to those found in Buzzards Bay occupy silt-clay and sand habitats of other nearby bays such as Long Island Sound and Narragansett Bay. Although 30 years ago Sanders (1956) found a similar species composition, and somewhat higher densities and biomass in Long Island Sound when compared to Buzzards Bay, more recent studies have found much lower densities of animals in Long Island Sound (Table 1-2). The cause of the recent decline in abundance in Long Island Sound is unknown.

Grassle and Grassle (1984) and Grassle et al. (1985) examined the community of Narragansett Bay along a gradient extending from the Providence River to offshore Rhode Island Sound. They report dominance by *Nucula annulata* offshore, and by *Mediomastus ambiseta* at their mid-bay station (Table 1-2). They found a repeatable seasonal pattern in total abundance driven largely by fluctuations in the numerically dominant species, *Mediomastus ambiseta* occurred. Though much more pronounced than in Buzzards Bay, the seasonal pattern was characterized by a winter-spring increase in benthic fauna followed by a mid to late summer crash, similar to that observed by Banta et al. (1990) at the WEEP site in Buzzards Bay. These seasonal fluctuations may be driven by increases in benthic food supply occurring after the spring plankton bloom settles to the bottom, followed by depletion of food resources as organic matter decay in the sediments accelerates during warm summer months (Rudnick and Oviatt, 1986).

Cape Cod Bay differs markedly from Buzzards Bay. It is located within the Arctic-boreal faunal province, is deeper, better flushed by shelf water and considerably colder than Buzzards Bay (bottom water temperature ranges from -1.5 to 10 ºC vs. -1.5 to 22 ºC). Rhoads and Young (1971) report faunal abundance and biomass comparable to those observed by Sanders (1960) in Buzzards Bay (Table 1-2), but found different species composition. Michael (1975) reports much lower abundances than found in Buzzards Bay (Table 1-2). This may be due in large part to the sieve size (1. 0 mm) used in this study. However, there are faunal differences that do not appear to be due to the sampling technique. In contrast to Buzzards Bay, where the bivalve, *Nucula*, dominates numerically, polychaetes made up about 91% of the macrofauna in Cape Cod Bay (Young and Rhoads, 1971). This was true even in sandy sites where the Ampeliscid amphipod community would have been expected in Buzzards Bay. The broad spatial separation between deposit and suspension feeding species observed in Buzzards Bay was not found in Cape Cod Bay. Suspension feeders such as the tube dwelling polychaete *Euchone incolor* coexist with deposit feeders such as the sea cucumber, *Molpadia oolitica* (Young and Rhoads, 1971; Rhoads and Young, 1971).

Summary of Open Bay Management Recommendations

At the current time most areas of the open portion of Buzzards Bay do not appear to be in serious danger due to nutrient loading. Nutrient inputs to Buzzards Bay are less than those entering Narragansett Bay and Long Island Sound (Table 1-3). The chemical and biological data would also indicate that Buzzards Bay is not eutrophic when compared to other estuaries. As previously discussed, Chlorophyll *a* and DIN in the water column appears to be lower in Buzzards Bay than other estuaries such as Narragansett Bay or Long Island Sound (Table 1-3). Benthic respiration in Buzzards Bay is also similar to or lower than benthic respiration in Narragansett Bay or Long Island Sound (Table 1-3). On the other hand, there do appear to be local increases in water column productivity, benthic respiration, and abundance of benthic infaunal species such as *M. ambiseta* indicative of nutrient enrichment near the Clark's Point sewage outfall serving New Bedford.

More data should be gathered before fully comparing primary production in Buzzards Bay to other estuaries (Table 1-3). If Roman and Tenore's (1978) data are

Table 1-3. Comparison of nutrient inputs in Buzzards Bay, Narragansett Bay, and Long Island Sound.

Water Body	**Chlorophyll ($mg\ m^{-3}$)**	**Primary Production ($g\ C\ m^{-2}\ y^{-1}$)**	**DIN µM**	**Benthic Respiration ($g\ C\ m^{-2}\ y^{-1}$)**	**Size (ha)**	**N Inputs ($m\ mol\ m^{-2}\ y^{-1}$)**	**N inputs ($m\ mol\ m^{-3}\ y^{-1}$)**
Buzzards Bay	2 -15[a]	106[b]-350[c]	2-3[a]	64-85[d]	55,000	252[i]	24
Narragansett Bay	7-25[e]	22-310[f]	6[e]	140[g]	32,413	950	100
Long Island Sound	6-28[e]	160-205[h]	6[e]		318,540	400	30

Notes: [a] Turner et al. (1989), [b] Roman and Tenore (1978), [c] Smayda (1989), [d] Range calculated by Banta (1992), [e] Nixon and Pilson (1983), [f] Range of net values summarized in Oviatt et al. (1981), [g] Nixon et al. (1981), [h] Riley (1956), [i] SAIC (1990)

representative, than it would appear that Buzzards Bay is considerably less productive than many other estuaries including Narragansett Bay, Long Island Sound, Delaware Bay, the Mid-Chesapeake, the Patuxent and Pamlico estuaries (data compiled in Nixon and Pilson, 1983). These sites have primary production values in the range of 200 to 500 $g\ C\ m^{-2}\ y^{-1}$. However, if Smayda's site is representative, primary production in Buzzards Bay would be quite similar to what has been reported for these other systems, although still at the lower end of the range.

These findings would indicate that nitrogen inputs to the bay should be monitored, but presently it does not appear necessary to reduce nitrogen inputs to protect the health of the open bay. Basic chemical and biological parameters should also be monitored, perhaps on a 5-8 year time scale to determine if changes are occurring. The use of satellite photographs to examine spatial and temporal trend in *Chlorophyll a* should be explored. The New Bedford to Station R transect should be periodically revisited (e.g. biannually), to assess whether the impacted area is increasing in size. Care should be taken to sample at the same time of the year during each survey (e.g. June/July), and to use identical sampling and sorting techniques. Ideally, SCUBA collected cores should be taken, but the Van Veen grab appears to do an adequate job (Gage, 1975). Sediments should be processed by sieving through 0.3 mm mesh, and retained fauna should be stained with vital dyes prior to sorting under dissecting microscopes.

Nearshore and Coastal Habitats

Coastal Embayments and Tidal Rivers

Introduction

There are 27 major embayments around Buzzards Bay (Table 1-4). Some of these, like the Westport River embayment, are estuarine areas whose biological and chemical characteristics are heavily influenced by surface water flow. In others, such as Buttermilk Bay, groundwater inputs are larger than surface water flow. Coastal embayments incorporate a number of specific habitats including fresh, brackish, and salt marshes, barrier beaches, eelgrass beds, and tidal flats (see Figure 1-10). These specific habitats are discussed separately. In this section, we will deal with the aspects of embayments that make them unique from open bay areas.

Only a few of the embayments around Buzzards Bay have been studied, and frequently these studies had very specific purposes such as examining the impact of oil or PCB pollution. For example, the circulation and chemical contamination of Acushnet River New Bedford Harbor has been examined in great detail because of the large PCB contamination found there (Farrington and Capuzzo, 1989). There have been several investigations on the effect of oil spills in Wild Harbor and West Falmouth (Burns and Teal, 1979; EPA, 1979; Hampson and Moul, 1978; Sanders, 1978; Sanders et al., 1980). There was a general survey of nutrients in a number of the embayments carried out by DEQE in 1975-6 (reviewed by Kelly et al., 1990) and coliforms are regularly monitored by DMF. Costa (1988) examined historical changes in eelgrass in a number of the embayments.

Two embayments have been well studied. There was a complete characterization of the marine resources of the Westport River done in 1966-67, which included a physical and chemical characterization of the estuary (Fiske et al., 1968). Buttermilk Bay has been intensively studied since the mid 1980s by a number of investigators (Valiela and Costa, 1988; Finn and Deegan, 1989; Fish, 1987) and is now the site of a Buzzards Bay Project demonstration project.

While a better characterization of the embayments of Buzzards Bay would be highly desirable, there is a great deal of knowledge about other salt ponds and embayments in New England to draw upon (see bibliography compiled in

Table 1-4. The area and depth of embayments in Buzzards Bay. The data for entire embayment unless otherwise noted (from ACI, 1991).

Embayment Name	Water Area (ha) HTL[a]	Depth (m)
Acushnet River	1,073	4.2
Allens Pond	77	1.1
Apponagansett Bay	293	2.3
Aucoot Cove	29	2. 9
Brandt Island Cove	34	1.4
Buttermilk Bay	217	1. 7
Clarks Cove	286	4.1
Hen Cove	26	1.5
Marks Cove	43	1.4
Mattapoisett Harbor	432	4.4
Nasketucket Bay	205	2.1
Onset Bay	239	1.8
Phinneys Harbor	217	2.6
Pocasset River	80	1.5
Quissett Harbor	47	2.2
Red Brook Harbor	61	2.4
Sippican Harbor	745	3.1
Slocums River	197	1.3
Squeteague Harbor	30	1.4
Wareham River	249	1.6
W. Falmouth Harbor	80	1.2
Westport River, East	802	1
Westport River, West	532	1.2
Weweantic	238	0.5
Widows Cove	54	1.5
Wild Harbor	49	1.8
Wings Cove	88	2
Total Area	6,523	

[a] area was calculated using the high tide line (HTL)

Giblin, 1990). Consequently, the factors affecting habitat quality in general are fairly well known.

Areal Extent

Embayments, harbors, coves, and tidal rivers make up approximately 10% of area of Buzzards Bay covering 65.2 sq km (l sq km is equivalent to 100 ha) (Table 1-4). The largest of the embayments is made up by the two branches of the Westport River, which together cover over 13.3 sq km (Figure 1-10). Many are quite small; 12 of the embayments are under 1 sq km, and 22 are under 3 sq km.

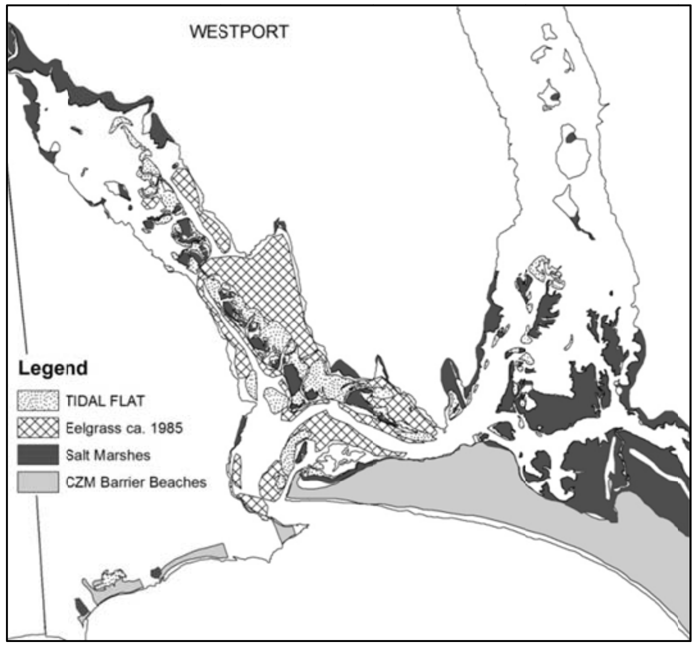


Figure 1-10. Map of Westport River estuary showing the location of barrier beaches, marshes, tidal flats, and eelgrass beds.

Eelgrass coverage not available for the East Branch of the Westport River.

Physical and Chemical Characteristics

Coastal embayments are shallow, semi-enclosed estuarine systems connected to the sea by narrow inlets. In Buzzards Bay, most were formed at the end of the last ice age when the glaciers retreated and sea level rose although some owe their origin to natural indentations of bedrock along the coast (Fitzgerald, 1985). The inlets along Buzzards Bay are classified as microtidal. Because tidal range is an important factor controlling inlet size most of the inlets in Buzzards Bay are small (Fitzgerald, 1985). In addition, the size and flushing rate of most New England coastal embayments are decreasing. This is due to the washover of the barrier beach, the delivery of sediment from flood tidal currents and wind, and the sedimentation of fine-grained material within the inlets.

The average salinity of the embayments ranges from nearly fresh in the upper reaches of embayments with surface water inflow to 30% in larger embayments with small freshwater inflows. Because they are shallow and have freshwater inputs, temperatures tend to be warmer in the summer and colder in the winter than the open bay.

Biological Characteristics and Major Species Present

The species found in embayments include those usually associated with eelgrass tidal flats, barrier beaches and marshes (see sections below). Because of their shallow protected nature, embayments are often considered nursery grounds for fish and are productive shellfishing areas. Fish species in riverine embayments may include anadromous and brackish water species such as the Atlantic silverside, sticklebacks, alewives, killifish, the American eel, and blueback herring. Nearly all embayments contain marine fish species such as sculpin, winter flounder, and scup. A number of fish use the embayments primarily as juveniles (blue fish, tomcod, white hake, and pollock) and are rarely present as adults. Shellfish can be abundant in embayments and these Buzzards Bay embayments are the major habitat for bay scallops, oysters, and hard and soft-shelled clams (see Grice, Chapter 2 of this report).

Eelgrass has historically been important in coastal embayments, and the fresher regions of estuaries were important refuges during the wasting disease of the 1930s (see sections below). Recently eelgrass beds in many embayments have been lost or replaced by drift macroalgae (Costa, 1988). Abundant algal species include *Cladophora vagabunda, Gracilaria*, *Codium*, and *Ulva lactuca*.

Productivity and Factors Affecting Habitat Quality

Nutrient enrichment is the major factor affecting habitat quality in most embayments. Coastal embayments are naturally productive environments. In general, levels of *Chlorophyll a* and macrophytes are higher in embayments than in open bays (Nixon et al., 1982). This is because embayments intercept a large proportion of the nutrient load coming from rivers and groundwater before it reaches the open bay (Nixon et al., 1982; Lee, 1980; Valiela et al., 1990; Giblin and Gaines, 1990). However, when nutrient loading becomes excessive, the species composition of ecosystem changes dramatically and there can be a loss of many of the commercially important species. As described below, eelgrass is sensitive to nutrient enrichment, and eutrophication can lead to the loss of eelgrass beds, which may be replaced by macroalgae. There is evidence that the loss of eelgrass causes changes in the fish community in which species such as flounder, pollock and white hake are replaced by species such as killifish and sticklebacks (Deegan et al., 1990).

Scallop recruitment may also be adversely affected although the relationship between scallops and eelgrass is still controversial. Another consequence of nutrient enrichment can be an increase in the occurrence of anoxia in the water column. Anoxia kills both fish and benthic invertebrates and can drastically reduce secondary production.

Elevated levels of coliform bacteria are a management problem in many embayments (Grimes and Heufelder, 1990). Shellfishing and bathing have been periodically closed in many areas in Buzzards Bay due to the presence of coliform bacteria that indicate the presence of fecal contamination. While coliform bacteria are a public health problem, and adversely affects human use of the embayment, their presence per se does not adversely affect the ecosystem. However, high coliform counts are frequently associated with nutrient loading from sewage or stormwater runoff so they may be an early warning sign of problems to come.

The Acushnet River - New Bedford Harbor embayment has been adversely affected by the discharge of large quantities of industrial waste, especially PCB's and metals. Concentrations of PCBs in the sediments from the inner harbor are among the highest ever recorded (Farrington and Capuzzo, 1989) and metal concentrations are orders of magnitude above background (Stoffers et al., 1977) High concentrations of PCBs have been found in fish, shellfish and lobsters from this area (Farrington and Capuzzo, 1989) and metal concentrations in a number of species are also elevated (SES, 1987). This has had an adverse effect on the human use of the embayment. The harvesting of fish, lobster and shellfish within the embayment is prohibited, because of both PCB and coliform contamination (Farrington and Capuzzo, 1989). Assessing the effect that these contaminants have had on the ecosystem is more complex. However, physiological and metabolic studies indicate that organisms from New Bedford Harbor are stressed and that settlement and survival of larvae on New Bedford sediments is adversely affected when compared to control areas (summarized in Farrington and Capuzzo, 1989).

New Bedford Harbor is now a superfund site, and there have been a number of proposals to clean up the Harbor, These proposals include dredging the sediments with disposal on land, to capping them in place. Clearly, any project of this magnitude will have a major impact on the embayment, whatever method is chosen.

The passage of oil barges though the canal makes large oil spills a potential problem for all the embayments. When oil reaches an embayment, the effects can be acute. A spill of 175,000 gallons of No. 2 fuel oil in West Falmouth eventually contaminated 5,000 acres of the subtidal sediments of Wild Harbor and covered 500 acres of marshland (EPA, 1979). The spill caused a mass mortality of benthic community and there is evidence that 20 years later the oil may still be adversely affecting some areas of Wild Harbor. Salt marshes are particularly sensitive to oil contamination.

Boats, moorings, docks, and piers are potentially an important factor affecting habitat quality in embayments.

Physically, the presence of these structures removes a portion of the subtidal habitat for eelgrass and the shading effects can increase the areas effected several fold. Little is known about the actual impact of these structures.

Barrier Beaches and Coastal Dunes

Introduction

Barrier beaches include both coastal beach areas lying roughly parallel to the shoreline, and coastal dunes (Figure 1-11). The geomorphology of some of the larger barrier beaches along the eastern and southern shores of Cape Cod have been extensively studied (Aubrey and Speer, 1985; Aubrey and Gaines, 1982; Fitzgerald and Levin, 1981; Geise et al., 1989). Much less information is available on the barrier beaches found around Buzzards Bay although work has been done on the Slocum-Westport River inlets (Fitzgerald, 1985; Fitzgerald et al., 1986). General information on the resources and management of barrier beaches can be found in Smith (1983), the "Barrier Beach Management Sourcebook"; Massachusetts CZM (1979), "Massachusetts Barrier Beaches"; and in Godfrey (1976), "Barrier Beaches of the East Coast."

Areal Extent

Barrier beaches cover 1689 acres (2.471 acres = 1 hectare) around the Bay (Table 1-5). In general, the size of these beaches is small (Hankin et al., 1985). Of the 30 largest barrier beaches in Massachusetts, only one, at the entrance of the Westport River estuary, is in Buzzards Bay.

Physical and Chemical Characteristics

The geomorphology of coastal beaches and dunes is altered by the combined action of water, wind, and biological factors. Barrier beaches are areas subjected to moderate to high wave activity. Sand on the intertidal zone of coastal beaches is regularly moved around by the actions of waves and currents, and is quite unstable. Higher up on the beach and in the dunes, wind is the primary force redistributing sand, although storm surges may lead to major changes in barrier beach topography.

Dunes form in areas where windblown sand is stabilized by the growth of plants. Because of the low nutrient and water content of most sandy beaches, grasses usually first become established at the strand line where deposition of detritus washed onto the beach creates conditions more favorable to plant growth. Dunes grow as more sand is trapped by the plants. The root systems of the colonizing grasses stabilize the sand. After the initial stabilization, a variety of species invades the dune. Eventually shrub thickets, salt marshes, and even woodlands may develop behind the dunes (Figure 1-11A).

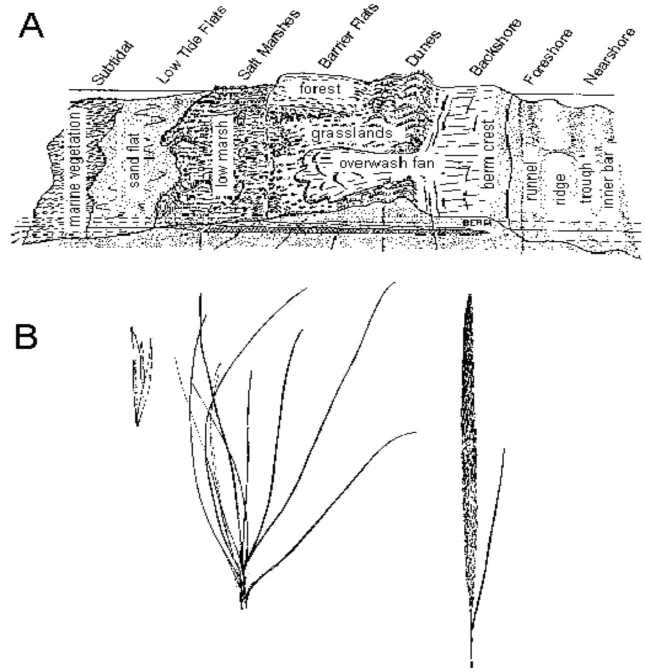


Figure 1-11. A. The basic zones of a barrier beach (from Godfrey 1976). B. Drawing of the dominant dune plant, the beach grass *Ammophila breviligulata* (from Petrey and Norman, 1968).

Barrier beaches and dunes are inherently dynamic features of the landscape. Under the current conditions of rising sea level, barrier beaches are migrating in a landward direction (Godfrey, 1976). As the dunes retreat, they wash over the marshland behind them and create shallow water conditions in the area behind the dunes (Figure 1-11A). New marshes may form in these shallow areas. As long as the barrier beaches are not prevented from migrating inland, the estuary will not be submerged but in areas where development interferes with migration, the marshes are lost (Godfrey, 1976).

Biological Characteristics and Major Species Present

One of the most conspicuous and important plants found along coastal beaches is beach grass, *Ammophila breviligulata* (Figure 1-11B). This plant typically grows above mean high water in areas which receive salt spray and where windblown sand accumulates. It serves an important function in stabilizing the dunes and is capable of surviving a sand burial rate of up to a meter per year (Ranwell, 1972). Plants spread across the dunes primarily by growth from rhizomes. Seedling establishment does occur but it is rare and may require periods of heavy rainfall.

A number of other plants are capable of colonizing primary dune areas. Common plants include dusty miller (*Artemisia stelleriana*), seaside goldenrod (*Solidago sempervirens*),

Table 1-5. Area of nearshore soft substrate communities by Town (ha).

Town	Salt Marsh	Eelgrass[a]	Barrier Beach [b]	Tidal Flats [b] Marine	Estuarine
Acushnet	9	-	-	0	20
Bourne	121	527	30	15	67
Dartmouth	463	167	62	6	108
Fairhaven	246	467	35	179	57
Falmouth	106 (bay)	559(bay)	113(all)	52	73
Gosnold	57	274	75(all)	10	4
Marion	124	331	16	19	19
Mattapoisett	142	414	34	178	6
New Bedford	0	1	0	0	44
Wareham	364	914	24	104	79
Westport	427	350	295	0	823
TOTAL	2,059	4004	684	563	1,300

[a]Costa (1988)
[b]Hankin et al. (1985)

beach pea (*Lathyrus japonicus var. glaber*), and beach heath (*Hudsonia tomentosa*). In the more sheltered areas behind the dunes where the vegetation is protected from salt spray, herbaceous and woody species such as poison ivy (*Rhus radicans*), salt spray rose (*Rosa rugosa*), bayberry (*Myrica pensylvanica*), and beach plum (*Prunus maritima*) are common. Interestingly, several of these species are not native to New England, but were introduced during the last two hundred years. Dusty miller, which has a vegetative growth habit very similar to beach grass, was imported from eastern Asia (Petry and Norman, 1968). *Rosa rugosa* was introduced into the US from Japan in 1872 and made its way to Cape Cod shortly thereafter (Petry and Norman, 1968). This plant has successfully colonized the areas behind dune ridges throughout the northeastern US.

Coastal beaches and dunes are harsh environments. Marine animals are limited in their ability to colonize beaches by desiccation and terrestrial species are limited by salt stress and low moisture availability. These conditions, plus freezing during winter, severely restrict both the diversity and the abundance of resident fauna. Common animals include amphipods (especially from the families *Talitraidae* and *Haustoriidae)*, and in more sheltered beaches a variety of gastropods including *Ilyanassa*, deep burrowing bivalves such as *Ensis*, and polychaetes such as bloodworms (family *Opheliidae*). For the most part, organisms migrate with the tide but do not make their burrows in the intertidal (Gosner, 1971). For example from the seaward side, the mole crab, *Emerita talpoida*, scavenges along the beach, while beach fleas (amphipods) such as *Talorchestia* sp. forage down to the water's edge but maintain burrows in the supralittoral. Although horseshoe crabs *(Limulus polyphemus*) live further offshore, they come up onto the beach in large aggregations in the spring to lay their eggs at the high tide line.

Factors Affecting Habitat Quality

The extensive placement of groins, jetties, and other structures designed to stabilize the shore have disrupted the normal movement of sand in many areas. Structures which interrupt the longshore transport of sand cause a seaward progradation of the shoreline on the down current side while the beach on the opposite side erodes because the supply of new sand is cut off. The other factors affecting the quality of beach and dune habitats are both foot and vehicular traffic. Dune vegetation is very prone to trampling, and even a small amount of foot traffic can kill the delicate plants. Once the vegetation is destroyed, the dune becomes unstable. Off-road vehicles (ORV) can pose an especially destructive hazard, although ORV traffic is usually limited to the more firmly packed sand of the lower beach. ORVs crush the infauna and reduce the amount of forage available for epibenthic predator and birds. Both ORVs and foot traffic also disturb nesting birds (see Chapter 5 by Poole).

Salt Marshes

Introduction

Salt marshes in Massachusetts are defined as coastal wetlands which extend landward up to the highest high tide line and which are characterized by plants that are adapted to living in saline soils. Salt marshes are divisible into a number of subhabitats and zones including tidal creeks, small pools, low and high marsh, and upland areas. In most marshes, the natural tidal creeks flowing through the marshes have been augmented with manmade ditches built to enhance drainage and reduce mosquito-breeding habitat.

Once considered to be wastelands infested with disease containing insects, marshes are now valued for their role in supporting coastal fisheries and bird populations. A number of comprehensive reviews on salt marshes are available including Teal (1986) on the ecology of the low marsh, Nixon (1982), on the ecology of the high marsh, and Daiber (1982) on animals of the tidal marsh. A great deal of information on Buzzards Bay salt marshes is available because of research projects carried out by John Teal (WHOI) and Ivan Valiela (BUMP) in the Great Sippewissett Marsh since 1970 (See references in Tripp, 1985).

Areal Extent and Historical Changes

Salt marshes cover about 2,059 ha in Buzzards Bay (Table 1-5; SREPEDD, 1989). The ratio of marsh area to the size of the Buzzards Bay embayment is 0.037. Although small when compared to the marsh dominated estuaries of the southeastern United States, this is nearly twice the marsh: embayment ratio of either Narragansett Bay or Long Island Sound (Welsh et al., 1982).

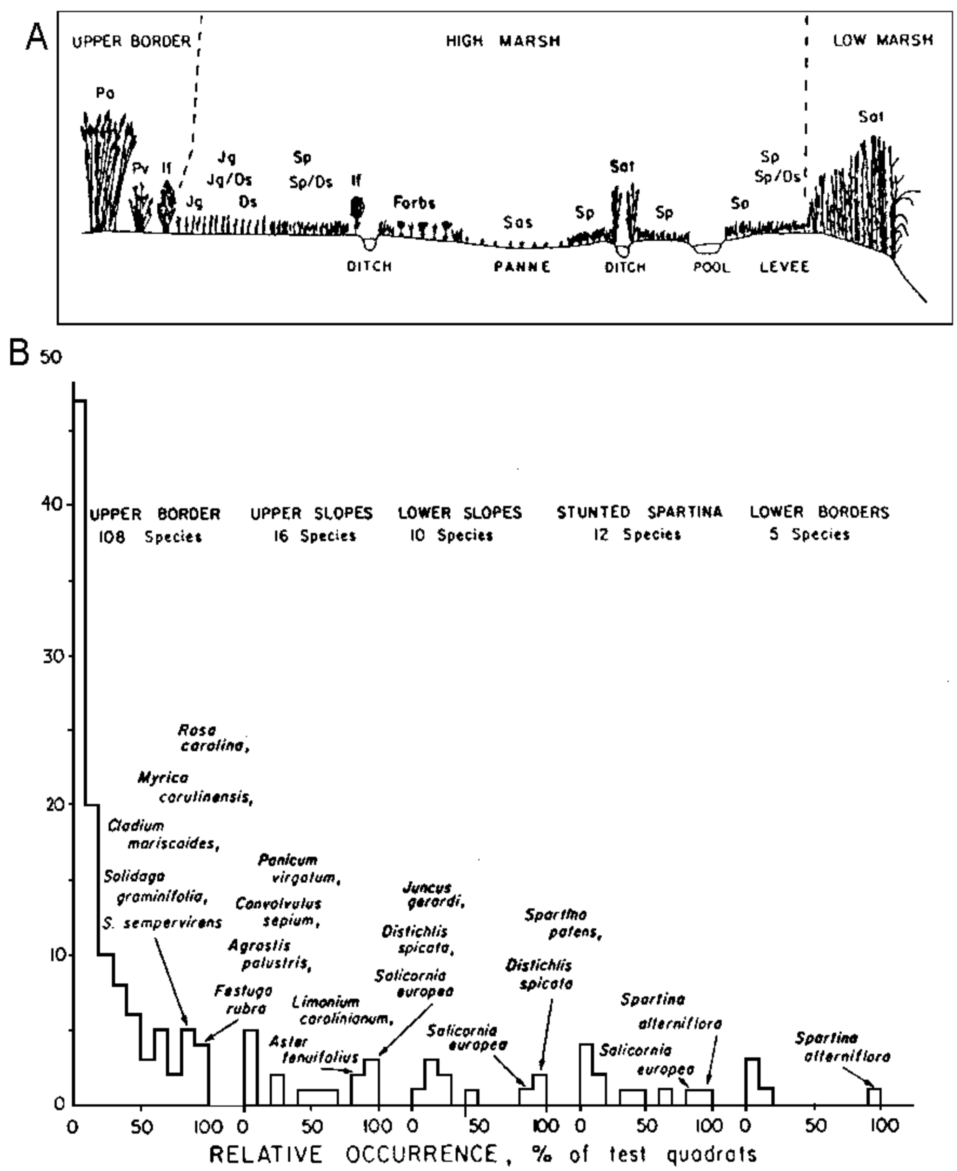


Figure 1-12. A. Generalized transect from the uplands to the low intertidal in a "typical" New England salt marsh showing the common vegetation types.

Key to symbols: Sat = tall *Spartina alterniflora*; Sp=*Spartina patens*; Ds= *Distichlis spicata*; Sas=short *Spartina alterniflora*; If= *Iva frutescens*; Jg= *Juncus gerardii*; Pv= *Panicum virgatum*; Pa= *Phragmites australis*. From Niering and Warren (1980). B. Relative diversity, dominance, and major species composition of vegetation zones described by Miller and Egler (1950) at the Wequetequock-Pawcatuck marshes in Connecticut. In each zone, species listed are those present in 80% to 90% or 90% to 100% of the sample quadrats. For example, in the upper border 108 plant species were found: 5 species occurred in 80% to 90% of the quadrats sampled, and 4 species occurred in 90% to 100% of all quadrats. Almost 50 species were rare and only found in 1% to 10% of the quadrats

It has been estimated that approximately 10% of the salt marsh area present in 1951 has been lost, with most of the losses occurring before 1971. Wetland protection laws have in most cases, stopped the destruction of salt marshes. Nearly all of this loss occurred in three towns: Bourne, Wareham, and Westport.

Physical and Chemical Characteristics

Salt marshes occur in areas protected from direct wave action, such as behind barrier beaches or around salt ponds and estuaries (Figure 1-10). In these quiescent areas, sediments accumulate and become colonized by plants capable of withstanding saline conditions (halophytic plants). The grass blades slow current flow and promote the deposition of sediments and the partially decomposed plant remains. Sediments in marshes are accreting at approximately the same rate as sea level is rising. The development of salt marshes in New England is strongly influenced by barrier beach migration. In response to rising sea level, salt marshes must migrate inland with the barrier beach, or become buried beneath the dunes (Redfield, 1972).

The vegetated portion of salt marshes is normally defined as either low marsh, which is the area of the marsh regularly flooded by the tides, or high marsh, which encompasses the area only flooded during spring high tides. The intertidal low marsh area is characterized by peaty soils that are usually saturated with water. The high marsh area also contains peaty sediments, but tends to be somewhat drier near the surface than low marsh sediments. Sediments in both the low and high marsh tend to be highly reducing at depth (i.e. do not have oxygen present), and may contain substantial quantities of hydrogen sulfide. Unvegetated depressions, known as pannes and pools are frequently found on the marsh surface. The origin of pannes may be related to the deposition of wrack on the marsh surface, which smothers and shades grasses, killing them (Hartman, 1984).

Biological Characteristics and Major Species Present

The cordgrass, *Spartina alterniflora*, dominates the low marsh area in salt marshes throughout all of New England and most of the Eastern seaboard (Figure 1-12; Teal, 1986). This grass usually occurs in monotypic stands, although other plants such as *Salicornia* (glassworts) and *Limonium* (sea lavender) may be present in low numbers. *Spartina alterniflora* is a halophyte (salt tolerant) adapted to living in the anoxic (without oxygen) soil of salt marshes. The plant spreads primarily by the growth of rhizomes, although there may be some colonization of bare flats by seeding. The grass has two characteristic growth forms, "short" and "tall" (in reality there is a continuum of heights; Valiela et al., 1978). At the lower elevations, and in areas of good drainage and/or nutrient supply, the "tall" form reaches a height of up to three meters. Higher in the intertidal, a more stunted "short form" occurs which may only reach 20-40 cm.

There is a greater diversity of vascular plants in the high marsh, but the community is still dominated by a few halophytic grasses (Figure 1-12; Nixon, 1982; Hartman, 1984). The two major species are salt marsh hay *Spartina patens*, and spike grass *Distichlis spicata*. *Salicornia* and *Limonium* also occur in the high marsh. At the upper edge of the high marsh zone, *Juncus gerardii* (spike grass) may make up a significant portion of the community (Figure 1-12; Hartman, 1984; Nixon, 1982) and the shrub, marsh elder (*Iva frutescens*), is found in a transition zone between the marsh and upland vegetation. Macro and microalgae can be locally important as primary producers in both the emergent marsh and in tidal creeks. The macroalgae *Ascophyllum nodosum*, *Fucus vesiculosus*, *Enteromorpha*, *Ulva*, and *Codium fragile* may all be found growing in tidal creeks. Occasionally *Ascophyllum* and *Fucus* may form fairly dense mats at the lower end of the low marsh. Microalgae, mostly diatoms, as well as blue green bacteria, colonize both the marsh surface between the grass shoots and the sediments of tidal creeks. Diatoms living on the marsh surface are sometimes referred to as edaphic (soil) algae, to distinguish them from diatoms living on tidal mud and sand flats (Sullivan and Moncrieff, 1988). The major species present are in the genera *Navicula*, *Nitzschia*, *Achnanthes*, and *Amphora* (Sullivan, 1978; Van Raalte et al., 1976b). Most benthic and epiphytic diatoms are pennate forms (i.e. are fusiform in shape) as opposed to most planktonic species which tend to be radially symmetrical, centric forms.

Benthic diatoms use two basic strategies to maintain their position in the sediments, and avoid resuspension and grazing. Epipsammic species which live mainly in sandy substrates, attach themselves directly to the sediment grains. Epipelic forms are motile and may migrate to the surface of sediments when tidal and light conditions are favorable, then migrate downwards when conditions become unfavorable (e.g. in the dark or when the tide is high and resuspension and/or grazing would threaten them) (Harper, 1977). Diatoms can also grow epiphytically attached to the surface of fronds of macroalgae (Lee et al., 1975; McIntire and Moore, 1977). Benthic diatoms have high nutritional value compared to vascular plants, and even though their standing stock is much lower than that of the grasses which colonize the marsh surface, they are heavily grazed by deposit feeding invertebrates and fish (Foreman, 1989; Pace et al., 1979; Werme, 1981). They appear to be nutritionally important components of the salt marsh food web (Lopez and Levinton, 1978; Levinton and Bianchi, 1981; Montagna, 1984; Sullivan and Moncrieff, 1990).

A variety of animals of both terrestrial and marine origin are found in marshes. Insects have received considerable attention. The marsh mosquito, *Aedes sollicitans*, is common in New England and has been the object of many control strategies. The adults lay their eggs in the high marsh areas where they develop. Larvae hatch out after spring tides or heavy rains (Teal, 1986). Biting midges and horse flies may also be locally abundant.

Other animals of terrestrial origin are found in the salt marsh where they live primarily in the high marsh, but may venture into the low marsh areas to feed. For example, at low tide the endangered diamond back terrapin (*Malaclemys terrapin*) feeds on fish, mollusks, and crustaceans in the tidal creeks. The marsh mouse (*Microtus pennsylvanicus*) nests in the high marsh but forages in the low marsh feeding on the basal stem of *S. alterniflora*. A large number of birds including the black duck (*Anas rubripes*), snow geese (*Chen caerulescens*) and Canada geese (*Branta canadensis*), herons, bitterns, egrets, and ospreys (Poole Chapter 5) all feed in the marsh, but nest on higher ground. There are a few birds which do nest in the marsh and these include clapper rails (*Rallus longirostris*), grackles and red-winged blackbirds.

Marine invertebrates, especially the benthic infauna, living in the marshes include many species common to both sand and mud flats. There are, however, a number of species whose distribution is restricted to the salt marsh. Among these specialists include two species of fiddler crabs, *Uca pugnax* and *Uca pugilator* and the marsh crab *Sesarma reticulatum*, although, Cape Cod is close to the northernmost range of these species. The green crab (*Carcinus maenas*) is an important predator in tidal creeks. The blue crab (*Callinectes sapidus*) is occasionally found in low numbers although, once again, Cape Cod is near the northern range of this species. The ribbed mussel

(*Geukensia demissa*) is very abundant in the tidal creeks and at the base of the stems of *S. alterniflora*. *Geukensia* filters suspended matter from the water column and obtain nutrition from both phytoplankton and *Spartina* detritus (Peterson et al., 1985). The pulmonate snail *Melampus bidentatus* feeds on the mud and stems of *Spartina* and climbs to the tops of the grass stems at high tide.

Productivity

Salt marshes are considered to be among the most productive ecosystems of the world. Estimates of above ground net primary production range from 300 to 3,000 g m^{-2} y^{-1}, and total production may exceed 7,000 g m^{-2} y^{-1} of organic matter (see review Schubauer and Hopkinson, 1984). In general, primary production in New England salt marshes is lower than that reported for more southern marshes, but still quite high when compared to other environments. Within the marsh, there is a great variation in above ground production with the highest productivity occurring in the tall *S. alterniflora* zone and considerably less in the areas of short *S. alterniflora* and in the high marsh (Table 1-6). Total production is much more difficult to measure but it appears that the production of roots and rhizomes below ground in marshes is very high in all areas (Table 1-6).

There have been a great number of studies on the factors which control the primary production of salt marsh grasses (see review by Chalmers, 1982). The striking difference in above ground primary production in the different tidal zones led investigators to suspect that soil drainage and/or flushing was an important factor controlling marsh production. At nearly the same time, a series of experiments in Great Sippewissett marsh demonstrated that adding a nitrogen containing fertilizer could dramatically increase the above ground primary production, although the below ground production of roots and rhizomes did not appear to change (Valiela et al., 1976). It is now thought that production is controlled by a complex interaction between soil aeration, salinity, and nitrogen availability - all of which are controlled at least in part by soil/water movement. Drainage removes hydrogen sulfide from the rooting zone and may allow for oxygen penetration (Howes et al., 1981). Increased flushing lowers interstitial salinity. Both high salinity and sulfide levels inhibit the metabolic processes necessary for nitrogen uptake, causing growth to be limited by nitrogen availability. This is true even though soil nitrogen concentrations may be higher in stagnant areas (Mendelssohn, 1979). Adding additional nitrogen allows the plants to at least in part to overcome this nitrogen limitation.

In addition to the grasses, benthic macro- and microalgae are important primary producers in marshes. Ruber et al. (1981) found that macroalgal production in pools of standing water was about 514 g organic matter m^{-2} $\mathbf{y^{-1}}$ (ash free dry weight), similar in magnitude to the above ground grass production. Productivity of edaphic microalgae of salt marshes ranges from 50-200 g C m^{-2} y^{-1}, or between 8-33% of the vascular plant production (Sullivan and Moncrieff, 1988 and references cited therein). At Great Sippewissett marsh adjacent to Buzzards Bay, microalgae growing on the marsh surface reportedly produce 105 g C m^{-2} y^{-1} (Van Raalte et al., 1976a). This is comparable to productivities observed in *Spartina* marshes in Delaware (80 g C m^{-2} y^{-1} Gallagher and Daiber, 1974) and Mississippi (57 g C m^{-2} y^{-1} (Sullivan and Moncrieff, 1988).

Table 1-6. Primary production in the different marsh zones at Great Sippewissett March (Valiela, 1976) and of benthic algae growing beneath the grass canopy (van Raalte et al., 1976a).

Grasses	**Above g OM $m^{-2}y^{-1}$**	**Below g OM $m^{-2}y^{-1}$**	**Total g OM $m^{-2}y^{-1}$**
Short	420	3,500	3,920
Tall	1,320	3,315	4,635
High	630	2,520	3,150
	g C m^{-2} y^{-1}		**g Cm^{-2} y^{-1}**
Benthic algae	42		42

Depending on the site, time, and space scales of the experiments, light, nutrients, and grazing have all been reported to limit edaphic algal productivity. Van Raalte et al. (1976a) found light was the most important factor limiting production of epibenthic algae. She conducted experiments in the Great Sippewissett marsh in which removal of the grass canopy greatly enhanced productivity, while addition of fertilizer only slightly increased algal production. Whitney and Darley (1983) reported that edaphic algae of a Georgia salt marsh were also primarily light limited. On the other hand, in small scale enrichment experiments in which ammonium solutions were injected directly into sediment cores transplanted to the field, Darley et al. (1981) found that nutrients and grazing exerted more control over the growth of edaphic algae than light.

At some times of the year, epipelic microalgae are found in high abundance in tidal creeks. Their biomass peaks in May-June (Foreman, 1989). Heavy grazing during the summer reduces algal abundance to very low levels by September/October. Microalgal populations then build up again over the following winter and spring. The ecology of creek bottom microalgae will be discussed in more detail in the section on tidal flats.

Factors Affecting Habitat Quality

Until the early 1900s *S. patens* was cut and harvested for forage, and, occasionally, animals were allowed to directly graze on the marsh. Nixon (1982) reviews the historical importance of this source of fodder and points out that in spite of the mosquito problem, early settlements were located adjacent to salt hay marshes. Based upon data from other areas, we can assume that the impact of these activities was fairly low, although grazing can alter species composition of the high marsh, and decrease marsh grass productivity (Shanholtzer, 1974).

Historically the most important factor affecting habitat quality in marshes has been the filling of marshes and the human alteration of drainage patterns. About 10% of the total salt marsh area in Buzzards Bay was lost between 1951 and 1971, and much of this loss was due to dredging and filling. Tidal flushing in many other marshes was altered by culverts and other structures. The close coupling between the hydrologic regime and primary production makes the salt marsh quite vulnerable to changes in tidal inundation and drainage. For example, Sears and Parker (1985) reported on an extensive die-off of *Spartina alterniflora* in a marsh in South Dartmouth, MA. They attributed this die off to the restriction of flow in a culvert that drained the marsh. Dikes, formed from dredge spoils from mosquito ditching, also reduced circulation and affected drainage. These may have contributed to the problem in South Dartmouth as well. The recolonization of even moderately sized bare areas by *S. alterniflora* is very slow (Sears and Parker, 1985; Hartman, 1984), thus drainage problems caused by culverts can have long lasting consequences.

Marsh hydrology in New England has also been altered by ditching carried out between the 1930s and 1960s for mosquito control. The purpose of the ditching was to drain standing pools of water where mosquitoes can breed. These pools are also extensively used by birds and fish, so the elimination of this habitat reduces foraging areas (Teal, 1986). In addition, extensive ditching and the careless disposal of spoils contributed to the conversion of low marsh area to high marsh area (Teal and Teal, 1969). Newer techniques of 'open water' marsh management are now being tested by the Massachusetts Audubon Society. With this strategy, marsh ponds are deepened so that fish can survive at low tide. The fish in these ponds eat mosquito larvae and keep populations below nuisance levels (Nickerson, 1985).

Marsh habitat quality throughout New England has been altered by both the deliberate and accidental discharge of pesticides. During the 1950s, marshes were sprayed extensively with DDT for mosquito control (Teal and Teal, 1969, see chapter on birds). The large reduction of osprey populations on the east coast is believed to be due to this practice (see chapter on birds). Once DDT was banned, the ospreys began to recover. The effects of DDT and other pesticides on the marsh have not been as well studied, although experimental studies in Great Sippewissett Salt Marsh have shown that fiddler crabs are susceptible to chlorinated pesticides (Krebs et al., 1974).

Marshes along the Acushnet River estuary have been severely contaminated with heavy metals and PCBs (SES, 1988). A study in this estuary found no indication of adverse effects on the vegetational community, although levels of Cr, Pb, Cu, and Zn were elevated. The fauna, however, may be effected because the northern area of the marsh were dominated by opportunistic species typical of polluted areas while ribbed mussels and fiddler crabs, typical of unpolluted marshes, were nearly absent. This area of the marsh also receives fresh water and high nutrient loading so it is not known if the PCB and metal pollutants were the major factor affecting the fauna. Weaver (1982) reported that shellfish are sensitive to PCB contamination and data from experimental plots on Great Sippewissett marsh has suggested that the survival of tabanid larvae may be affected (Meany et al., 1976) so a direct toxic effect cannot be ruled out.

PCBs appear to be accumulating in some portions of the food web in the Acushnet River marsh (SES, 1989). For example, the ribbed mussels analyzed contained average concentrations of Aroclor 1242 over 20 ppm while concentrations of Aroclor 1254 averaged over 5 ppm. Animals which consume mussels as part of their diet such as ring-billed gulls, had muscle tissue concentrations of Aroclor 1254 averaging about 15 ppm. A single duck analyzed had a muscle tissue concentration of 100 ppm. These levels of PCBs are high enough to suggest that some organisms feeding at the higher trophic levels may be accumulating potentially hazardous levels of PCBs (SES, 1989). The high PCB levels observed in the black duck sample are considerably above the FDA standard for human consumption.

The effect of oil on salt marshes is well known because of the studies on two spills that occurred in Buzzards Bay. The low molecular weight hydrocarbons found in oil are toxic to both marsh vegetation and fauna. It was estimated that up to 95% of the benthic animals were killed because of a No. 2 oil spill in West Falmouth Harbor. Oil was sorbed into the sediments where it persisted, inhibiting recovery eight years later (Burns and Teal, 1979). In Windsor Cove, the oiling of the marsh with No. 2 fuel oil in 1974 resulted in mortality of the salt marsh grass, which had not recovered three years after the spill (Hampson and Moul, 1978). As a result, erosion rates in this marsh were 24 times greater than at a nearby control site. The spill also caused an extensive mortality among crustaceans, polychaetes, and mollusks, which still showed reduced numbers of individuals and species three years later (Hampson and Moul, 1978).

Tidal Flats

Introduction

Tidal Flats are intertidal areas of soft sands or muds. Under the Massachusetts Wetlands Protection Act they are defined as those nearly level portions of coastal beaches which usually extend from mean low water landward to the more steeply sloping face of the beach. They are exposed at low tide and may connect to the beach or be separated from the beach by an area of deeper water. The communities inhabiting the muddy and sandy bottoms of tidal creeks and pools in salt marshes closely resemble tidal flat communities, and so we include them here. A complete description of the ecology of New England tidal flats is given in Whitlatch (1982).

Areal Extent

In Buzzards Bay, tidal flats cover about 1,863 ha (Table 1-5). Approximately 60% of the tidal flats in Buzzards Bay are found within small bays, coastal ponds, and around river mouths. These flats receive some inputs of low salinity water and are classified as estuarine flats. The remainder of the tidal flats in Buzzards Bay are found around the open bay areas and are classified as marine flats.

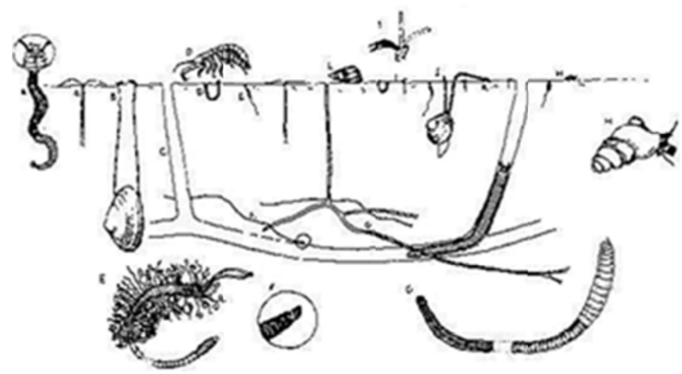


Figure 1-13. Some representative New England mud flat benthic invertebrates

Suspension feeder: B=*Maya arenaria* (soft-shelled clam). Surface deposit feeders: A=*Polydora ligni* (spionid polychaete), D=Corophium spp. (Gammaridean amphipod), H=*Hydrobia totteni* (hydrobid gastropod), I=*Streblospio benedicti* (spionid polychaete), J=*Macoma balthica* (bivalve), L=*Ilyanassa obsoleta* (mudsnail). Burrowing omnivore: C=*Nereis virens* (nereid polychaete). Burrowing deposit feeders: E=Tharyx sp. (Cirratulid polychaete), F=*Lumbrinereis tenuis* (lumbrinerid polychaete), G=*Heteromastus filiformis* (capitellid polychaete), K=oligochaete\

Physical and Chemical Characteristics

Tidal currents and wave action largely control the texture of the sediments found in tidal flats. In exposed areas, sediments are composed of siliceous sands and coarse material while in more protected areas finer clays and muds accumulate.

Physical and chemical conditions on tidal flats show greater variation than in adjacent subtidal areas. Exposure to the atmosphere during low tide subjects tidal flats to greater temperature fluctuations than subtidal areas. Exposed flats can experience salinity fluctuations from precipitation. In winter, ice can build up and scour large areas of the flats.

Biological Characteristics and Major Species Present

Most tidal flats around Buzzards Bay do not support rooted macrophytes or macroalgae. However, in some of the more eutrophic embayments *Ulva* and *Enteromorpha* can be found. In sheltered tidal creeks, macroalgae such as *Codium* and *Fucus* can also grow and persist. Benthic microalgae, on the other hand, are abundant in most tidal flat areas. They are the major primary producers available to consumers. Estimates of the annual productivity of the benthic microflora in tidal flats range from 5-892 g C m^{-2} y^{-1} (Colijn and de Jonge, 1984), but most values fall in the range of 50-200 g C m^{-2} y^{-1} reported above for edaphic algae of salt marshes. In the upper portion of protected tidal flats, large standing stocks of benthic algae and photosynthetic and chemosynthetic bacteria can form dense "algal mats." These mats trap fine grain sediments and are known to accelerate rates of sediment accretion (Whitlatch, 1982).

Diatoms dominate the microalgal assemblage in most areas. Motile diatoms, such as *Navicula*, *Hantzschia,* and *Nitzschia* are abundant and may be favored by their ability to migrate into the sediments to prevent displacement from tidal action (Harper, 1977). However, non-motile forms also contribute significantly to the primary production (Sullivan, 1975). Recently, Admiraal (1984) has comprehensively reviewed work on the ecology of benthic diatoms.

Many of the same groups of organisms (polychaetes, amphipods, gastropods, and bivalves) important in subtidal habitats are also found in tidal flats. The epifauna largely consists of mobile crustaceans and gastropods, although bivalves such as scallops, oysters, and blue mussels are important in some areas (Figure 1-13). A number of the epifaunal species are important predators on mollusks including the blue crab, *Callinectes sapidus*; the green crab, *Carcinus maenas*; the horseshoe crab, *Limulus Polyphemus;* and the gastropods *Polinices duplicatus*, *Lunatia heros*, and *Busycon canaliculatum*. Deposit feeders such as the mud snail *Ilyanassa obsoleta*, and the mud fiddler crab, *Uca pugnax*, can be extremely abundant on mud flats. Hermit crabs (*Pagurus longicarpus, P. pollicaris*) and sand fiddler crabs (*Uca pugilator*) are more common on sand flats.

Mud and sand flats are characterized by different infaunal suites of species. In mud flats, which are usually anoxic below the top 1 cm, surface deposit feeders such as the spionid polychaetes *Streblospio benedicti* and *Polydora ligni* tend to predominate (Figure 1-13). Where lower salinities are found, the oligochaete *Paranais littoralis* may be abundant. *Corophium* spp., a genus of amphipods which live in shallow U shaped tubes and feed on the flocculent surface layer of the sediment, are found in dense patches on the mud flat. In addition, some deeper burrowers such as the capitellid polychaete *Heteromastus filiformis*, and the nereid, *Nereis virens*, may be found. The minute hydrobid, *Hydrobia totteni* can be very abundant.

Sand flats are oxic to deeper depths, and fauna penetrate further into the sediment. Head down feeders such as the orbiniid polychaetes (*Scoloplos* spp.) and bamboo worms (e.g. *Clymenella torquata*) are common (Figure 1-13). Suspension feeders ranging from large razor clams (*Ensis directus*) to the tiny clam, *Gemma gemma*, and to haustorid amphipods abound. A sand dwelling sea cucumber, *Leptosynapta* spp., occurs in the low intertidal.

Tidal flat communities are strongly impacted by grazing and predation because there is little surface structure (i.e. no grass blades as on the surface of the salt marsh or in eelgrass beds) to provide cover or impede the foraging activity of epifauna (Reise, 1985; Vince et al., 1976). The impact of epifauna on the infauna of tidal flats has been examined by placing cages over portions of the flat to exclude epifauna

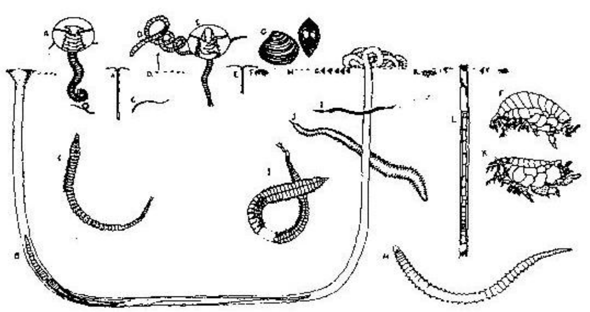


Figure 1-14. Representatives of New England mud and salt flat invertebrates (from Whitlatch 1982).

Surface deposit feeders: A=*Spiophanes bombyx* (spionid polychaete), B=*Saccoglossus kowalevskii* (protochordate), E=Pygospio elegans (spionid polychaete). Burrowing deposit feeders: C=Aricidea sp. (Paraonid polychaete), D=oligochaete, H=*Exogone hebes* (syllid polychaete) I=*Scoloplos* spp. (Orbiniid polychaete), J=*Nephthys* spp. (nephtyid polychaete). Suspension feeders: G=*Gemma gemma* (venerid bivalve), F=*Protohaustorius deichmannae* (haustorid amphipod), K=*Acanthohaustorius millsi* (haustorid amphipod). Conveyor-belt deposit feeder: L=*Clymenella torquata* (maldanid Polychaete)

such as snails, shrimp, fish, and crabs from sections of the habitat. This can result in large increases in the density of benthic microalgae (Pace et al., 1979; Foreman, 1989), macrofauna (Peterson, 1979; Wiltse, 1980; Wiltse et al., 1984) and meiofauna (Foreman, 1989; Palmer, 1988; Reise, 1979) in areas covered by the cages. Epibenthic herbivores and predators may cause the mid- to late summer crash in standing stocks of microflora and infauna commonly observed in tidal flats

(Colijn and Dijkema, 1981; Davis and McIntire, 1983; Whitlach, 1977). In tidal creeks of the Great Sippewissett Marsh, exclusion of epifauna by cages prevents the summer "crash" in infauna from occurring (Wiltse et al., 1984).

Eelgrass

Introduction

Costa (1988) has extensively reviewed the present day distribution, production, and historical changes in abundance of eelgrass in Buzzards Bay. An excellent general review on the ecology of eelgrass meadows of the Atlantic coast is provided in Thayer et al. (1984). Intensive local studies on eelgrass in Cape Cod area have been carried out by Costa (1988); Dennison (1987); Dennison and Alberte (1985; 1986).

Present Day Areal Extent

Using aerial photography and ground-truth estimates, Costa (1988) has calculated that eelgrass beds are present in about 4004 ha of the bay. The density of eelgrass in the beds varies greatly. If a correction is made for the percent cover in the beds, then eelgrass covers 2929 ha (Table 1-5). More than two thirds of the eelgrass in Buzzards Bay occurs in well flushed waters of the open bay. The remainder is found in shallow protected bays, coastal ponds, and portions of the major river estuaries. Most of the eelgrass in Buzzards Bay is found at a depth between the intertidal zone and 3.6 m (MLW) but a few beds may extend to 6 m. As explained below, in factors affecting habitat quality, eelgrass coverage has varied dramatically over the last 50-100 years.

Physical and Chemical Characteristics

Eelgrass is found on a variety of sediment types in Buzzards Bay ranging from gravel bottoms to fine muds. It grows in both poorly flushed areas, as well as high velocity areas where currents may reach speeds of 1.5 m s^{-1} (Fonseca et al., 1983). Current velocities are low enough in Buzzards Bay that eelgrass distribution is probably not limited by this factor. Wave exposure and ice scouring does limit eelgrass colonization in some areas such as the surf zone of the open bay. In Buzzards Bay, eelgrass is generally confined to regions of estuarine embayments where the salinity ranges from about 20 to 32 ppt. Eelgrass is reported to be capable

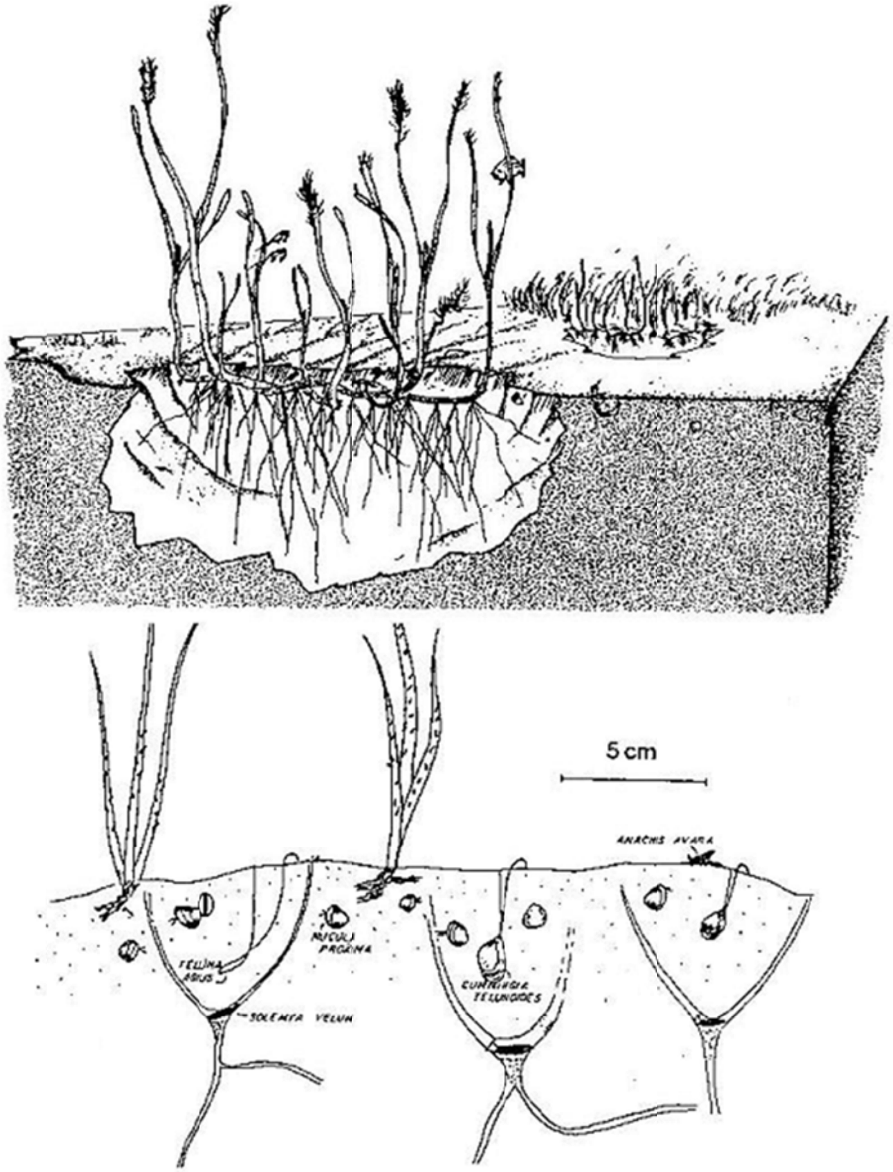


Figure 1-15. Eelgrass community structure.

Upper: Three dimensional depiction of an eelgrass bed showing the root and rhizome structure of the dominant plant *Zostera marina*. Note the epiphytes on the blades (from Thayer et al., 1984). Lower: Cross section of an eelgrass bed showing some of the common infauna found in Buzzards Bay (from Levinton and Bambach 1975).

of withstanding sustained salinities as low as 5 ppt (Biebel and McRoy, 1971), so exclusion of eelgrass from the upper portions of embayments such as New Bedford Harbor, Little Bay, Fairhaven and Apponagansett is probably not due to low salinity (Costa, 1988). Eelgrass was present in the upper reaches of these bays previously (Costa, 1988).

The major factor which influences eelgrass distribution in Buzzards Bay, and elsewhere, is believed to be light (Dennison, 1987; Kemp et al., 1983; Lee et al., 1985). Light availability to eelgrass is controlled by a number of factors including water depth, phytoplankton abundance, epiphyte cover, and the load of suspended sediments. In poorly flushed embayments subjected to high nutrient loads, standing stocks of epiphytes and phytoplankton may increase, resulting in shading of eelgrass. In shallow systems, excessive boat traffic can resuspend enough sediment to significantly reduce light availability. As a consequence, eelgrass beds grow to deeper depths near the southern and eastern shores of Buzzards Bay than at the northwestern end which is less well flushed, and has larger nutrient inputs (Costa, 1988).

Biological Characteristics and Major Species Present

Eelgrass beds are so named after the dominant vascular plant, *Zostera marina L.* found growing subtidally in beds along the coastal zone (Figure 1-14). Eelgrass is a marine angiosperm that is found only in the temperate zone of the Northern hemisphere. The eelgrass habitat differs from unvegetated benthic habitats in several important respects (reviewed by Thayer et al., 1984): 1) eelgrass roots and rhizomes reduce current velocity inside the bed and thereby limit sediment resuspension; 2) eelgrass roots and rhizomes stabilize the sediments; 3) the presence of eelgrass blades serves as baffles of current flow and which promotes sedimentation of suspended particles; 4) the physical structure of the eelgrass plants may create a refuge for animals which reduces the risk of predation; 5) eelgrass detritus serves as a food source, and 6) eelgrass blades serve as a substrate for other plants and animals. As a consequence of both the high in-situ production of eelgrass beds and the increased sedimentation, total organic matter in the sediments of eelgrass beds is normally higher than nearby unvegetated areas.

Associated with eelgrass are a wide variety of organisms including epiphytic algae, hydroids, sponges, and bryozoans growing on the eelgrass blades as well as a variety of benthic invertebrates living both among the blades and in the sediments (Figure 1-15). Harlin (1980) has reviewed the literature on eelgrass epiphytes and compiled a list of 354 macroalgal, 152 microalgae and 124 faunal species which are found as epiphytes on eelgrass blades. Allee (1923) listed 140 animal species in eleven phyla that were found in eelgrass communities and classified 55 of these species as "characteristic." In general, these species are not endemic to eelgrass beds, but rather they are representative of the fauna of nearby unvegetated areas (Thayer et al., 1984). However, a few species, such as the shrimp *Hippolyte zostericola* are true endemics. After the wasting disease of 1931 about a third of the "characteristic' species such as gastropods *Bittium* and *Mitrella* disappeared or became very rare (Stauffer, 1937) demonstrating their heavy dependence upon eelgrass beds. The commercially important bay scallop *Argopecten irradians* experienced a catastrophic population decline at this time, as did the Atlantic brant (*Branta bernicla hrota*) (Thayer et al., 1984).

It has been speculated that eelgrass communities help support coastal fisheries. Studies have indicated that the abundance of infauna and mobile animals are greater in eelgrass beds than in nearby unvegetated areas (Thayer et al., 1975; Summerson and Peterson, 1984) although no data is available for Buzzards Bay. The large decline of bay scallops following the wasting disease suggested that eelgrass beds are important to the productivity of this species, however, in general there was not a whole-scale decline in other coastal fisheries following the large scale eelgrass decline of the 1930s (Thayer et al., 1984).

Productivity

Net primary production of eelgrass in Buzzards Bay is approximately 393 g C m^{-2} y^{-1} (Costa, 1988). Most of this production, approximately 350 g C m^{-2} y^{-1}, occurs above ground. Eelgrass production in the entire bay has been estimated as 78 x 10^{8} 1 g C y^{-1}, more than twice the estimate salt marsh production (Costa, 1988). In addition to production that can be directly attributed to eelgrass, carbon is fixed by epiphytes growing on eelgrass leaves. Epiphyte cover on eelgrass leaves varies greatly. Maximum epiphyte load is found on beds in poorly flushed areas.

Costa (1988) has estimated that, bay-wide, epiphytes contribute an addition 20% to primary production in eelgrass beds, or 15 x 10^{8} g C y^{-1}. Overall, eelgrass and its epiphytes make a significant contribution to the primary production of the open bay, accounting for about 13% of the carbon fixed annually in the bay (Costa, 1988).

Historical Changes

During the early 1930s, eelgrass along the coasts of both North America and Europe was virtually destroyed by the "wasting disease." The cause of wasting disease has been shown to be a pathogenic strain of slime mold *Labyrinthula* (Short et al., 1987). Eelgrass was essentially wiped out Buttermilk Bay, Sconticut Neck, West Falmouth, and around Woods Hole (summarized by Costa, 1988). It has been estimated that less than 0.1% of the eelgrass beds in the upper bay survived (Stevens et al., 1950). Some beds in deeper water, as well as beds in low salinity areas, were not affected (Costa, 1988). Costa (1988) has used aerial photos to document changes in eelgrass cover in Buzzards Bay since the wasting disease. He found that in deeper, well-flushed embayments, such as Nasketucket Bay, there was a slow and nearly steady recolonization over a 30-year period until the early 1960s and since that time beds have been relatively stable. In many of the shallower embayments, such as the Westport River area, there have been wide swings in abundance. Some of these changes in abundance appear to correlate with physical disturbances such as hurricanes or ice accumulation in the bay. However, many of these shallow embayments show a general increase of cover until the 1960s, and then a decline beginning in the 1970s. Costa (1988) suggests that the more recent declines in shallow embayments are due to increased nutrient loading, boat traffic, and dredging.

Factors Affecting Habitat Quality

As discussed above, both natural and anthropogenic factors have led to great changes in the area covered by eelgrass, and in the nature of the eelgrass habitat. Severe storms and icing in the bay can also result in the large-scale removal of eelgrass from the bay. The periodic occurrence of the "wasting disease" has obviously played a major role in determining eelgrass abundance. Recently Short et al. (1987) have reported localized occurrences of the wasting disease in areas both north and south of Buzzards Bay. However, the recent declines observed by Costa (1988) in shallow embayments appear to most likely have been caused by decreased light reaching the plant as a result of increased nutrient loading and sediment resuspension due to dredging and boat traffic; and the physical removal of the beds as a consequence of shellfishing, boat propellers and the construction of docks and piers. The loss of eelgrass populations from many of the same low salinity areas which served as a refuge during the 1931 wasting disease epidemic is a cause for some concern.

Rocky Shores

Introduction

There is very little rocky shore habitat in Buzzards Bay. There are some rock outcroppings and rocky ledges along the mainland and some rocky shore areas around the Elizabeth Islands and Gull Island. Although these areas are small they may be important for seals (see chapter on mammals). In addition to natural, hard substrate areas, manmade substrates, such as piers, serve as settlement sites for many of the same organisms found on rocky shores.

Physical, Chemical and Biological Characteristics

The height above mean tide and the degree of exposure relative to wind and waves are the two factors that determine the species distribution on hard substrates. The upper zone, which is only wetted by spring or storm tides, is dominated by semi-aquatic lichens and periwinkles (*Littorina littorea* and *L. saxatilis*). The high and mid-intertidal zone is dominated by barnacles and mussels and the macroalgae *Fucus vesiculosus* and *Ascophyllum nodosum*. Large numbers of amphipods, worms, bryozoans, hydroids and small anemones can be found in association with the macroalgae. In the lower intertidal and upper subtidal, red (*Chondrus*) and brown (*Laminaria digitata*) macroalgae become dominant and the numbers and diversity of animals increase.

Biological factors strongly influence the present day distribution of the major plant species in the New England rocky intertidal zone (see Lubchenco, 1980; Lubchenco and Menge, 1978). Lubchenco (1978) demonstrated that *L. littorea*, the dominate herbivore of the higher intertidal zone, seldom eats the perennial *Fucus* sp. *A. nodosum* and *C. crispus*. Ephemeral (short-lived) algae are the preferred food of *L. littorea* (Lubchenco, 1978), and therefore grazing prevents these species from fully colonizing the intertidal zone. Geiselman (1980) demonstrated that the perennial algae possess chemical factors that deterred the feeding of *L. littorea*, while the ephemerals do not.

The structure of the rocky intertidal community in Buzzards Bay, and in all of New England, may have been significantly different several hundred years ago. *L. littorea* was introduced into New England in from Europe (Carlton per. com.). Thus, while the present day make up is strongly structured by the grazing of *L. littorea*, other factors controlled algal species distributions several hundred years ago.

Competition between species and predation are two other major factors structuring the rocky intertidal community (Lubchenco and Menge, 1978). In protected sites, barnacles (*Balanus balanoides*) and *Chondrus* are present in great numbers because predators such as starfish and snails *(Thais lapillus*) prevent the blue mussel (*Mytilus edulis*) from occupying all of the space. In more exposed areas the predators cannot withstand the wave shock and mussels out compete barnacles and *Chondrus* for space, resulting in a monoculture of mussels.

References

ACI. 1991. Determination of flushing rates and hydrographic features of selected Buzzards Bay embayments. Aubrey Consulting. Inc. Draft Interim Report to the Buzzards Bay Project.

Admiraal, W. 1984. The ecology of estuarine sediment-inhabiting diatoms. Prog. Phycol. Res. 3: 269-322.

Allee, W. C. 1923. Studies in Marine Ecology. III. some physical factors related to the distribution of littoral invertebrates. Biol. Bull. 44: 167-191.

Aller, R. C. 1977. The influence of the macrobenthos on chemical diagenesis of marine sediments. Ph. D. dissertation. Dept. Geology and Geophysics, Yale University. 600 pp.

Anraku, M. 1964a. Influence of the Cape Cod canal on the hydrography and on the copepods in Buzzards Bay and Cape Cod Bay, Massachusetts. I. Hydrography and distribution of copepods. Oceanogr. 9: 46-60.

Anraku, M. 1964b. Influence of the Cape Cod Canal on the hydrography and on the copepods in Buzzards Bay and Cape Cod Bay, Massachusetts. II. Respiration and Feeding. Limnol. Oceanogr. 9: 195-206.

Aubrey, D. G., and A. G. Gaines 1982. Recent Evolution of an Active Barrier Beach Complex: Popponesset Beach, Cape Cod, MA. Woods Hole Oceanographic Inst. WHOI- 82-3, p. 77.

Aubrey, D. G., and P. E. Speer. 1985. A study of non-linear tidal propagation in shallow inlet/estuarine systems. Part I: Observations. Estuarine, Coastal, & Shelf Sci. 21: 185-205.

Banta, G. T. 1992. Decomposition and nitrogen cycling in coastal marine sediments controls by temperature, organic matter inputs, and benthic macrofauna. Ph. D. dissertation, Boston University.

Banta, G. T., A. E. Giblin, J. E. Hobbie, and J. Tucker. 1990. Benthic Respiration and nitrogen release in Buzzards Bay, Massachusetts. U.S. EPA draft report.

Biebel, R. and C. P. McRoy. 1971. Plasmatic resistance and rate of respiration and photosynthesis of *Zostera marina* at different temperatures and salinities. Mar. Biol. 8: 48-56.

Boynton, W. R., W. M. Kemp, and C. W. Keefe. 1982. A comparative analysis of nutrients and other factors influencing estuarine phytoplankton production. In V. S. Kennedy (ed.), Estuarine Comparisons, pp. 69-90. Academic Press, N.Y.

Burns, K. A. and J. M. Teal. 1979. The West Falmouth oil spill: Hydrocarbons in salt marsh ecosystem. Est. Coast. Mar. Sci. 8: 349-360.

Chalmers, A. G. 1982. Soil Dynamics and the productivity of *Spartina alterniflora*. In V. S. Kennedy (ed.), Estuarine Comparisons, pp. 231-242. Academic Press, N. Y.

Christensen, H., and E. Kanneworff. 1985. Sedimenting phytoplankton as a major food source for suspension and deposit feeders in the Oresund. Ophelia 24: 223-244.

Colijn, F., and Dijkema, K. A. 1981. Species composition of benthic diatoms and distribution of chlorophyll a on an intertidal flat in the Dutch Wadden Sea. Mar. Ecol. Prog. Ser. 4: 9-21.

Colijn, F., and V. N. de Jonge. 1984. Primary production of the microphytobenthos in the Ems-Dollard estuary. Mar. Ecol. Prog. Ser. 14: 185-196.

Collings, W. S., C. Cooper-Sheehan, S. C. Hughes, and J. L. Buckley. 1981. The Effects of Power Generation on Some of the Living Marine Resources of the Cape Cod Canal and Approaches. Massachusetts Dept. of Fisheries, Wildlife and Recreational Vehicles, Division of Marine Fisheries. 212 pp.

Collings, W. S., C. Cooper-Sheehan, S. C. Hughes, and J. L. Buckley. 1983. The spatiotemporal distribution of American lobster *Homarus americanus*, larvae in the Cape Cod Canal and approaches, p. 35-40. In: M. J. Fogarty (ed.), Distribution and abundance of the American lobster, *Homarus americanus* larvae:

New England investigations during 1974-79, 64 pp. NOAA Technical Report. NMFS SSRF-775.

Costa, J. E. 1988. Eelgrass in Buzzards Bay: Distribution, Production, and Historical Changes in Abundance. Report to the Buzzards Bay Project. Sponsored by the U. S. EPA and the Massachusetts EOEA, BBP-88-05.

Daiber, F. C. 1982. Animals of the Tidal Marsh. Van Nostrand Reinhold Company, New York. 422 pp.

Darley, W. M., C. L. Montague, F. G. Plumley, W. W. Sage and A. T. Psalidas. 1981. Factors limiting edaphic algal biomass and productivity in a Georgia salt marsh. J. Phycol. 17: 122-128.

Davis, M. W., and C. D. McIntire. 1983. Effects of physical gradients on the production dynamics of sediment-associated algae. Mar. Ecol. Prov. Ser. 13: 103-114.

Deegan, L. A.; S. Saucerman, and D. Basler. 1990. Changes in the Waquoit Bay fish community over a twenty year period. pp 57-58. In: A. E. Giblin (ed.) New England Salt Pond Data Book. Woods Hole Oceanographic Institution Technical Report, WHOI90-21, CRC-89-2 116 pp.

Dennison, W. C. 1987. Effects of light on seagrass photosynthesis, growth and depth distribution. Aquat. Bot. 27: 15-26.

Dennison, W. C., and R. S. Alberte. 1985 The role of daily light period in the depth distribution of *Zostera marina L.* (eelgrass). Mar. Ecol. Prog. Ser. 25: 51-61

Dennison, W. C., and R. S. Alberte. 1986 Photoadaptation and growth of *Zostera marina L.* (eelgrass) transplants along a depth gradient. J. Exp. Mar. Biol. Ecol. 98: 265282.

Driscoll, E. G. 1975. Sediment - animal - water interaction, Buzzards Bay Massachusetts. J. Mar. Res. 33: 275-302.

Driscoll, E. G., and D. E. Brandon. 1973. Mollusc-sediment relationships in Northwestern Buzzards Bay, Massachusetts, U. S. A. Malacologia 12: 13-46.

EPA. 1979. A Small Oil Spill at West Falmouth. US EPA Decision Series EPA 600/9-79-007.

Farrington, J. W., and J. McDowell Capuzzo. 1989. Toxic chemicals in Buzzards Bay: Sources, fates and effects. Final Draft Report submitted to the Buzzards Bay Project; US EPA and Massachusetts EOEA

Federle, T. W., R. J. Livingston, D. A. Meeter, and D. C. White. 1983. Modifications of estuarine sedimentary microbiota by exclusion of epibenthic predators. J. Exp. Mar. Biol. Ecol. 73: 81-94.

Finn, J. T., and L. A. Deegan. 1989. An evaluation of remote sensing data for use and application in watershed land use and water quality investigations 1987-1988. Final report to Massachusetts Executive Office of Environmental Affairs for Research and Demonstration Project #87-11.

Fish, C. B. 1987. Computer enhanced modeling of tidal velocities and circulation patterns, Buttermilk Bay, Massachusetts: A model study and development of methods for general application.

Fiske, J. D., J. R. Curley, and R. P. Lawton. 1968. A Study of the Marine Resources of the Westport River. In: Monograph Series #7. Boston, KA: Div. Marine Fisheries, DNR, p. 52.

Fitzgerald, D. M. 1985. The Development of Coastal Bays and Tidal Inlets. In S. Bliven and A. L. Hankin (eds.), Salt Ponds and Tidal Inlets: Maintenance and Management Considerations. New Bedford, MA: Lloyd Center Pub. #2-85, pp. 25-44.

Fitzgerald, D. M., A. Saiz, C. T. Baldwin, and D. M. Sands. 1986. Split Breaching at Slocum River Inlet: Buzzards Bay, Massachusetts. Shore and Beach, Oct. : 11-17.

Fitzgerald, D. M., and D. R. Levin. 1981. Hydraulics, Morphology, and Sediment Transport Patterns at Pamet River Inlet: Truro, Massachusetts. Northeastern Geology. 3: 16-224.

Fonseca, M. S., J. C. Zieman, G. W. Thayer, and J. S. Fisher. 1983. The role of current velocity in structuring eelgrass *(Zostera marina)* meadows. Estuar. Coast. Shelf Sci. 17: 367-380.

Foreman, K. H. 1989. Regulation of benthic microalgal and meiofaunal productivity and standing stock in a salt marsh ecosystem: The relative importance of resources and predation. Ph. D. thesis, Boston University, 224 pp.

Forster, G. R. 1953. A new dredge for collecting burrowing animals. J. Mar. Biol. Ass. U. K. 32: 193-198.

Gage, J. D. 1975. A comparison of the deep-sea epibenthic sledge and anchor-box dredge with van Veen grab and hand coring by diver. Deep Sea Res. 22: 693-702.

Gallagher, J. L., and F. C. Daiber. 1974. Primary production of edaphic algal communities in a Delaware salt marsh. Limnol. Oceanogr. 19: 390-95.

Geiselman, J. A. 1980. Ecology of chemical defenses of algae against the herbivorous snail, *Littorina littorea*, in the New England rocky intertidal community. Ph. D. dissertation, Massachusetts Institute of Technology and the Woods Hole Oceanographic Institution. 209 pp.

George, D., and J. George. 1979. Marine Life: An Illustrated Encyclopedia of Invertebrates in the Sea. Wiley-InterScience, N. Y. 288 pp.

Giblin, A. E. 1990. New England Salt Pond Data Book. Woods Hole Oceanographic Institution Technical Report, WHOI-90-21, CRC-89-2 116 pp.

Giblin, A. E., and A. G. Gaines. 1990. Nitrogen inputs to a marine embayment: The importance of groundwater. Biogeochemistry 10: 309-328.

Giese, G. S., D. G. Aubrey, and J. T. Liu. 1989. Development, characteristics, and effects of the New Chatam Harbor Inlet. Woods Hole Oceanographic Institution Technical Report, WHOI-8-19, CRC-89-4.

Godfrey, P. J. 1976 Barrier beaches of the East Coast. Oceanus 19: 27-40.

Gosner, K. L. 1971. Guide to identification of Marine and Estuarine Invertebrates Cape Hatteras to the Bay of Fundy. Wiley-InterScience, N. Y. 693 pp.

Gosner, K. L. 1978. A Field Guide to the Atlantic Seashore, Houghton Mifflin Co., Boston, MA. 329 pp.

Grassle, J. F., and J. P. Grassle (1974). Opportunistic life histories and genetic systems in marine benthic polychaetes. J. Mar. Res. 32: 253-284.

Grassle, J. F., J. P. Grassle, L. S. Brown-Leger, R. F. Petrecca and N. J. Copley 1985. Subtidal macrobenthos of Narragansett Bay. Field input on benthic populations. In Marine Biology of Polar Regions and Effects of Stress on Marine Organisms, J. S. Gray and M. E. Christiansen (eds.), pp. 421-434. John Wiley & Sons, N. Y.

Grassle, J. P., and J. F. Grassle 1984. The utility of studying the effects of pollutants on single species populations in benthos of mesocosms and coastal embayments. In Concepts in Marine Pollution Measurements, H. H. White (ed.), pp. 621- 642. Maryland Sea Grant Program, College Park, MD.

Gray, J. S. 1980. The measurement of effects of pollutants on benthic communities. Rapp. P. -v. Réun. Cons. int. Explor. Mer. 179: 188-193.

Griffith, R. E. 1961. Phytoplankton of Chesapeake Bay' An Illustrated Guide to the Genera. University of Maryland Natural Resources Institute, College Park, MD. 79 pp.

Grimes, D. J. and G. R. Heufelder. 1990. Synthesis Report on Pathogen Issues. Buzzards Bay Project Synthesis Report.

Hampson, G. R. 1990. Ground truth verification of a Remots ® survey of Buzzards Bay. Final Draft Report WHOI proposal No. 4765. 1, prepared for US EPA. Water Management Division, Region I. 33 pp.

Hampson, G. R. and E. T. Moul. 1978. No. 2 fuel spill in Bourne, Massachusetts: Intermediate assessment of the effects on marine invertebrates and a 3-year study of growth and recovery of a salt marsh. J. Fish. Res. Board Can. 35: 731-744.

Hankin, A. L., L. Constantine, S. Bliven. 1985. Barrier Beaches, Salt Marshes, and Tidal Flats: An Inventory of the Coastal Resources of the commonwealth of Massachusetts. Lloyd Center for Environmental Studies and Massachusetts Coastal Zone Management. Publication #13899-27-1-85.

Hargrave, B. 1980. Factors affecting the flux of organic matter to sediments in a marine bay. In Marine Benthic Dynamics, K. R. Tenore and B. C. Coull (eds.), pp. 243-263. U. South Carolina Press, Columbia, S. C.

Harlin, M. M. 1980. Seagrass epiphytes. Pp. 117-151 in R. C. Phillips and C. P. McRoy (eds.) Handbook of seagrass biology, and ecosystem perspective. Garland STPM Press. N. Y.

Harper, M. A. 1977. Movements. In The Biology of Diatoms, D. Werner (ed.), pp. 224- 249. University of California Press, Berkeley.

Hartman, J. M. 1984. The role of wrack disturbance in the vegetation of a New England salt marsh. Ph. D. Dissertation, University of Connecticut. 130pp.

Henrichs, S. M., and J. W. Farrington 1987. Early diagenesis of amino acids and organic matter in two coastal marine sediments. Geochim. Cosmochim. Acta 51: 1-15.

Howarth, R. 1988. Nutrient limitation of net primary production in marine ecosystems. Ann. Rev. Ecol. 19: 89-110.

Howes, B. L., R. W. Howarth, I. Valiela, and J. M. Teal. 1981. Oxidation-reduction potentials in a salt marsh: *Spatial patterns* and *interactions* with primary production. Limnology and Oceanography 26: 350-360.

Jorgensen, C. B. 1975. Comparative physiology of suspension feeding. Ann. Rev. Physiol. 37: 57-79.

Jorgensen, C. B. 1983. Fluid mechanical aspects of suspension feeding. Mar. Ecol. Prog. Ser. 11: 89-103.

Kelly, J. R., I. Valiela, and D. Hersh. 1990. Nutrients and the trophic status of Buzzards Bay, Massachusetts. Draft report to the Buzzards Bay Project.

Kemp, W. M., W. R. Boynton, R. R. Twilley, J. C. Stevenson, and J. C. Means. 1983. The decline of submerged vascular plants in Upper Chesapeake Bay: Summary of results of possible causes. Mar. Tech. Soc. J. 17: 78-89.

Krebs, C. T., I. Valiela, G. Harvey, and J. M. Teal. 1974. Reduction of field populations of fiddler crabs by uptake of chlorinated hydrocarbons. Mar. Poll. Bull. 5: 140142.

Lee, J. J., M. E. McEnery, E. M. Kennedy, and H. Rubin. 1975. A nutritional analysis of a sublittoral diatom assemblage epiphytic on *Enteromorpha* from a Long Island salt marsh.

Lee, V. 1980. An Elusive Compromise: Rhode Island Coastal Ponds and Their People. In: Coastal Resources Center, Marine Technical Report 73. Kingston, RI: U. Rhode Island, p. 82.

Lee, V., S. Olsen, and J. Boothroyd. 1985. Tidal Inlet Modification, A Rhode Island Example of the Need for an Holistic Approach to the Management of Salt Ponds. In S. Bliven and A. L. Hankin (eds.), Salt Ponds and Tidal Inlets: Maintenance and Management Considerations. New Bedford, MA: Lloyd Center Pub. # 2-85, pp. 1-16.

Levinton, J.S. and R. K. Bambach. 1975. A comparative study of Silurian and Recent deposit-feeding bivalve communities. Paleobiology, 1, 97-124.

Levinton, J. S., and T. S. Bianchi. 1981. Nutrition and food limitation of deposit feeders. I. The role of microbes in the growth of mud snails (Hydrobiidae). J. Mar. Res. 39: 531-545.

Lopez, G. R., and J. S. Levinton. 1978. The availability of microorganisms attached to sediment particles as food for *Hydrobia totteni* Montague (Gastropoda, Prosobranchia). Oecologia 20: 263-275.

Lopez, G. R., and J. S. Levinton. 1987. Ecology of deposit-feeding animals in marine sediments. Quart. Rev. Biol. 62: 235-260.

Lubchenco, J. 1978. Plant species diversity in a marine intertidal community: Importance of herbivore food preference and algal competitive abilities. Am. Nat. 112: 23-39.

Lubchenco, J. 1980. Algal zonation in the New England rocky intertidal community: An experimental analysis. Ecology 61: 333-344.

Lubchenco, J., and B. A. Menge. 1978. Community development and persistence in a low rocky intertidal zone. Ecol. Mono. 59: 67-94.

Massachusetts Coastal Zone Management Program. 1979. Massachusetts Barrier Beaches. Mass. CZM, Boston, Mass. 80 pp.

May, R. M. 1984. An Overview: Real and apparent patterns in community structure. In Ecological Communities Conceptual Issues and the Evidence, D. R. Strong, D. Simberloff, L. G. Abele and A. B. Thistle (eds.), pp 1-16. Princeton Univ. Press, Princeton, N. J.

McIntire, C. D., and W. W. Moore. 1977. Marine littoral diatoms: Ecological considerations. In The Biology of Diatoms, D. Werner (ed.), pp. 333-371. University of California Press, Berkeley.

McNichol, A. P., C. Lee, and E. R. M. Druffel. 1988. Carbon cycling in coastal sediments: 1. A quantitative estimate of the remineralization of organic carbon in the sediments of Buzzards Bay, MA. Geochim. Cosmochim. Acta 52: 1531-43.

Meany, R. A., I. Valiela & J. M. Teal. 1976. Growth, abundance and distribution of larval tabanids in experimentally fertilized plots Massachusetts salt marsh. J. Appl. Ecol. 13:323-332

Mendelssohn, I. A. 1979. Nitrogen metabolism in the height forms of *Spartina alterniflora* in North Carolina. Ecology 60: 574-584.

Michael, A. D. 1975. Structure and stability of three marine benthic communities in southern New England. In Effects of Energy Related Activities on the Atlantic Continental Shelf, B. Manowitz (ed.). pp. 109-125.

Michael, A. D., C. R. Van Raalte, and L. S. Brown. 1975. Long-term effects of an oil spill at West Falmouth, Massachusetts. In Proceedings Conference on Prevention and Control of Oil

Pollution, API, EPA and U. S. Coast Guard, San Francisco, CA. pp. 573-582.

Miller, W. R. and F. E. Egler.1950. Vegetation of the Wequetequock-Pawcatuck Tidal-Marshes, Connecticut. Ecological Monographs 20:143–172.

Montagna, P. A. 1984. In situ measurement of meiobenthic grazing rates on sediment bacteria and benthic diatoms. Mar. Ecol. Prog. Ser. 18: 119-130.

Moore, J. R,. III. 1963. Bottom sediment studies, Buzzards Bay, Massachusetts. J. Sed. Petrol. 33: 511-558.

Moul, E. T. 1973. Marine Flora and Fauna of the Northeastern United States. Higher Plants of the Marine Fringe. NOAA Technical Report NMFS CIRC-384. US Govt. Printing Office, Washington, D. C.

Niering, W. A., and R. S. Warren. 1980. Vegetation patterns and processes in New England salt marshes. BioScience 30:301-307.

Nickerson, N. H. 1985. Water quality in tidal inlets and salt ponds: Marshes, stagnation, mosquitoes, and public health. In: S. Bliven and A. L. Hankin (eds.). Salt Ponds and Tidal Inlets: Maintenance and Management Considerations, pp 17-24. Lloyd Center Publication # 2-85.

Nixon, S. 1981. Remineralization and nutrient cycling in coastal marine ecosystems. In B. J. Neilson and L. E. Cronin (eds.), Estuaries and Nutrients. New York: Academic Press, pp. 111-138.

Nixon, S. W. 1982. the Ecology of New England High Salt Marshes: a Community Profile. U. S. Fish and Wildlife Service, Office of biological Services, Washington, DC FSW/OBS-81/55.

Nixon, S. W., and M. E. Q. Pilson. 1983. Nitrogen in Estuarine and Coastal Marine Ecosystems. In E. J. Carpenter and D. G. Capone (eds.), Nitrogen in the Marine Environment. New York: Academic Press, pp. 565-648.

Nixon, S. W., B. N. Furnas, R. Chirunan, S. Granger, and S. Heffernan. 1982. Nutrient Inputs to Rhode Island Coastal Lagoons and Salt Ponds Final Report to Rhode Island Statewide Planning. Kingston, RI. U. Rhode Island, p. 23.

NOAA (National Oceanic and Atmospheric Administration). 1988. Strategic Assessment of Near Coastal Waters: Northeast Case Study. Susceptibility and status of Northeast estuaries to nutrient discharge. NOAA/EPA Team on Near Coastal Waters July 1988.

O'Neill, R. V., D. L. DeAngelis, J. B. Waide and T. F. H. Allen. 1986. A Hierarchical Concept of Ecosystems. Princeton University Press, Princeton, N. J., 253 pp.

Oviatt, C., B. Buckley, and S. Nixon. 1981. Annual phytoplankton metabolism in Narragansett Bay calculated from survey field measurements and microcosm observations. Estuaries 4: 167-175.

Pace, M. L., S. Shimmel and W. M. Darley. 1979. The effect of grazing by the gastropod, *Nassarius obsoletus*, on the benthic microbial community. Estuar. Coast. Shelf Sci. 9: 121-134.

Palmer, M. A. 1988. Epibenthic predators and marine meiofauna: separating predation, disturbance and hydrodynamic effects. *Ecology* 69: 1251-1259.

Pearson, T. H., and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. mar. biol. *A. Rev*. 16: 229-311.

Pearson, T. H., J. S. Gray, and P. J. Johannessen. 1983. Objective selection of sensitive species indicative of pollution-induced change in benthic communities. 2. Data analyses. Mar. Ecol. Prog. Ser. 12: 237-255.

Peterson, B. J., R. W. Howarth, and R. H. Garritt. 1985. Multiple stable isotopes used to race the flow of organic matter in estuarine food webs. Science 227: 1361-1363.

Peterson, C. H. 1979. Predation, competitive exclusion, and diversity in the soft sediment benthic communities of estuaries and lagoons. In R. J. Livingston (ed.), Ecological Processes in coastal and Marine Systems. New York: Plenum Publishing Corp., pp. 233-264.

Petry, L. C., and M. G. Norman. 1968. A Beachcomber's Botany. Chatham Conservation Foundation, Chatham, MA. 158 pp.

Ranwell, D. S. 1972. Ecology of Salt Marshes and Sand Dunes. Halsted Press, New York. 258 pp.

Redfield, A. C. 1934. On the proportions of organic derivatives in sea water and their relation to the composition of plankton, pp. 176-192. In James Johnstone memorial volume. Liverpool Univ. Press.

Redfield, A. C. 1972. Development of a New England salt marsh. Ecol. Monograph. 42: 201-237.

Reid, R. N., A. B. Frame, and A. F. Draxler. 1979. Environmental baselines in Long Island Sound, 1972-1978. NOAA Technical Report, SSRF-738.

Reise, K. 1979. Moderate predation on meiofauna by the macrobenthos of the Wadden Sea. Helgol. Wiss. Meeresunters. 32: 453-465.

Reise, K. 1985. Tidal Flat Ecology. Springer-Verlag, Berlin. 191 pp.

Rhoads, D. C. 1963. Rates of sediment reworking by *Yoldia limatula* in Buzzards Bay, Massachusetts, and Long Island Sound. J. Sed. Pet. 33: 723-727.

Rhoads, D. C. 1967. Biogenic reworking of intertidal and subtidal sediments in Barnstable Harbor and Buzzards Bay, Massachusetts. J. Geol. 75: 461-476.

Rhoads, D. C., and D. K. Young. 1970. The influence of deposit-feeding organisms on sediment stability and community trophic structure. J. Mar. Res. 28: 150-178.

Rhoads, D. C., and D. K. Young. 1971. Animal-sediment relations in Cape Cod Bay, Massachusetts II. Reworking by *Molpadia oolitica* (Holothuroidea). Mar. Biol. 11: 255-61.

Rhoads, D. C., and L. F. Boyer 1982. The effects of marine benthos on physical properties of sediments: A successional perspective. In Animal-Sediment Relations, P. L. McCall and M. J. S. Tevesz (eds.), pp. 3-52. Plenum Press, N. Y.

Rhoads, D. C., L. Boyer, B. Welsh, and G. R. Hampson. 1985 Seasonal dynamics of detritus in the benthic turbidity zone (BTZ); implications for bottom-rack molluscan mariculture. Bull. Mar. Sci., in press.

Rhodes, D. C., K. Tenore, and M. Browne. 1975. The role of resuspended bottom mud in nutrient cycles of shallow embayments. pp. 563-579 In: L. E. Cronin (ed.) Estuarine Research Vol. I: Chemistry, biology and the estuarine system. Academic Press. N. Y.

Riley, G. A. 1956. Oceanography of Long Island Sound, 1952-1954. IX. Production and utilization of organic matter. Bull. Bingham. Oceanogr. Coll. 15: 324-344.

Roman, M. R. 1978. Tidal Resuspension in Buzzards Bay, Massachusetts II. Seasonal changes in the size distribution of chlorophyll, particle concentrations, carbon and nitrogen in resuspended particulate matter. Est. Coast. Mar. Sci. 6: 47-53.

Roman, M. R. 1980. Tidal resuspension in Buzzards Bay, Massachusetts. III. Seasonal Cycles of Nitrogen and Carbon:

nitrogen ratios in the Seston and Zooplankton. Est. Coast. Mar. Sci. 11: 9-16.

Roman, M. R., and K. R. Tenore. 1978. Tidal Resuspension in Buzzards Bay, Massachusetts. I. Seasonal changes in the resuspension of organic carbon and Chlorophyll a. Est. Coast. Mar. Sci. 6: 37-46.

Ruber E., G. Gillis, and P.A. Montagna. 1981. Production of dominant emergent vegetation and of pool algae on a northern Massachusetts salt marsh. Bulletin of the Torrey Botanical Club 108: 152-165.

Rudnick, D. T., and C. A. Oviatt. 1986. Seasonal lags between organic carbon deposition and mineralization in marine sediments. J. Mar. Res. 44: 815-837.

Sanders, H. L. 1956. Oceanography of Long Island Sound, 1952-1954. X. The biology of marine bottom communities. Bull. Bingham. Oceanogr. Collection, 15: 345-414.

Sanders, H. L. 1958. Benthic studies on Buzzards Bay. I. Animal-sediment relationships. Limnol. Oceanogr. 3: 245-258.

Sanders, H. L. 1960. Benthic studies on Buzzards Bay. III. The structure of the soft-bottom community. Limnol. Oceanogr. 5: 138-153.

Sanders, H. L. 1978. Florida oil impact on Buzzards Bay benthic fauna: West Falmouth. J. Fish. Res. Bd. Can. 35: 717-730.

Sanders, H. L., J. F. Grassle, G. R. Hampson, L. S. Morse, S. Garner-Price, and C. C. Jones. 1980. Anatomy of an oil spill: long-term effects from the grounding of the barge Florida off West Falmouth, Massachusetts. J. Mar. Res. 38: 265-380

Sanford Ecological Services, Inc. (SES) 1988. New Bedford Harbor Superfund Project Wetland Assessment. Prepared for the U. S. Army Corp. of Engineers.

Schoener, T. W. 1986. Overview: Kinds of ecological communities - ecology becomes pluralistic. In Community Ecology, J. Diamond and T. J. Case (eds.), pp. 467-479. Harper & Row, New York.

Schubauer, J. P., and C. S. Hopkinson. 1984. Above and below ground emergent macrophyte production and turnover in a coastal marsh ecosystem, Georgia. Linmol. Oceanogr. 29: 1052-1065.

Science Applications International Corp (SAIC). 1990. Characterization of Pollutant Inputs to Buzzards Bay. Prepared for the Buzzards Bay Project, US EPA and MA CZM.

Sears, J. R., and H. S. Parker. 1985. Die-back of vegetation in a Massachusetts salt marsh. In: S. Bliven and A. L. Hankin (eds.). Salt Ponds and Tidal Inlets: Maintenance and Management Considerations, pp 63-78. Lloyd Center Publication 2-85.

Shanholtzer, G. F. 1974. Relationship of vertebrates to salt marsh plants. - In: Riemold, R. J. and Queen, W. H. (eds.), Ecology of Halophytes. Academic Press. New York, pp. 463-474.

Short, F. T., L. K. Muehlstein, and D. Porter. 1987. Eelgrass Wasting Disease: Cause and Recurrence of a Marine Epidemic. Biol. Bull. 173: 557-562.

Signell, R. P. 1987. Tide- and Wind-Forced Currents in Buzzards Bay, Massachusetts. M. S. Dissertation, Massachusetts Institute of Technology, Woods Hole Oceanographic inst. Tech. Rept., WHOI-87-15, 86 pp.

Smayda, T. J. 1989. Assessment of primary productivity and eutrophication potential in New Bedford outer harbor in response to nutrient regime and potential inputs. Submitted to Camp, Dresser and McKee, Inc.

Smith, D. L. 1977. A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae. Kendall/Hunt Publishing Co., Dubuque, Iowa. 159 pp.

Smith, L. B. Jr. 1983. Barrier Beach Management Sourcebook. Massachusetts Coastal Zone Management Program, Boston, MA, 48 pp.

SRPEDD (Southeastern Regional Planning and Economic Development District). June 1989. Land use changes in the Buzzards Bay area 1951-1985. Draft Report to the Buzzards Bay Project.

Stauffer, R. C. 1937. Changes in the invertebrate community of a lagoon after disappearance of the eelgrass. Ecology 18: 427-431.

Stevens, N. E., H. R. Ellis, and R. B. Stevens. 1950. Wasting and recovery of *Zostera marina* on the Atlantic coast of the United States. Plant Dis. Rep. 34: 357-62.

Stirn, J., A. Avcin, I. Kerzan, B. M. Marcotte, N. Meith-Avcin, B. Vriser and S. Vukovic 1973. Selected biological methods for assessment of marine pollution. In Marine Pollution and Marine Waste Disposal, Proceedings of the 2nd International Congress (Suppl. to Progress in Water Technology), E. A. Pearson and E. de Fraja Frangipane, eds. pp. 307-327. Pergamon Press, NY.

Stoffers, P., C. Summerhayes, U. Forstner, and R. Patchineelam. 1977. Copper and other heavy metal contamination in sediments from New Bedford Harbor, Massachusetts: A Preliminary Note. Environ. Sci. Tech. 11: 819-821.

Sullivan, M. J. 1975. Diatom communities from a Delaware salt marsh. J. Phycol. 11:384-390.

Sullivan, M. J. 1978. Diatom community structure: taxonomic and statistical analyses of a Mississippi salt marsh. J. Phycol. 14: 468-75.

Sullivan, M. J., and C. A. Moncrieff . 1990. Edaphic algae are an important component of salt marsh food-webs: evidence from multiple stable isotope analyses. Mar. Ecol. Prog. Ser. 62: 149-159.

Sullivan, M. J., and C. A. Moncrieff. 1988. Primary production of edaphic algal communities in a Mississippi salt marsh. J. Phycol. 24: 49-58.

Summerson, H. C., and C. H. Peterson 1984. Role of predation in organizing benthic communities of a temperate-zone seagrass bed. Mar. Ecol. Prog. Ser. 15: 63-77.

Sumner, F. B., R. C. Osburn, and L. J. Cole 1911. A biological survey of the waters of Woods Hole and vicinity. Bull. Bureau Fish. 31: 1-544.

Taylor, W. R. 1957. Marine Algae of the Northeastern Coast of North America. University of Michigan Press, Ann Arbor, MI. 509 pp.

Teal, J. M. 1986. The Ecology of Regularly Flooded Salt Marshes of New England: a Community Profile. U. S. Fish Wildl. Serv. Biol. Rep. 85 (7. 4). 61 pp.

Teal, J. M., and M. Teal. 1969. Life and Death of a Salt Marsh. National Audubon Society. Random House Publishers. 274 p.

Thayer, G. W., S. M. Adam, and M. W. LaCroix. 1975. Structural and functional aspects of a recently established *Zostera marina* community. pp. 517-540 in L. E. Cronin (ed.) Estuarine Research, Vol. I. Academic Press, N. Y.

Thayer, G. W., W. J. Kenworthy, and M. S. Fonseca. 1984. the Ecology of Eelgrass Meadows of the Atlantic Coast: A Community Profile. U. S. Fish. Wildl. Serv. FVS/OBS-84/02.

Tripp, B. W. 1985. Buzzards Bay Bibliography: A reference collection of scientific and technical reports published on Buzzards Bay. WHOI -85-27.

Turner, J. T., D. G. Borkman, W. Lima, and R. W. Pierce. 1989. A seasonal study of plankton, larval fish, and water quality in Buzzards Bay, Massachusetts. An interim data report Oct. 1987 through Sept. 1988, submitted to Mass. Div. Water Pollution Control Board, DEP.

Valiela, I. 1984. Marine Ecological Processes. Springer-Verlag, N. Y. 546 pp.

Valiela, I., and J. E. Costa. 1988. Eutrophication of Buttermilk Bay, a Cape Cod Coastal Embayment: Concentrations of Nutrients and Watershed Nutrient Budgets. Environmental Management 12: 539-553.

Valiela, I., J. Costa, K. H. Foreman, J. M. Teal, B. L. Howes, and D. Aubrey. 1990. Transport of groundwater-borne nutrients from watersheds and their effects on coastal waters. Biogeochemistry 10: 177-197.

Valiela, I., J. M. Teal, and N. Y. Persson. 1976. Production and dynamics of experimentally enriched salt marsh vegetation: Belowground biomass. Limnology and Oceanography 21: 245-252.

Valiela, I., J. M. Teal, and W. G. Deuser. 1978. The nature of growth forms in the salt marsh grass Spartina alterniflora. American Naturalist 112: 461-469.

Van Raalte, C. D., I. Valiela and J. M. Teal. 1976a. Production of epibenthic salt marsh algae: Light and nutrient limitation. Limnol. Oceanogr. 21: 862-872.

Van Raalte, C. D., I. Valiela and J. M. Teal. 1976b. The effect of fertilization on the species composition of salt marsh diatoms. Water Research 10: 1-4.

Verrill, A. E., and S. I. Smith. 1873. Report upon the Invertebrates of Vineyard Sound and the adjacent waters, with an account of the physical characteristics of the region. U. S. Fish Comm. Rep., 1871-72: 295-896.

Vince, S., I. Valiela, N. Backus and J. M. Teal. 1976. Predation by the salt marsh killifish *Fundulus heteroclitus (L.)* in relation to prey size and habitat structure: Consequences for prey distribution and abundance. J. Exp. Mar. Biol. Ecol. 23: 255-266.

Weaver, G. 1982. PCB pollution in the New Bedford, Massachusetts area. MA Coastal Zone Management Program, 62pp.

Welsh, B. L., R. B. Whitlatch, and W. F. Bohlen. 1982. Relationship between physical characteristics and organic carbon sources as a basis for comparing estuaries in southern New England. pp. 53-68. In: V. S. Kennedy (ed.) Estuarine Comparisons. Academic Press, New York.

Werme, C. E. 1981. Resource partitioning in salt marsh fish communities. Ph. D. thesis, Boston University.

Weston, D. P. 1990. Quantitative examination of macrobenthic community changes along an organic enrichment gradient. Mar. Ecol. Prop,. Ser. 61: 233-244.

Whitlach, R. B. 1977. Seasonal changes in the community structure of the macrobenthos inhabiting the intertidal sand and mudflats of Barnstable Harbor, Massachusetts. Biol. Bull. 152: 275-294.

Whitlach, R. B., L. F. Boyer, H. L. Sanders, and G. R. Hampson. 1975. Station R revisited: Long-term persistence of a subtidal benthic community. (unpublished manuscript).

Whitlatch, R. B. 1982. The Ecology of New England Tidal Flats: A Community Profile. U. S. Fish. Wildl. Serv. FVS/OBS-81/01.

Whitney, D., and W. Darley. 1983. Effect of light intensity upon salt marsh benthic microalgal photosynthesis. Mar. Biol. 75: 249-252.

Wiltse, W. I., K. H. Foreman, J. M. Teal and I. Valiela. 1984. Effects of predators and food resources on the macrobenthos of salt marsh creeks. J. Mar. Res. 42: 923-942.

Wood, R. D., and J. Lutes. 1967. Guide to the phytoplankton of Narragansett Bay, Rhode Island. Kingston Press, Peace Dale, R. I. 65 pp.

Young, D. K. 1971. Effects of infauna on the sediment and seston of a subtidal environment. Vie Milieu, Suppl. 22: 557-571.

Young, D. K., and D. C. Rhoads. 1971. Animal-sediment relations in Cape Cod Bay, Massachusetts I. A transect study. Mar. Biol. 11: 242-254.

2. Buzzards Bay Shellfish Resource and Fishery

By Frank Grice[3]

Introduction

Buzzards Bay is a small estuary, 30 miles long and 10 miles wide. It is bounded on the west by heavily developed communities, which have been the most economically troubled in the Commonwealth since the 1930s. To the east, with the exception of the Elizabeth Island chain, are some of the fastest growing residential communities in New England. The shoreline and waters of the bay lure hundreds of thousands of tourists in the summer and more than 4,300 moorings and slips are utilized by the boating public.

Some 20,000 vessels pass through Buzzards Bay each year on their way through the Cape Cod Canal. More than 19,000,000 tons of commercial cargo are involved in this shipping and included is almost all of the fuel oil used in New England. The New Bedford/Fairhaven Harbor area is the base for the most important fishery on the East Coast. Because of polychlorinated biphenyl (PCB) contamination from industry, it is also the only designated Superfund site in the marine environment in the United States.

Despite these environmental pressures, Buzzards Bay is an important shellfish area from both a commercial and recreational point of view. By far the most numerous and valuable shellfish of the bay is the quahog (Figure 2-1, *Mercenaria mercenaria*), also known as the hard clam. Other shellfish utilized include soft shell clams (Figure 2-2, *Maya arenaria*), bay scallops (Figure 2-3, *Argopecten irradians*) and the American oyster (Figure 2-4, *Crassostrea virginica*). Annual catches of these species have varied considerably in the last 20 years, ranging from fewer than 50,000 to more than 140,000 bushels, with quahogs being the most consistent and scallops showing the greatest fluctuation.

Most commercial shellfishermen in the bay concentrate their effort on quahogs, except in those years when bay scallops are present in sufficient numbers to provide for a winter fishery. Recreational fishermen harvest the majority of soft-shell clams.

The towns and cities have primary responsibility for managing shellfish resources in Massachusetts. In towns and cities involved, there is a great variety in the administration of this responsibility. As a minimum, however, each local community employs a shellfish officer and utilizes a permit

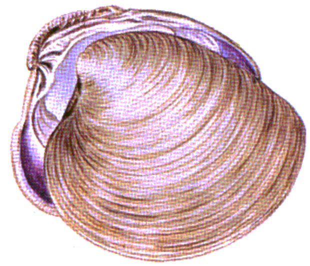


Figure 2-1. *Mercenaria mercenaria* (quahog)

Figure 2-2. *Maya arenaria* (soft shell clam)

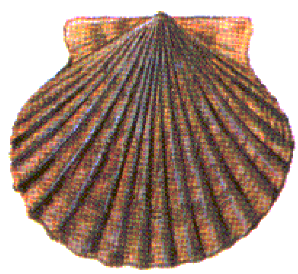


Figure 2-3. *Argopecten irradians* (bay scallop)

Figure 2-4. *Crassostrea virginica* (American Oyster)

[3] Retired, Massachusetts Division of Marine Fisheries.

Accepted September 26, 1990

system to regulate both recreational and commercial fishermen. Since 1967, the total number of permits issued by the towns has ranged from 10,000 to 15,000 with commercial permits usually numbering less than 1000. The state Division of Marine Fisheries works cooperatively with the towns and provides technical and financial assistance designed to improve the management of these public resources.

The utilization of shellfish in Buzzards Bay has been greatly impacted by pollution from both domestic and industrial sources. Thousands of acres of productive shellfish growing areas are closed to fishing because of bacterial contamination from domestic sewage. Annually, hundreds of thousands of bushels of quahogs lie unharvested and eventually die a natural death because of this pollution. This problem is increasing rather than being resolved. In addition to the economic loss, the shellfish closures are a clear indicator of a fouled environment that threatens the quality of life in this otherwise most desirable coastal habitat. Buzzards Bay communities and the Commonwealth as a whole must face this issue promptly and decisively; otherwise, the blight will be spread and despoil the entire coastal environment. The Buzzards Bay Project and its published reports must result in a public awareness of this danger and lead to remedial action.

Status of Fisheries

In Buzzards Bay the most important shellfish resources consist of four major species and several other species with only minor significance to man. The northern quahog is by far the most important because of its abundance and high economic value. In some years the bay scallop has been important both to commercial and recreational fishermen, but its abundance fluctuates widely from year to year and recently has been greatly reduced.

The other two species of shellfish, the soft-shell clam and American oyster, are much more localized and are utilized primarily by recreation fishermen for home consumption. Even smaller amounts of other species such as conchs or whelks, blue mussels, ocean quahogs, surf or sea clams, sea scallops and razor clams are taken sporadically with marketability usually more of a factor than abundance. Several of these latter species are found primarily in the deeper, open-water portion of the bay where they are less accessible than the more commonly harvested species.

Much of the attraction of coastal areas such as Buzzards Bay to the native Indians, who occupied the area before white men arrived, was the abundant use of clams and quahogs by these early inhabitants. Although the colonists also utilized the shellfish of the area, commercial shellfishing was not an important industry until the late 1800s.

According to Belding (1909) commercial quahogging started on Cape Cod during the early 1800s and grew slowly until 1890. He listed Massachusetts production of quahogs in 1879 as 11,050 bushels valued at $5,525. By 1907, he reported landings of 144,044 bushels with a value of $194,687. He further pointed out that by the early 1900s, production was declining, and he attributed this to over-fishing because of market demands.

The fishery for bay scallops developed in a similar fashion. Belding (1910a, b) reported that the scallop fishery did not become commercially important in Massachusetts until 1870. There is no evidence that the Indians taught the early colonists to eat scallops as they did with quahogs and soft-shell clams. In fact, there are reports that scallops were used extensively by early settlers for fertilizer on their inland farms.

In Buzzards Bay, Belding reported the scallop fishery began in 1870 in New Bedford and quickly spread to the upper end of the bay by 1879, where it flourished until 1889. Early records of the production or value of this fishery are not available. Apparently, it was short lived since Belding stated that by 1890 the fishery had collapsed and did not commence again until 1907.

Unlike quahogs and bay scallops, the early settlers of New England immediately utilized soft-shell clams. Belding (1930) in the "Soft-Shelled Clam Fishery of Massachusetts" stated that the colonists became dependent upon clams for home consumption, especially in times when other food was scarce. Even though they were an important part of the coastal dwellers' diet, no appreciable commercial market developed.

In the early 1800s a new industry emerged that supplied the offshore fishing fleet with bait in the form of shucked clams. This industry developed rapidly, especially on the north shore of Massachusetts, where large intertidal mud flats provided a favorable environment for the soft-shell clam. In Buzzards Bay, suitable conditions are much more limited than to the north, primarily because of less extensive tidal flats. The substantial reduction in tidal amplitude in the Buzzards Bay area compared with Cape Cod to the north favors the production of quahogs rather than soft-shell clams.

Although the bait industry for clams did not become as extensive in the Buzzards Bay area as in other parts of the Commonwealth, there was a steady use for home consumption, and by the early 1900s, the few formerly productive areas, especially in Falmouth and Dartmouth, were over-exploited. Belding reported in 1930 that proper management could restore these areas so that they would produce many times their current amount.

Apparently, the oyster resource of Buzzards Bay was originally much more restricted than that of quahogs, soft-shell clams, or bay scallops. Belding (1909) reported that there were once natural beds of oysters in Buzzards Bay and the Taunton River area, but that oyster production in most areas by the early 1900s was dependent upon the settling out of young oysters or spat on bottom suitable for their growth to marketable size. More recently, most oysters for public use have been harvested from areas under private cultivation or from areas planted by town shellfish officers. By the 1950s, oyster harvests in Buzzards Bay were reported to average about 2,000 bushels annually.

In 1985, about 150,000 bushels of shellfish were reported harvested from Buzzards Bay according to the town shellfish officers (Alber, 1987). Of this total, 40,000 bushels were taken by recreational or family fishermen and the remainder or 75% was harvested by commercial shellfishermen. In the 1980s, the harvest showed some increase: the average catch from 1967 to 1985 was about 86,000 bushels, whereas the 1981 to 1985 average was more than 100,000 bushels.

Since 1967, quahogs have accounted for more than 50% of the total catch, with the town of Dartmouth producing one third of this harvest. The recreational catch of quahogs has always been important and in recent years has averaged about 50% of the total taken. Of all the shellfish resources of Buzzards Bay, the quahog resource has been most impacted by pollution. Hundreds of thousands of bushels cannot be utilized for human consumption because of sewage contamination.

In recent years, the fishery for bay scallops has been marked by wide annual fluctuations in the landings, with some years showing minimal catches of about 1000 bushels and as much as 70,000 bushels in other years. The reasons for such a variation are not known, but the fact that each annual scallop crop consists of one age group, 16 to 20 months old, means that the success or failure of the fishery is completely dependent on the previous year's spawning. This is not true of quahogs, soft-shell clams or oysters, because the populations of these shellfish normally consist of several different age groups, including juveniles and adults that range up to 10 years old.

According to annual shellfish officer reports, the recreational catch of bay scallops averaged about 27% of the total catch in recent years. Almost all of the commercial harvest is taken by scallop dredges or drags towed from powerboats, whereas a significant portion of the recreational catch is taken by dip net or rake by individuals wading at low tide. Both the commercial and recreational fishery are restricted to the fall and winter months after the mature scallops have completed spawning in the previous summer.

Unlike quahogs and bay scallops, most of the soft-shell clams harvested in the Buzzards Bay area are taken by recreational or family diggers for home consumption. In the 19-year period from 1967 to 1985, the recreational catch averaged 96% of the total, which ranged from fewer than 2000 bushels to more than 14,000 bushels. Soft-shell clam harvests have shown a general decline in recent years (Alber, 1987). This may be primarily a reflection of increased shellfish area closures due to sewage contamination.

Oysters provide only a limited fishery in Buzzards Bay because their production is almost entirely dependent upon culture by individuals or town shellfish officers. Since 1957, the harvest has averaged about 2100 bushels, with the recreational catch amounting to about 62% of the total. In recent years, some oyster grant operations have existed in the Buzzards Bay area. For most of these operations, financial success does not appear to be consistent or even usual, although detailed economic information is sketchy or non-existent.

The total annual production of shellfish from Buzzards Bay has declined considerably since the late 1800s, especially for bay scallops and oysters. Belding (1910a,b) concluded that by the early 1900s the depletion was obvious and was attributable to over-exploitation brought about by higher prices paid to the shellfishermen. In his 1911 report entitled "A Report upon the Quahog and Oyster Fisheries of Massachusetts," Dr. David L. Belding went into great detail as to what were the major reasons for the decline of the quahog industry in the late 1800s and early 1900s. What he said then is just as appropriate now for this and any other public fishery:

> *So long as the natural increase of the quahog equals the amount taken from the flats it is evident that the supply will not diminish. As soon, however as the demand of the market necessitates a constantly greater annual production, the balance of nature is upset, and a diminution of the natural supply takes place. As we have already seen, the simultaneous decrease in the supply and increase in the demand caused a rise in the price, sufficient for a time to lure more men into the industry. This time of prosperity has already passed, and many men are leaving the fishery to seek a livelihood in other pursuits, as, in spite of the high prices, they are unable any longer to make a living. The discovery of large quahog beds in the deep water was the only factor that prevented the destruction of the quahog fishery long ago. These beds are now being over-fished, and when they are depleted the disappearance of the great industry will be complete.*

The "great industry" that Belding referred to has never been restored. In its place is a much smaller scattered commercial fishery for quahogs and an increased use of the resource for recreational fishing. Since those early years of over-exploitation, continued demand for shellfish has maintained or increased the market value for all four species, with quahogs and bay scallops especially commanding prices many times higher than was paid formerly. Recently Alber (1987) reported that the wholesale value of shellfish harvested from Buzzards Bay was $5,000,000. The Massachusetts Division of Marine Fisheries has used a multiplier of 4.5 times to convert wholesale prices to retail value for shellfish. On this basis, the retail value would have been more than $22,000,000 in 1985.

It should be realized that public health closures affecting hundreds of thousands of bushels of quahogs greatly reduce this overall value. In addition, management that is more effective could also increase production and result in greater values. Thus, the potential for both tremendous increases in commercial shellfish values and extensive opportunities for recreational shellfishing are present in Buzzards Bay if the trend of increasing contamination and inefficient management of the shellfish resource can be reversed.

Resource Issues

Of the four species of shellfish most important to fisherman in the Buzzards Bay area, the American oyster and bay scallop have probably shown the greatest decline in abundance since colonial days. However, it is also the case that contamination by sewage and other bacteria sources has had a profound effect on the utilization of quahogs and soft-shell clams. In effect, their contaminated status in many locations has protected significant portions of the resource from over-exploitation that often took place in non-contaminated areas. This is especially true of the quahog resource that was almost universally distributed throughout the bay in early times but now is reduced in many towns. Although quahogs have a substantial ability to repopulate suitable areas after heavy exploitation, their numbers can be kept low by excessive fishing effort.

In Massachusetts, the cities and towns have primary jurisdiction over shellfish resources. However, most of these coastal communities have only limited ability to systematically assess their shellfish populations and, in fact, rely on harvest data to provide most of the information available for management purposes. The state marine fisheries agency does conduct shellfish resource assessment surveys, particularly in contaminated areas where the towns have minimal stock assessment data because of a lack of fishing activity. In addition, state biologists may work cooperatively with local shellfish agents to carry out specific resource assessments.

Since the early 1970s, the state has encouraged each of the cities and towns to develop a master plan for the management of their shellfish resources, but few of these plans are based on detailed stock assessment. More often, each shellfish officer develops a good working knowledge of the productive shellfish areas in his or her town, and can estimate what will be produced from these areas on an annual basis. The quality of these estimates varies from town-to-town based on the sophistication of the management program and the time and effort put into the assessment. In those towns with extensive closed areas because of sewage pollution, there may be very little assessment of shellfish stocks by the town since no harvesting occurs and any control exercised is primarily to enforce the closures.

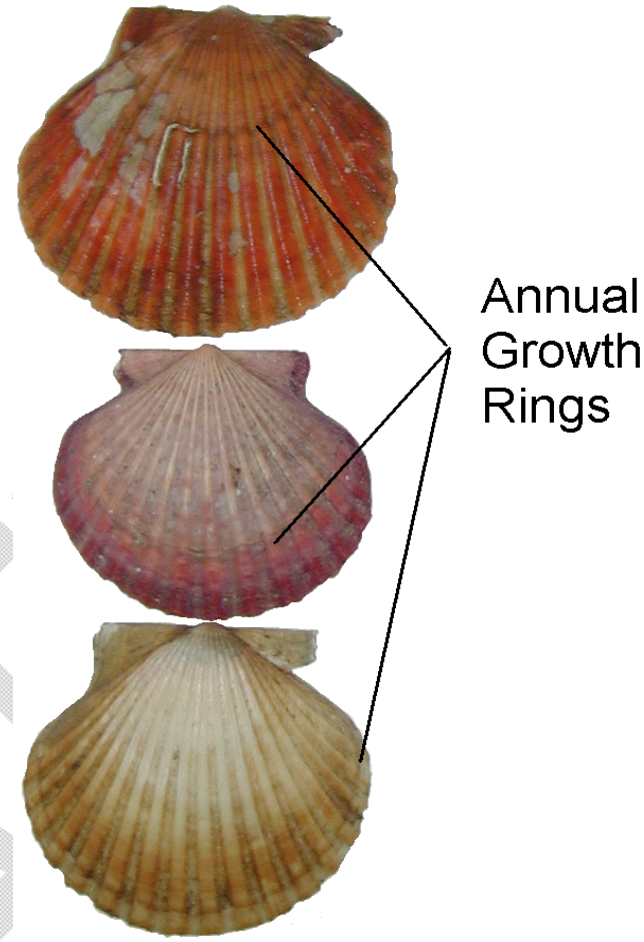


Figure 2-5. Scallop shells showing annual growth ring.

Each of the four major shellfish species presents different problems with regard to stock assessment. This is due to differences in the depth distribution, longevity, and mobility of the species. With regard to quahogs, any sampling system must take into account the fact that this species is buried up to a foot deep in the substrate under water depths of 12 feet or more. Bay scallops present an entirely different situation, since they do not burrow in the bottom and in fact are capable of extensive movement in the water column. In addition, since bay scallops live for less than two years, stock assessments must be conducted on young-of-the-year scallops or just prior to the fall harvest on one-year-old populations (see Figure 2-5).

In the Buzzards Bay area, most soft-shell clams are restricted to intertidal flats in relatively narrow bands of suitable substrate in the more protected parts of bays and harbors. This limits their distribution more than the other species and makes stock assessment surveys less extensive and labor intensive. Oyster populations are the least difficult to assess because practically all existing oyster stocks in the bay are derived from planted individuals, and show little movement after being set out. Assessments involve periodically sampling oyster density and size to document growth, predation, and other mortality factors.

In the Buzzards Bay area, important shellfish stock assessment studies, particularly in closed areas, have been carried out by the state Division of Marine Fisheries. Thus, detailed information on the quahog resources of the greater New Bedford area is not available. Other agencies or contractors have provided for special studies such as the status of soft-shell clam resources in Buttermilk Bay, an upper portion of Buzzards Bay.

The largest potentially productive shellfish area currently closed to fishing because of sewage contamination is the New Bedford Harbor/Clarks Cove area. This area, encompassing part of New Bedford, Fairhaven, and Dartmouth consists of more than 7300 acres. Much of this area was the subject of a comprehensive survey of quahog stocks conducted by the Division of Marine Fisheries in 1980-81 (Hickey, 1983). Hickey reported that historical data on this resource were not extensive, although Belding (1909 and 1912) included some information as part of his study of shellfish areas of the Commonwealth. Belding reported that even in the early 1900s much of the New Bedford/Fairhaven area was closed to quahogging because of sewage contamination. He estimated that Buzzards Bay contained about 8000 acres of quahog territory altogether and that much of the area was over-harvested and improperly managed.

The 1980-81 survey by the state was conducted in the New Bedford, Fairhaven, and Dartmouth area in water depths of 12 feet or more and did not include all of the closed area of those three towns. The sampling was carried out by towing a dredge behind the Division's research vessel. Hickey reported that the survey found that more than 415,900 bushels or 33,000,000 pounds of quahogs existed in the areas sampled. Subsequently the Conservation Law Foundation (CLF, 1988) used this estimate as the basis for their population estimate of more than 500,000 bushels or 40,000,000 pounds for the entire closed area in the three towns.

This enormous resource has provided little direct benefit in recent years. Since 1982, about 70,000 bushels of quahogs were taken from the Clarks Cove area for transport to other areas free of contamination in other towns. Shellfish biologists believe that annual harvests of 20% of adult quahog stocks may be taken without seriously depleting long-term population levels (Hickey, 1983). This means that up to 100,000 bushels or 8,000,000 pounds of quahogs could be harvested annually from this closed area if sewage contamination was eliminated or some method of purifying the shellfish was developed. Other less extensive areas in Buzzards Bay are also closed to shellfishing because of water pollution problems.

Another intensive survey of the shellfish resources of a portion of Buzzards Bay was carried out by the Boston University Marine Program at Woods Hole in 1985 and 1986 (Alber, 1987). This survey focused on soft-shell clams with the purpose of determining the density and size distribution of this species in Buttermilk Bay, which lies in the towns of Bourne and Wareham in the northernmost part of Buzzards Bay (Figure 2-6). Based on shellfish officer reports, seven areas supporting softshell clam populations were sampled intensively by digging quadrants in the intertidal zone and sifting out the clams from the sediment removed from each sample plot. These clams were then counted and measured to determine the density and size frequency at each site, including what percentage were legal-sized at the time of sampling.

Although no figures on the total standing crop of Buttermilk Bay clams were reported, the seven areas sampled were rated for clam density from "low" to "high," with a range of 47 to 624 clams per square meter. It was noted in the study that great variability existed in both the density and size distribution of clams in each of the seven beds studied.

Sampling was conducted both in 1985 and in 1986. Considerable differences in both densities and size distributions were found between the fall 1985 sampling and that conducted in the spring of 1986. Most clam beds sampled in the fall showed lower densities and larger sizes than those sampled in the spring. The reasons for these differences were not completely clear according to (Alber 1987) but it was surmised that both biological and environmental factors contributed to this variation.

Environmental Issues

The effects of sewage pollution on shellfish have already been referred to, particularly for the New Bedford area. Most of this impact consists of a loss of utilization for food rather than direct mortality of the shellfish. Seldom are water quality or substrate conditions so noxious that shellfish cannot survive. Exceptions to this would include areas affected by some oil spills, pesticide contamination,

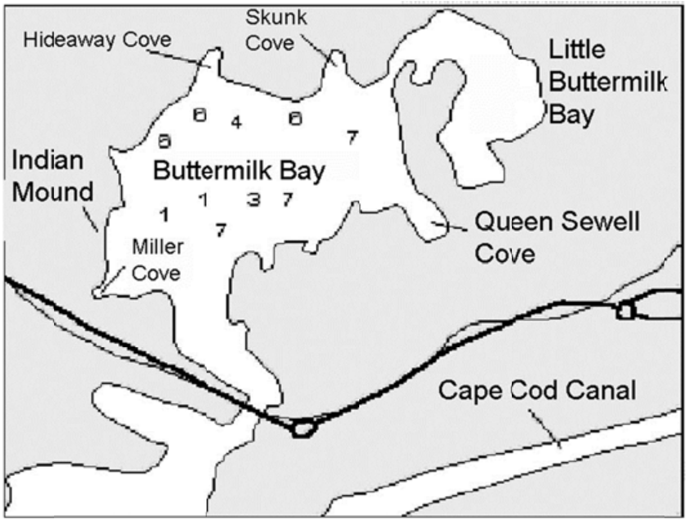


Figure 2-6. Sampling sited in Buttermilk Bay

noxious sewage outfall situations, and bottom areas altered by dredging or filling. These conditions are most often attributable to "accidents" rather than chronic conditions in the environment. When they occur, they usually are recognized and often constitute an illegal act subject to fines or other penalties.

Although better control over these and other types of environmental "accidents" would be highly desirable, the more insidious effects of water pollution should be recognized as having the most serious impact on our utilization of shellfish stocks. For years, local, state, and national public health agencies have advocated the disposal of human waste into whatever water system was available. On a worldwide basis, the use of water transport has resulted in the greater distribution of infectious diseases and toxic materials. Too often disposal into the aquatic or marine environment was perceived to be the cheapest, most expedient alternative because of an out-of-sight out-of-mind set that dominated the builders of our society. This attitude, made even more disastrous by our tendency to cluster human habitation along the shorelines of waterbodies, has led to our present water quality status. Even today, it is normal procedure for public officials to question the degree of sewage treatment that should be required before effluent is dumped into our waterways. Often the missing ingredient in these discussions is the ecological cost of such disposals. There is a lopsided argument with detailed engineering figures for various degrees of effluent treatment on one hand and an undocumented, nebulous environmental concern on the other hand. In order to fairly evaluate this issue, the costs of environmental and ecological impacts must be documented and well known to the decision makers and involved public. Only then can an informed choice be made that will reflect true societal costs.

Belding (1912) reported that in 1901 legislation was enacted in Massachusetts to require the Commissioners of Fisheries and Game to close portion of the tidal waters to the taking of shellfish when so requested by the State Board of Health in order to protect the public from contaminated quahogs, clams and oysters. Under this act, portions of New Bedford Harbor were closed in the early 1900s, and have remained closed since.

This act was adopted primarily because of concern that shellfish from these areas could transmit typhoid fever. Later, the main public health issue involved the transmission of infectious hepatitis. Thus for more than 80 years this shellfish resource, recognized as one of the largest in the Commonwealth, has existed essentially unused and unmanaged while sewage pours into the harbor. Although some attempts at utilization occurred, they were sporadic and often ill-advised and were eventually abandoned. The most important and long standing of these efforts was the transplantation of quahogs from this area to other clean areas where the shellfish could be purified and eventually made available for human consumption. Such a transplant program, although technically and economically feasible, suffered from political considerations since the city of New Bedford, where most of the transplanted quahogs came from, did not benefit directly as did the recipient towns. For years, the Division of Marine Fisheries supervised this transplant program, but eventually a lack of appropriate funding and cost sharing led to its demise. Since 1982, only 70,000 bushels have been transplanted from the Clarks Cove area to open areas. As reported earlier, Hickey (1983) estimated that up to 20% or 100,000 bushels of quahogs could be removed annually from this area without depleting the resource. Even considering only the wholesale value of this resource, almost $5,000,000 annually is being lost to the communities of New Bedford, Fairhaven, and Dartmouth. Obviously, even a portion of such a sum could greatly defray the costs of new sewage treatment facilities necessary to clean up the area. The Conservation Law Foundation report entitled "Lost Harvest" (CLF, 1988), states that:

> *... the New Bedford area is losing millions of dollars in income every year due to the sewage contamination-related closures of the shellfish beds in Clarks Cove and New Bedford Outer Harbor. The three affected communities are sitting on a resource that, at current prices, is worth of $24 million, with more than half of that value in New Bedford's waters. Shellfish harvesting alone could generate nearly $6 million per year in income for the area, and over $14 million in annual economic activity. This overall lost economic value of the fishery is nearly $22 million per year.*

This report also points out that these pollution problems will not be resolved in the immediate future. The problems involve the entire sewage treatment and stormwater

Figure 2-7. New Bedford sewage discharges (including CSOs).

collection system and are compounded by combined sewer and stormwater directly into the harbor during heavy runoff periods (Figure 2-7). The separation of sewage from stormwater runoff will constitute a massive undertaking in New Bedford at a cost of many millions of dollars and years of construction-caused traffic disruption.

The existing sewage treatment facility at Fort Rodman is inadequate and must be upgraded and expanded. According to Camp, Dresser and McKee, Inc. (1987), this facility has not met its original design standards since it construction in 1972. The City of New Bedford has recently undergone rapid growth with 1751 housing unit permits issued in the 1980-1987 period. Currently more than 23,000,000 gallons a day of only minimally treated sewage are being discharged into the harbor by the city of New Bedford.

Recently the city has agreed to a schedule that outlines the steps necessary to bring its sewage system into compliance with state and federal laws. However, experience has shown that even after the opening of new treatment facilities in heavily developed urban areas, there may still be sufficient water quality problems to preclude the opening of adjacent shellfish beds. This possibility in no way diminishes the need for better treatment. What it does require is a realistic solution to utilization of the shellfish resource even if water quality is not pristine.

This problem of utilization is also critical for other parts of Buzzards Bay where bacterial pollution problems, although not as severe as in the greater New Bedford area, have resulted in increased shellfish closures. Figure 2-8 shows this increase since 1960. By 1988, closed areas in Buzzards Bay amounted to more than 11,000 acres and continue to increase. In many instances, areas formerly considered relatively pristine were closed for the first time. Coastal development accounts for these closures because development increases the amount of coliform bacteria in surface runoff through point and non-point sources. Point sources, such as industrial drainpipes and treatment plants, are often thought of as the principal cause of water pollution, but on Cape Cod, the problem is more often due to non-point sources such as stormwater runoff, septic system discharges, and waterfowl and animal wastes. Non-point contamination is obviously a much more diverse problem, which can only be controlled by constant attention at the local level.

Management and Jurisdictional Issues

The current management system in the Commonwealth with regard to shellfish is a mixture of local, state, and even federal control. The towns and cities have principal responsibility for the resource and harvesting aspects. State and federal agencies share responsibilities for the control of shellfish in the marketplace and for water quality standards and enforcement. Although this combination of jurisdiction is often confusing and administratively difficult, it does provide for both local and more distant control that is necessary when shellfish are being marketed for human consumption. In many coastal states, no local control of shellfish resources is exercised since the state has primary jurisdiction. Except in the case of contaminated areas, in Massachusetts the state Division of Marine Fisheries has encouraged local control as a way of providing more on-site management than could ever be carried out by the state. Through a system of financial aid and technical assistance, the Division has attempted to develop a working partnership between the cities and towns and state and federal agencies that can address all the diverse issues.

Recently, legislative changes have invested more authority over contaminated shellfish issues with the Division of Marine Fisheries rather than with the state Department of Public Health. This has resulted in improved working relations between the towns and the state on contaminated shellfish management and provided for increased water quality sampling. Unfortunately, state budget cutbacks have precluded staff expansions promised to the Division and instead resulted in reduction of both personnel and financial aid to the towns. It is hoped that these cuts represent only a temporary setback to what has been a productive and well-accepted program of great benefit to the users of the shellfish resource.

Most of the towns and cities derive at least a portion of the funds necessary to operate their shellfish program from permit fees charged both recreational and commercial fishermen. These fees differ from town to town and the income generated varies considerably. As pointed out earlier, each town employs a shellfish officer whose principal duties are the management of the resource and the enforcement of the shellfish regulations. In most towns, these individuals are assisted by part- or full-time deputies and possibly other town employees. A substantial portion of their time is spent checking shellfishermen in the field to insure that they have purchased the appropriate permits. In many towns, the fees charged for commercial and recreational permits are too low to generate enough income to provide significant benefit to the program. This often results in widely differing funding levels from town to town and limits cooperative management efforts on common resources. It is doubtful that the towns can provide for an adequate shellfish program financed by permit fees alone, especially if state monies are not maintained or increased in the near future.

The federal government provides little or no financial assistance even though they are involved in the control of interstate shipment of shellfish, through the National Shellfish Sanitation Program, with the coastal states. Some federal agencies do conduct research and monitoring activities connected to shellfisheries, especially for specific

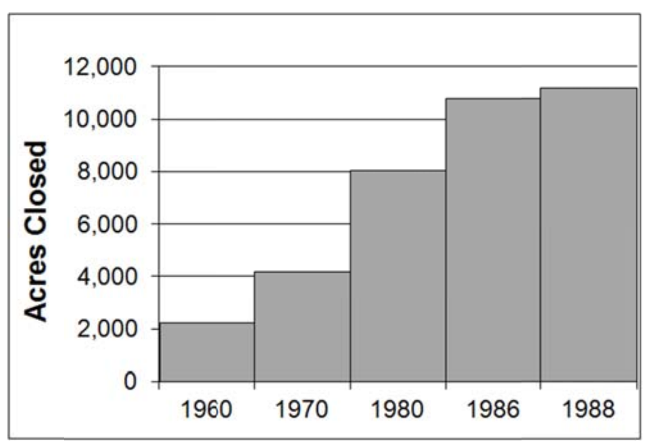


Figure 2-8. Acreage closed to shellfishing in Buzzards Bay.

Data from the Division of Marine Fisheries.

instances such as toxic pollution releases, oil spills, or other major environmental impacts.

Another appropriate area for federal involvement would be the development of new criteria for measuring the impact of pollution on the edibility of shellfish stocks. The coliform indicator and standard currently in use was developed during the 1920s when the target disease was typhoid fever, which is now of minor occurrence. The principal concern is now infectious hepatitis, which is caused by a virus that may not be detected by the coliform indicator. According to Hickey (1989) the relationship between viral pathogens and the bacterial indicator has not been established nor has the validity of the standard. He points out that:

> *Research is needed to investigate the current indicators in terms of their numerical relationship to pathogens. Any change in the indicator or the numerical relationship for classifying growing waters should be accompanied by appropriate changes in the tolerance limits for shellfish; i. e., the current market standard.*

He further states that no changes should be made in the current system until a new standard is developed and made a part of the National Shellfish Sanitation Program.

Another area of need is greater public awareness of the shellfish losses associated with waste pollution. Too often in the past, the entire emphasis of announcements on closures has been to protect the public from contaminated shellfish. While such notification is necessary and appropriate, it should also point out the source of the contamination and indicate what the extent of the loss to the public will be. In this way, the true impact would be better understood so that pollution abatement would be recognized as the most appropriate long-term solution.

Recommendations

Management of the shellfish resources of Buzzards Bay is a diverse responsibility of many local, state, and federal jurisdictions. By far the greatest problems are due to our proclivity to use the coastal waters for the disposal of sewage wastes. This practice is so widespread and entrenched that even today we are losing the few remaining clean areas to the increasing impacts of coastal development. Thus, as we provide more and more housing in these delightful coastal communities, we are also destroying the qualities that make them so desirable. The following recommendations are offered to take action against those activities that are so detrimental to these renewable resources.

1. The Division of Marine Fisheries and the involved cities and towns in the greater New Bedford area should convene a special task force to develop a comprehensive quahog utilization program. The goal of this program would be to make available up to 100,000 bushels of purified shellfish annually from Clarks Cove/Outer New Bedford Harbor area. More than 500,000 bushels of quahogs are present in this area. Past efforts at utilization of this resource have been marked with factionalism, a lack of long-term planning, and insufficient funding. What is needed is a thorough analysis of the available options and a commitment from all involved to work out mutually beneficial solutions. Given the values involved (more than $22,000,000 annually), the local communities and state must not continue to ignore this resource.

2. The involved federal and state agencies should accelerate research into development of an appropriate indicator of shellfish bacterial and viral contamination.

The present coliform bacteria indicator was developed many years ago and may well be inappropriate both for the protection of the public from diseases associated with the consumption of contaminated shellfish and to provide for rational utilization of shellfish resources. The issue of whether the indicator and the standards used are appropriate for measuring viral contamination must be addressed. On the other hand, since it is clear that high coliform counts can be due to fecal matter from birds or other mammals, or from multiplication in the environment, unnecessary closures may be brought about by application of the existing standards. Although some work is currently ongoing, results are not expected soon unless some urgency is applied to the issue.

3. The Commonwealth of Massachusetts should provide adequate funding to the Division of Marine Fisheries to carry out its expanded role of shellfish area monitoring and other shellfish management activities.

Several years ago, the state legislature transferred many responsibilities with regard to shellfish monitoring from the Department of Public Health to the Division of Marine Fisheries. At the same time, it was planned that personnel and funds necessary to carry out these mandates would be forthcoming. Budget cutbacks have changed this commitment so that the Division now has the responsibilities but not the staffing and funds to do the job. To do the best it can with fewer people and less money, the Division of Marine Fisheries has enlisted local shellfish officers' help in the monitoring process. This effort should be made permanent and expanded through state reimbursement for local involvement and expanded Division of Marine Fisheries funding.

4. Both the coastal towns and the Commonwealth should encourage the development of shellfish grants and mariculture programs to enhance the production of shellfish.

Although current state laws allow the towns and cities to issue shellfish grants, there has been only limited use of these options because of many problems associated with cultural enterprises. In some cases, failure of individual operations can be attributed to unnecessary restrictions on harvesting these grants and water quality changes that have precluded marketability of the shellfish produced.

To enhance or restore populations of oysters and bay scallops, the production of spat or seed from large-scale mariculture operations would be most beneficial. Although some sources of seed may now be available, costs and problems associated with out-of-state transfers make new in-state sources a highly desirable objective.

5. The coastal cities and towns should develop appropriate permit fee schedules and other methods to fund their shellfish programs.

Although shellfish resource values differ widely among coastal towns, each town has an obligation to manage what it has in an efficient manner. In these days of increased acceptance of user fees, it is appropriate that the towns adopt reasonable fees for public usage of the resources. This could include a landing fee for each bushel taken in the commercial fishery and individual daily fees for recreational fishermen.

Such a system should be designed to provide detailed effort and harvest data for all shellfish, thereby enhancing the compilation of catch statistics that in many towns is currently inadequate.

6. On both the state and federal level the development of a "pollution tax" should be considered with part of the proceeds earmarked for shellfish resource enhancement. Any discharges that contribute to the bacterial or other contamination of shellfish should be assessed fees, a portion of which would be earmarked for shellfish restoration or management. Likewise, any fines or penalties resulting from illegal discharges should also help to defray management costs. Such a system would not only provide funding but also help to publicize the impacts of pollution on shellfish resources. Local conservation commissions should also assess fees on coastal alteration projects to mitigate shellfish losses.

References

Alber, M. 1987. Shellfish in Buzzards Bay: a resource assessment. Boston University Marine Program. Woods Hole, MA, A report prepared for the Buzzards Bay Project, 75 pp.

Belding, D. L. 1909. A report upon the mollusk fisheries of Massachusetts. Wright and Potter, Boston, MA, 234 pp.

Belding, D. L. 1910. A report upon the scallop fishery of Massachusetts. including the habits. life history of Pecten irradians, its rate of growth, and other facts of economic value. Wright & Potter Printing Co., Boston. 150 pp.

Belding, D.L. 1910. Scallop studies on Cape Cod, MA, Mass. D.M.F. report, 200 pp.

Belding, D. L. 1912 (reprint 1964). A report upon the quahog and oyster fisheries of Massachusetts. Massachusetts Division of Fisheries and Game, 134 pp.

Belding, D. L. 1931 (reprint 1964). The scallop fishery of Massachusetts. Massachusetts Division of Fisheries and Game, 3: 51.

Camp, Dresser, and McKee, Inc. 1987. Draft Phase I Facilities Plan and Screening Studies. Boston, Massachusetts. Report prepared by Camp, Dresser & McKee, Inc., for the City of New Bedford.

Capuzzo, J. M., A. McElroy; and G. Wallace. 1987. Fish and shellfish contamination in New England waters. Coastal Alliance, 218 D Street, S. E. Washington DC, 59 pp.

Conservation Law Foundation (CLF). 1988. Lost Harvest: Sewage, Shellfish and Economic Losses in the New Bedford Area. 54 pp.

Division of Marine Fisheries, Commonwealth of Massachusetts. 1985. Massachusetts marine fisheries: assessment at mid-decade. Executive Office of Environmental Affairs. Publication #14224-65-500-70-85-CR, 31 pp.

Hickey, J. M. 1983. Assessment of quahog stocks in contaminated waters of southeastern Massachusetts. Massachusetts Division of Marine Fisheries.

Hickey, J. M. 1989. Massachusetts shellfish closures, monitoring programs, regulations, and the concern over the bacterial standard. Division of Marine Fisheries, Commonwealth of Massachusetts.

Marine Resources Coordinating Committee, 1987. Action plan to address marine fisheries and water quality problems in Massachusetts, 8 pp.

Sindermann, C. J. 1979. Pollution-associated diseases and abnormalities of fish and shellfish: a review. Fishery Bulletin Vol. 76, No. 4.

3. Buzzards Bay Lobster Resource and Fishery

By Frank Grice[4]

Introduction

The American lobster (*Homarus americanus*, Figure 3-1), has not always been held in high esteem by New England residents. During colonial times, it was reported that lobster tails were often used as bait to catch striped bass, which were highly prized. Lobsters were so abundant in some areas that large numbers could often be collected along the shoreline after heavy coastal storms had abated.

The lack of power of the boats and the hauling in of pots or traps greatly restricted the size of the catches of the early lobstermen as the fishery developed during the early 1800s. Yet by the late l800s, many reports of greatly reduced catches led to dire warnings of impending depletion and a host of state laws to protect small, immature lobsters and egg-bearing females.

In Buzzards Bay, the lobster fishery, although important to the local economy, has not been as dominant in the overall Massachusetts fishery landings as in other parts of the coastal waters such as Massachusetts Bay. In the period 1979 to 1988, only about 3% of the statewide landings of

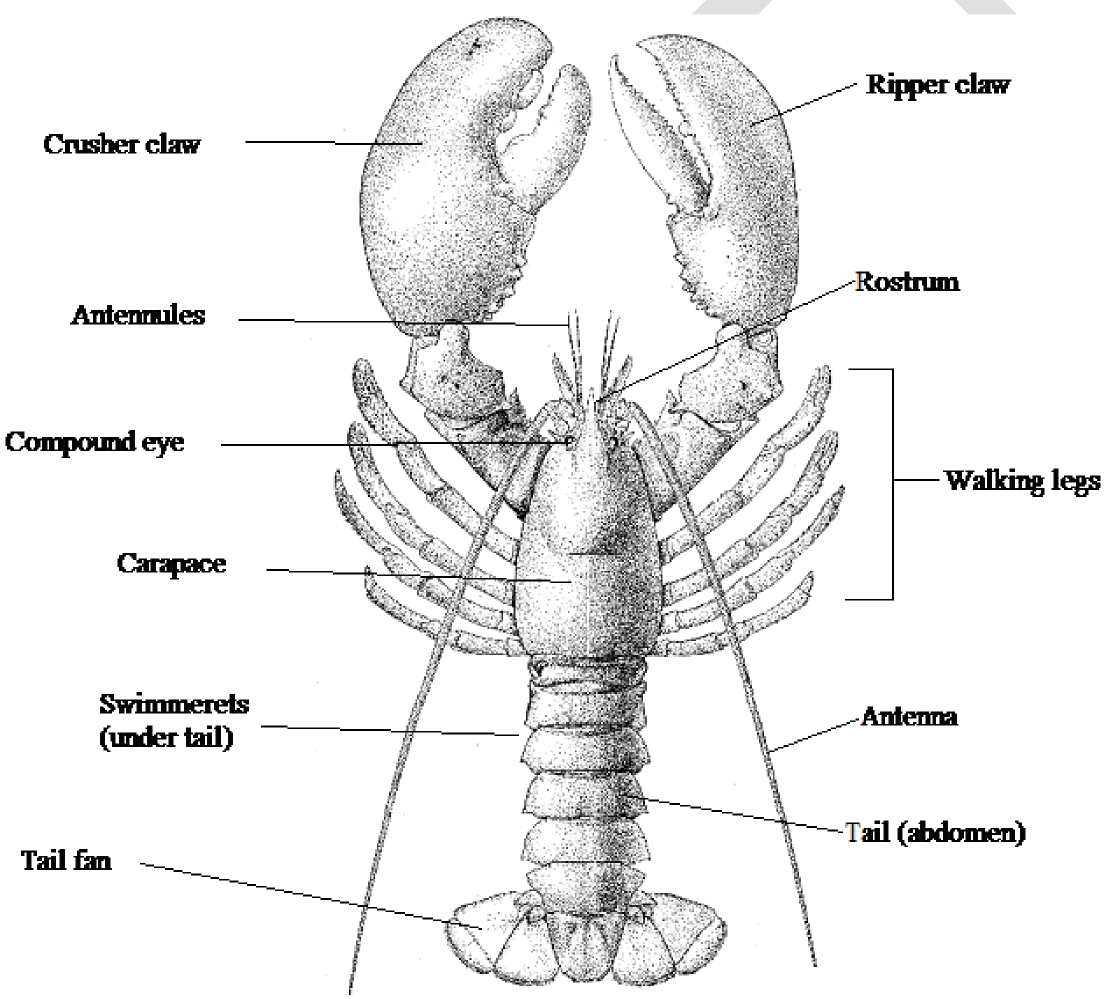


Figure 3-1. Dorsal view of American lobster showing major body parts and appendages.

[4] Retired, Massachusetts Division of Marine Fisheries.

Accepted September 26, 1990

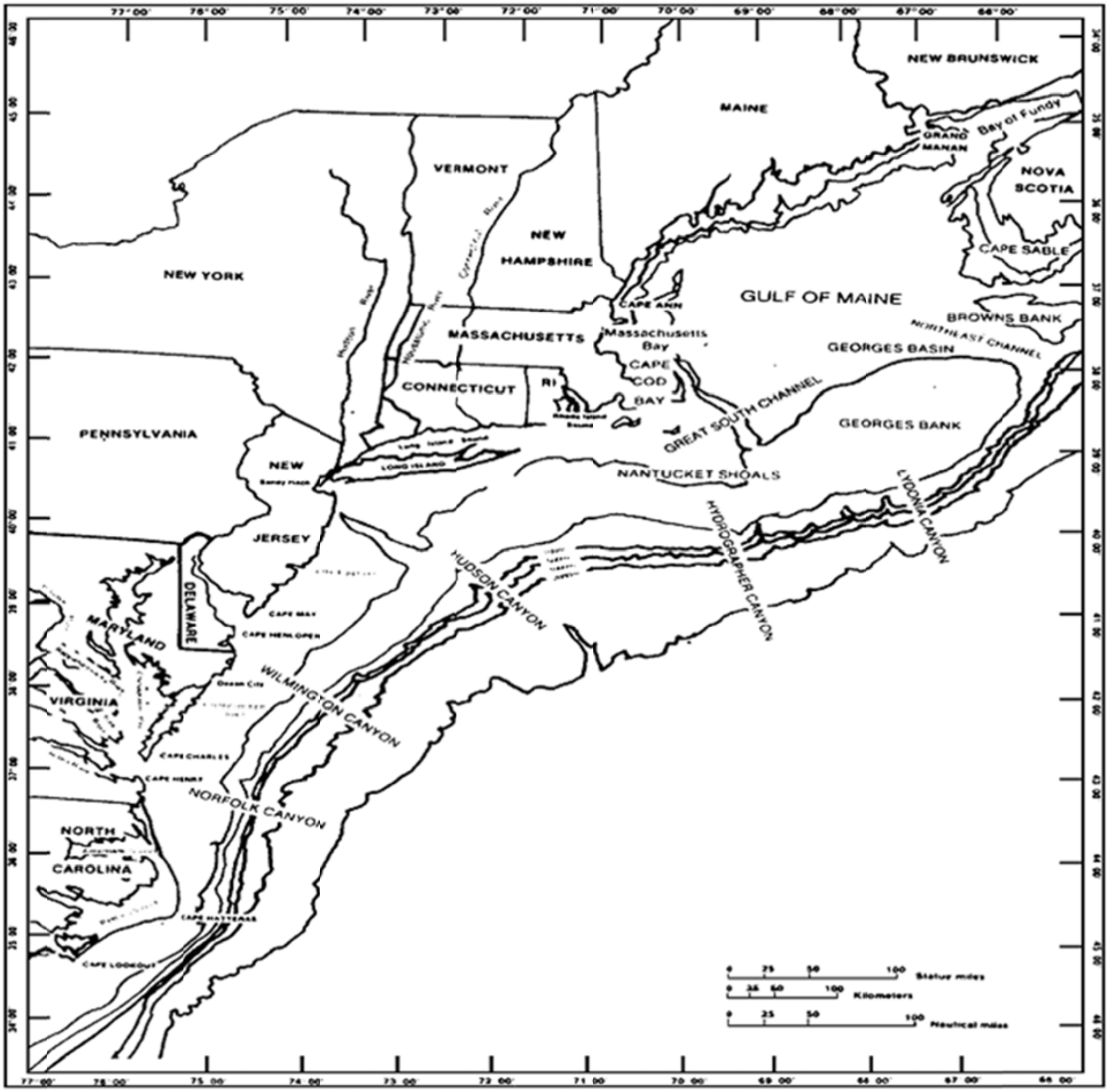


Figure 3-2. Outline map of east coast of United States and Maritime Provinces of Canada including the continental shelf which is the principal range of the American lobster.

lobster came from Buzzards Bay. It was estimated that 200 to 250 commercial lobstermen fished this area and sold about $1,000,000 worth of lobster in 1988.

Studies have shown recently that Buzzards Bay shelters large numbers of egg-producing lobster that mature at a smaller size than in most other areas. This has resulted in the production of tremendous quantities of larval lobster compared with other coastal waters. Annually, millions of larvae are produced here, many of which are eventually carried into Cape Cod Bay, where they settle to the bottom and contribute to future fisheries there.

In recent years, a portion of Buzzards Bay acquired the dubious distinction of being the only area in the state closed to lobstering because of pollution. The greater New Bedford Harbor area was closed in 1979 because of high levels of polychlorinated biphenyls (PCBs) in lobster and other marine organisms. In this and other parts of the bay, lobster populations have exhibited pollution-enhanced diseases of the gills and shells. Stress in the environment brought about by disposal of industrial and domestic wastes appears to increase the incidence of these naturally occurring diseases.

Status of Lobster Fishery

The American lobster supports an important inshore fishery in Massachusetts with annual retail values of about $40,000,000. In addition, the offshore fishery beyond territorial waters lands about 2,000,000 pounds annually with a retail value of $6,000,000. Massachusetts also serves as the main distributor for live lobsters taken in Maine and the Canadian Maritime Provinces with many millions of pounds being reshipped from Boston all over the United States and overseas (Figure 3-2). The Commonwealth has an extensive system of data collection of fishery statistics involving the landings and sale of lobster and also cooperates with federal agencies to provide information on the total U. S. industry.

Under the Massachusetts Division of Marine Fisheries' lobster catch reporting system, the Buzzards Bay area is included in Statistical Fishing Area 10, which encompasses the area from the Rhode Island line to another line east of Martha's Vineyard across Nantucket Sound (Figure 3-3). It is estimated that lobster landings from this area constituted

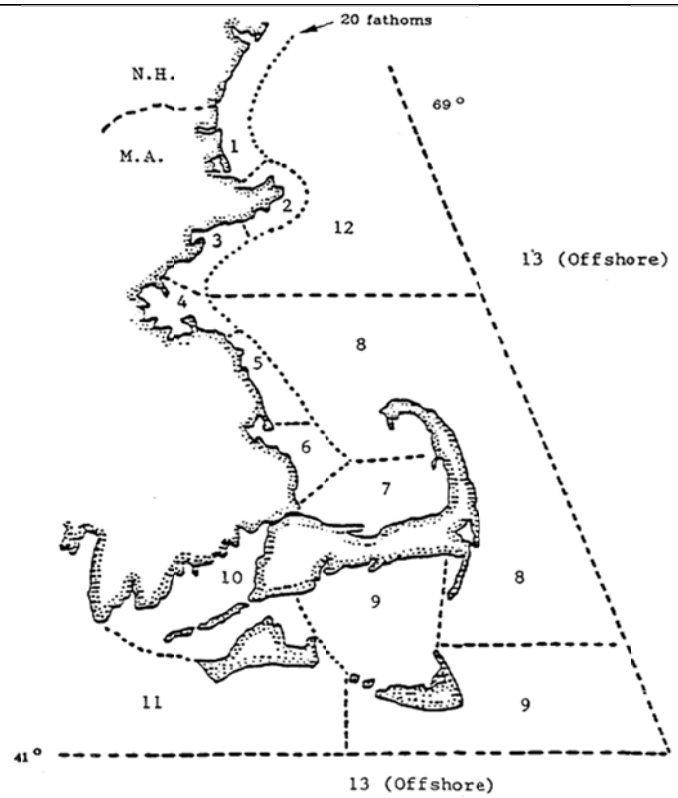


Figure 3-3. Location and description of Statistical Fishing Areas of the Massachusetts lobster fishery.

about 4% of the statewide coastal landings, averaging 366,380 pounds in the 1979-1988 period, Hoopes (1989). Of this total approximately 69% were taken from Buzzards Bay proper during the ten-year period. Thus, landings averaged 252,872 pounds between 1979 and 1988. This is less than 3% of the statewide landings and makes the Buzzards Bay area one of the least productive in the state in terms of adult lobster taken in the commercial fishery.

Estrella and Pichette (l989) stated that 272 commercial lobstermen reported taking lobsters from Fishing Area 10 in the 1979 to 1988 period. It is probable that some of these fishermen did not fish in the Buzzards Bay area at all during these years and others may have operated there in some years and not in others. Therefore, it seems likely that 200 to 250 commercial fishermen were involved annually in the Buzzards Bay fishery when landings were reported to average slightly more than 250,000 pounds.

In addition to the commercial harvest in Buzzards Bay, an unknown number of family or non-commercial lobster fishermen fished with up to the ten-trap limit allowed and/or dove to take lobster by hand. These fishermen are not allowed to sell lobster and must utilize the catch for their own home consumption. Traditionally, on a statewide basis, these non-commercial fishermen are much more numerous than the commercial operators, but they only take a small fraction of the total catch annually. In the years 1979 to 1988, more than 10,000 to 13,500 recreational permits were issued by the Division of Marine Fisheries. Many of these licensees reported not fishing for lobster after obtaining the necessary permit. Those who reported not fishing in the year they purchased their permit ranged from 35 to 55% statewide. Of the 4,725 to 7,946 who fished during these years, they reported harvesting a total between 345,000 to 396,000 pounds annually or about 4% of the statewide commercial catch from coastal waters.

Of the non-commercial lobster fishermen, about 19 to 33% reported diving for lobsters, but they only accounted for l% of the coastal Massachusetts landings. Divers are not allowed to spear or take lobsters by any means other than with their hands. They normally employ scuba gear and must display a distinctive flag on a float in the immediate vicinity while diving. All lobster fishing is restricted to daylight hours. Lobstermen using lobster traps are required to display distinctive buoy colors on the boat used in the fishery and on the buoys or floats that mark the location of the lobster traps or pots on the bottom. Most non-commercial fishermen haul individual traps by hand since the ten-trap limit mandated by state law obviates the need for a mechanical pot hauler such as that used by almost all commercial lobstermen. The vast majority of these non-commercial lobstermen fish only during the summer months and utilize a variety of boats, most of which are owned primarily for other fishing or recreational use.

The Commonwealth of Massachusetts also provides a seasonal commercial lobster permit that is available to full-time students. This permit allows a student to fish up to 25 traps at a time in the summer months and sell catch to a licensed dealer. Although some of these permit holders fish in the Buzzards Bay area, no breakdown of the total number who fished there or the amount of lobster harvested is available. It is believed that their lobster landings would be very minor compared with either the coastal commercial or the non-commercial permit holders.

In summary, recent values of lobster harvested from Buzzards Bay likely approach $1,000,000 annually to 250 or more commercial lobstermen who fish at least part of the time in these waters. According to the Division of Marine Fisheries, the total value of the statewide lobster fishery, which includes the value of vessels, gear and lobster, was $118,302,862 in 1988. If Buzzards Bay lobstermen's investment in the fishery is similar to other coastal fishermen, then it appears that the value of the Buzzards Bay fishery in 1988 approximated $2,340,000.

In addition, non-commercial permit holders, who were probably seven times as numerous as the coastal commercial fishermen in the Buzzards Bay fishery, spent large but undocumented amounts in the pursuit of lobster for home consumption.

A very high percentage of all lobster in the marketplace is sold to the final user alive. This requires an extensive system of dealers with seawater systems, many of whom are located well inland from any natural source of salt water. It also guarantees freshness to the consumers who, over the years, have come to expect that all lobster must be obviously alive when placed in a cooking pot. Thus, the lobster industry is unique in that very little processing of the product is involved, but handling and holding at all stages is absolutely critical to a successful operation.

Once live lobsters are sold by the fishermen, the ability to identify where they were taken is lost. Thus within one dealer's holding tank, lobster from Newfoundland may be crowded in with identical-appearing Buzzards Bay crustacea and some from far off the coast by the edge of the continental shelf. Because of this any effort to control the marketing of lobster from specific sites must be directed toward the fishermen. Traditionally, such action has resulted in area closures to lobster fishing to prevent the harvesting of contaminated lobster or to attempt to restore depleted stocks. Other management restrictions such as protection for egg-bearing females, minimum size limits, and fishing gear modifications are commonly employed by state or federal regulators.

In Buzzards Bay, the lobster fishery is regulated by the Massachusetts Division of Marine Fisheries through a combination of regulations and legislative acts. Unlike many other fishery stocks, the lobster population appears to be relatively stable, with annual production from the coastal waters showing slight increases over the last 10 years. This is somewhat surprising since the lobster fishery is so intense that most individuals (95%) are harvested immediately after molting into the legal size category.

The average carapace length of lobster harvested in the commercial fishery in Buzzards Bay in 1988 was 86.1 mm (3-7/16 in.), which is only 3.5 mm above the minimum legal limit, Estrella and Pichette (1989). With such an intense exploitation rate, the minimum size limit and its relationship to size at sexual maturity become critical to successful recruitment and ultimately, population size.

Resource Issues

The lobster resource of Buzzards Bay, although not as economically productive as that of some other Massachusetts coastal areas, does have some important characteristics that affect the lobster fishery elsewhere. Female lobsters in Buzzards Bay mature earlier and at a smaller size than in more northerly coastal areas. This means that the existing legal size limit (3-1/4 in.) tends to protect females that are more immature, and allow a higher percentage of them to become egg-bearing (ovigerous) before being legally harvested. This smaller size at sexual maturity may help account for an abnormally high incidence of egg-bearing lobster in Buzzards Bay. In 1988, it was reported that 28% of the female lobster sampled in the commercial fishery in Buzzards Bay were egg-bearing, whereas only 5% were egg-bearing in other samples from Gulf of Maine coastal areas, Estrella and Cadrin (1989).

Other investigators have attributed this earlier maturity to physical characteristics of the habitat such as relatively high summer water temperatures and restricted water circulation and exchange in combination with a high population density of lobster, Dow et al. (1975).

Probably this high incidence of female lobster ready to spawn is directly responsible for the unusually high numbers of lobster larvae present in Buzzards Bay waters in June and July of each year. Collings et al. (1983) found larval concentrations to be eight times as high in Buzzards Bay as in Block Island Sound during similar samplings in 1977 and 1978.

Based on this sampling in Buzzards Bay, hatching begins during the third week in May and was usually completed by early July. After hatching, lobster larvae go through three molts and then settle to their bottom-dwelling existence for the rest of their lives. During the first three larval stages, the young lobster float high in the water column near the surface and their movements are greatly dependent upon wind-driven currents. Buzzards Bay larvae took an average of 23 days to molt into the fourth stage, at which time they settle to the bottom. Of larval lobster hatched in Buzzards Bay, a significant portion end up in the Cape Cod Canal and further east in Cape Cod Bay. This drift is at least partly due to prevailing southeasterly winds and a net loss of Buzzards Bay water into Cape Cod Bay because of tidal action.

Because of higher water temperatures in Buzzards Bay, hatching occurs earlier than in Cape Cod Bay and the larvae reach each stage of development at an earlier date. Collings et al. (1983) found that larval lobster in the Cape Cod Canal had hatching times and development at a stage intermediate to Buzzards Bay and Cape Cod Bay. They estimated that during 1976, 1977, and 1978, 13.5 million, 26.0 million, and 9.2 million larvae, respectively, were deposited in Cape Cod Bay from Buzzards Bay and the Cape Cod Canal. The authors conclude, "If the larvae originating in Buzzards Bay are the major source of the sublegal and subsequent legal lobster stocks found in Cape Cod Bay and possibly areas to the south of Buzzards Bay, the protection of this area from future environmental damage should be given top priority by governmental agencies." They also point out that protection of the large egg-bearing lobster population in Buzzards Bay and the Cape Cod Canal is critical to future recruitment to a much wider coastal area.

Environmental Issues

Historically, lobster populations have seldom been impacted by environmental degradation. As inhabitants of open, cooler, high-salinity coastal areas and offshore canyons to a depth of more than 200 meters, few lobster are exposed to adverse conditions because of pollution or other man-induced environmental impacts. Yet it does happen, and unfortunately, Buzzards Bay is one of the areas in Massachusetts where lobster show the effects of pollution of their marine habitat. Together with Boston Harbor, Buzzards Bay has the dubious distinction of having the highest incidence, in Massachusetts, of two lobster diseases that are associated with noxious water conditions. In addition, lobsters sampled in the New Bedford harbor area have exhibited a high incidence of PCBs. This has led to the only pollution-caused closure to lobster fishing in Massachusetts.

The dumping of harbor dredge material in offshore disposal sites is particularly serious to living marine resources, especially if the dredged material contains toxic chemicals such as heavy metals and other industrial wastes. Several offshore disposal sites in Buzzards Bay have been utilized over the years. The adverse effects of ocean disposal may be magnified if natural conditions such as warmer water temperatures, shallow water depths, and wind-induced mixing of suspended solids are present as they are in portions of Buzzards Bay during summer months.

Because lobsters respire with their gills, large amounts of water are washed through these organs continuously. Consequently, in some polluted areas, suspended particles are being accumulated on the gill filaments. Eventually these particles cause a blackening of the gills and reduce their ability to exchange oxygen. Lobster have a very efficient system of cleaning their gills by reversing the flow of water, but under extreme pollution conditions even this system cannot function effectively and a condition known as black gill disease may develop.

Black gill disease was first observed in lobster in Buzzards Bay in 1983. This observation led to a statewide survey in 1983 and 1984 to determine the frequency of occurrence of this and another disease known as shell disease (Estrella l984). Lobster were collected from 12 sites and examined in the laboratory for evidence of gill damage and shell disease symptoms such as shell erosion, pitting and tunneling, and ulceration.

The study found that the incidence of black gill disease and shell disease in Buzzards Bay was relatively high compared with sites north and east of Cape Cod. Estrella (1984) reported that, except for one Massachusetts Bay site off Boston Harbor, all five Buzzards Bay sites exhibited higher incidence than did the other seven sites in Massachusetts. He found the heaviest disease symptoms to be from specimens collected at a site adjacent to New Bedford Inner Harbor. Here, half the lobster sampled showed evidence of both black gill disease and shell disease. He also found the most heavily diseased gills and shells on specimens from this area.

On sites where either disease was found, an increase in the incidence was related to larger sized lobster. It was speculated that this increase was due to longer environmental exposure time brought about by reduced molting of older, larger lobster. Smaller lobster molt more frequently and thus shed their shells and other parts before deterioration becomes as severe.

The impact of either or both of these diseases on the Buzzards Bay lobster resource is difficult to assess. It is known that the amount of contaminants in the body may produce nutritional deficiencies that can adversely affect shell formation and the ability to repair shell damage. As indicated earlier, black gill disease can result in reduced oxygen exchange and lower resistance to secondary infection. It would appear reasonable to assume that heavy infestations of these diseases in specific localities could seriously affect the associated lobster fishery through mortality or reduced marketability of the infected animals.

Based on this study of the incidence of these two lobster diseases in Massachusetts waters and other studies elsewhere involving highly contaminated waters, it is apparent there is a direct relationship between these diseases and high levels of pollution. Young and Pearce (1975) pointed out that lobster and crab collected near the New York Bight dumping grounds, which received large quantities of sewage sludge and dredge spoils, commonly exhibited appendage and gill erosion.

In addition to these diseases, contamination of lobster by PCBs and other industrial pollutants has been responsible for fishery closures in New Bedford Harbor since 1979. Division of Marine Fisheries' testing of lobster showed average PCB concentration, ranging from 1.0 to 4.9 parts per million (ppm), with individual lobster showing concentrations up to 23.8 ppm. At that time 20% of all lobster tested exceeded the existing state/federal tolerance level of 5 ppm. This level has since been reduced to 2 ppm by state/federal public health agencies and, although some reduction in PCB concentrations appear to have occurred, the area remains closed to lobstering.

Although lobster populations are not usually thought to be as severely impacted by domestic sewage contamination as are clams and other bivalves, they are dependent on a habitat capable of supporting a normal marine food chain. In addition, if the public develops a perception that the marine environment is contaminated (such as occurred in 1988 with medical wastes), the lobster fishery may suffer through reduced sales and lower prices. Thus lobster, as well as all other denizens of our coastal environment, are impacted by what is discharged into the watery world they live in. They will continue to reflect human ecological thoughtlessness until better solutions to waste disposal are found.

Management Issues

Lobster resources in Massachusetts and other coastal areas have been the subject of management laws and regulations for many years. In the 1930s, it was reported by state authorities that lobster populations were in a state of decline and would probably disappear if drastic controls on the fishery were not adopted. Since then numerous laws and regulations have been passed and implemented with varying degrees of success on both the lobster resource and the fishery it supports.

One of the difficulties involved in lobster management has been the inability to mark or tag individual lobster for months or years at a time to study their movements, growth, age at sexual maturity, legal size and other critical aspects of their life history. Unlike finfish or mammals, lobster regularly shed all their exterior body shell, thus leaving no trace of any previous markings or attachment sites on their new shell, which initially is a soft skin. Many attempts to overcome this identification problem have met with only partial success. Probably the most widely used mark has been the V-notch of the tail fin or telson, which was traditionally employed to mark female egg-bearing lobster to prevent their harvest in the future by lobstermen. This mutilation of the tail fin would often be recognizable after one or more molts but could not be used to identify individual lobsters.

Some success with an individually numbered tag anchored in the flesh just posterior of the carapace in a location where the shell normally splits open upon molting has been achieved in recent years. This tag has allowed some longer-term studies of lobster movement, particularly between inshore waters and offshore areas near the edge of the continental shelf. For many years, both biologists and fishermen had questioned the discreetness of these and other local stocks in New England and the Canadian Maritimes. Now it is known that considerable movement of offshore stocks to inshore waters occurs, particularly in the summer months. Without the ability to determine many of these basic lobster statistics, management has taken the form of restricting the take of all small or egg-bearing individuals on the assumption that every lobster population should have some protection.

In Massachusetts waters, restrictions on the retention of small or egg-bearing lobster are uniform with federal regulations in offshore areas and those in most other coastal states. As part of a coast-wide Lobster Management Plan adopted by the New England Fisheries Management Council in 1982, the size limit has been increased gradually with a goal of attaining a minimum size of at least 3-5/16 inches by 1992. In 1989, because of concern that lobster shipped into United States from Canada could come from some of the same offshore stocks or present an enforcement loophole for mislabeled U. S. lobsters, a federal law was passed requiring that all live lobster from Canada comply with our conservation measures.

Another popular management measure over the years has been the protection of ovigerous lobster (egg-bearing). Normally mature female lobster develop eggs internally for a few months and then extrude them to the underside of their abdomen. This egg mass becomes cemented to the female's swimmerets for about nine months, at which time the eggs hatch into the first larval stage. Since the attached egg mass covers most of the segmented underside of the lobster, there is no difficulty in identifying this stage. Massachusetts and federal laws prohibit the possession of these egg-bearing lobster.

Together, laws on the minimum size and protection for egg-bearing females have been the most effective way of insuring the preservation of coastal and offshore lobster stocks. But these and many other regulations have done little to control the number of lobster fishermen or the amount of lobster traps they fish. In addition, traditionally, where a lobsterman fishes has not been regulated, so that in some areas, competition is intense and large numbers of traps are concentrated. In extreme cases, traps may be set simply to reserve future fishing rights and discourage other participants from moving into the area. It is generally agreed that many more traps are being used in the fishery than are necessary to harvest the available resource. This excess creates inefficiency and undoubtedly results in higher costs to the consumer. It also creates more conflict between marine fishery user groups and intensifies the need for greater law enforcement. Many lobstermen recognize this problem, but they are involved in an intense effort to retain their share of the total catch and survive economically in an over-capitalized fishery.

The Massachusetts Division of Marine Fisheries has recognized this problem for many years and has made various attempts to restrict entry into the fishery. In 1971, laws were passed that restricted the number of coastal commercial permits that could be issued. However, since the fishery was already overcrowded, the legislation did little other than retain an excessive number of permit holders in the fishery. Even more pertinent was the fact that the restrictions on permit holders did not require any reduction in the number of traps each fisherman used. Thus the individual lobsterman, although assured some protection from new entries into the fishery, was still involved in fishing an excessive amount of gear to keep up with his fellow participants.

The lobster fishery is not alone in this regard. Over-capitalization has plagued many fisheries around the world. Resource managers have found that unrestricted entry into the exploitation of a public resource, such as a population of commercially, valuable fish, almost invariably leads to exploitation of the resource. They argue that unless the participants know that their respective shares are guaranteed in some way, there will be an inevitable spiral of increasing effort both by new entrants and existing participants.

In Massachusetts and New England in general, however, commercial fisheries since colonial days have been open to all citizens, and there exists now a great reluctance to change this tradition. Since the issue has been primarily an economic one rather than protection of the resource, most agencies have hesitated to advocate effort controls without strong industry support.

The Buzzards Bay commercial lobster fishery is now heavily over-capitalized. So intense is this fishery, that lobster traps are set with the intention of being in place when individual lobsters molt into legal size. Very few lobster survive beyond the first summer they reach legal size, and most females have the opportunity to spawn only once before final capture. Under such intense exploitation, the age structure of the adult population becomes distorted with older, larger individuals almost non-existent.

There is an inherent danger in such a population structure because the loss of a specific age group of lobster through natural or human causes could result in a drastic decline in the harvestable population for a given year and a great reduction of egg-bearers for the same period. Any fishery dependent upon a single year class for its annual harvest becomes much more susceptible to vagaries of nature and the assaults of manmade environmental disasters.

From both an economic and conservation point of view, the commercial lobster fishery in Buzzards Bay and other coastal areas of Massachusetts should be brought under effective control by limiting both the number of participants and the amount of traps they fish. Since non-commercial permit holders have only a minor impact on the total catch, their opportunity to participate in the fishery should be continued but the amount of traps they are allowed to utilize at any one time should be drastically reduced. Such changes would increase efficiency and if pursued diligently would eventually restore a more normal multi-age adult population of lobster capable of supporting consistent annual catches of larger, more valuable-size lobster.

To bring these changes about, the Division of Marine Fisheries should increase its effort to educate and inform those involved in the lobster fishery and the public who are the ultimate consumers of this public resource.

Recommendations

The lobster resource of Buzzards Bay supports a fishery worth about $81,000,000 annually. Even though catches have shown no significant decline recently, the resource is under considerable stress from both pollution and overcapitalization of the commercial fishery. Although few female lobster survive the fishery beyond the first year after they spawn, they contribute great numbers of larval lobster not only to Buzzards Bay but to the Cape Cod Canal and Cape Cod Bay also. Millions of young lobsters are annually deposited in Cape Cod Bay where they settle to the bottom and eventually return to that area north and east of Buzzards Bay.

Because of the value of the Buzzards Bay lobster fishery and its contribution to other coastal areas, the following recommendations are made:

1. The Commonwealth of Massachusetts should continue to actively support and participate in the Lobster Management Plan of the New England Fisheries Management Council.

Because of its knowledge and understanding of the lobster resource, the Division of Marine Fisheries should be an advocate of effective conservation controls over all lobster populations. This concern is relevant since the contribution to Massachusetts waters of offshore stocks in other areas may be substantial. In addition, many Massachusetts fishing vessels land lobsters from offshore areas in New Bedford and other ports.

2. The collection of lobster fishery statistics should be continued and enhanced to provide a database sufficient to allow effective management of the lobster resource and fishery.

Statistics specific to areas such as Buzzards Bay are necessary to determine values and measure changes in the status of the stock. Data on the non-commercial lobster fishery for Buzzards Bay should also be developed, including the number of participants, annual landings, and total value of the fishery.

Similar information should be developed for the seasonal commercial permittees for this area.

3. Monitoring of PCBs and other contaminants in the New Bedford Harbor area should continue. This should include analysis of lobsters and other animals as well as bottom sediments and the water column.

The contamination of New Bedford Harbor should be studied intensively to analyze public health risks and to determine the persistence and degradation rates of contaminants in the sediment, water column, and marine organisms. A program designed to analyze only the level of contaminants in lobster resources to determine their edibility is not sufficient to solve long-term problems of contamination.

Those agencies involved must seek answers to the broader issues; otherwise, little progress will be achieved toward a cleaner environment.

4. Further analysis of the contribution of Buzzards Bay larval lobster to the southeastern Massachusetts and Cape Cod Bay area should be conducted.

Research on the larval distribution and abundance of lobster spawned in Buzzards Bay has documented the substantial annual contribution to other coastal areas. A better understanding of the source and possible movement of both adult egg-bearing lobster and their larvae would be desirable. Questions such as what percentage of adult Cape Cod Bay lobster develop from Buzzards Bay larval lobster and what is the contribution, if any, of adult lobster from offshore areas to Buzzards Bay should be studied.

5. The Division of Marine Fisheries should reopen dialogue with commercial fishermen on the issue of effort limitation in the coastal fisheries.

It should be obvious to all involved that constant escalation of the amount of lobster gear in the fishery cannot logically continue.

Severe over-capitalization already has resulted in inefficiency, gear conflicts, and economic hardship within the lobster industry. The issue will not solve itself. Therefore, the Division should consider the appointment of a special task force to make recommendations on effort controls in the Massachusetts lobster fishery.

References

Collings, W. S.; C. Cooper-Sheehan; S. C. Hughes; and J. L. Ruckley. 1983. The Spatio-temporal Distribution of American Lobster (*Homarus americanus*) Larvae in the Cape Cod Canal and Approaches, p. 35-40. NOAA Technical Report. NMFS SSRF-775.

Dow, R. L., F. W. Bell, and D. M. Harriman. 1975. Bioeconomic Relationships for the Maine Lobster Fishery with Consideration of Alternative Management Schemes. NOAA Technical Report, NMFS SSRF-683, 44 p.

Estrella, B. T. 1984. Black Gill and Shell Disease in American Lobster as Indicators of Pollution in Massachusetts Bay and Buzzards Bay, Massachusetts. MA Division of Marine Fisheries, 17 p.

Estrella, B. T., and S. X. Cadrin. 1989. Massachusetts Coastal Commercial Lobster Trap Sampling Program, May-November, 1988. MA Division of Marine Fisheries, 23 p.

Estrella, B. T., and D. J. McKiernan. 1989. Catch per Unit Effort and Biological Parameters from the Massachusetts Coastal Lobster (*Homarus americanus*) Resource: Description and Trends, 21 p. NOAA Technical Report No. 87.

Estrella, E. T., and D. C. Pichette. 1989. Catch Trends and Status of the American Lobster (*Homarus americanus*) Resource in Buzzards Bay, Massachusetts. MA Division of Marine Fisheries, Draft Report, 14 p., for EPA Buzzards Bay Program Grant. #CX 1285201.

Fairbanks, R. B.; W. S. Collings; and W. T. Sides. 1971. An Assessment of the Effects of Electrical Power Generation on Marine Resources in the Cape Cod Canal. MA Division of Marine Fisheries, 48 p.

Hoopes, T. B., 1989. 1988 Massachusetts Lobster Fisheries Statistics, 17 p. MA Division of Marine Fisheries, Technical Report 23.

Young, J. S., and J. B. Pearce. 1975. Shell Disease in Crabs and Lobsters from New York Bight. Marine Pollution Bulletin, 6: 101-105.

.

4. Finfish of Buzzards Bay

By Frank Grice[5]

> "Buzzards Bay is a valuable Massachusetts resource – important for its economic, recreational and aesthetic values. The economic resources of the bay range from the harvest of its rich fisheries to its use as a transit route for the New Bedford fishing fleet and for shipping through the Cape Cod Canal. Its heavily indented coastline is uniquely beautiful and provides superb opportunities for fishing, bathing and boating. In addition it offers educational and research possibilities to academic institutions located on it shores". From the Buzzards Bay Project Annual Report, 1986

Introduction

The activities of man have greatly affected fishery resources of the Buzzards Bay area (Figure 4-1). Construction of the Cape Cod Canal changed the ebb and flow of the tide. With accelerated growth and development in the coastal zone, once pristine brooks and rivers that drained into the bay now run like open sores into a fouled New Bedford Harbor from which finfish, shellfish and lobsters may not be eaten. Yet, despite this century-old despoliation, much of the area remains attractive to more and more year-round residents and multitudes of summer visitors. Herein lies the greatest future threat to the natural resources of the bay. As the press of shoreline development inexorably alters the natural uplands, can the decline of marine species so dependent on what happens to the land around them be slowed or reversed?

These fishery resources will never be restored to their former abundance and variety. However, with good stewardship based on an adequate understanding of their needs, the impacts of development on land can be mitigated so that remaining resources will not further recede from our consciousness. The world and Buzzards Bay will be a better place to live if we can learn to coexist with those resources that still exist. The Buzzards Bay Project can help to show the way in this effort and therefore can be a turning point in this environmental awakening.

Status of the Fisheries

Even before the colonists arrived in New England, Buzzards Bay had been discovered and its fisheries noted by early explorers from Europe. Most prominent among these was Bartholomew Gosnold who, in 1602, sailed from Newfoundland around the eastern end of Cape Cod and into Vineyard Sound. Upon entry into Buzzards Bay, he is reported to have remarked on the beauty of the land and its two main rivers (the Acushnet and the Agawam). According to early historians, Gosnold was visited by an Indian chief and about fifty members of his tribe. They feasted on codfish and the Indians prolonged the feast by roasting crabs, red herring and ground nuts.

Later, in 1676, Captain Benjamin Church reported "... they crossed a river and opened a great bay (Buzzards Bay) where they might see many miles along the shore and saw a vast company of Indians some catching eels and flat fish in the water; some clamming, etc."

For almost 200 years, the abundance of fish and other seafood from the bay helped sustain the local inhabitants and provided work for many fishermen. However, by the 1800s, the fisheries had begun to decline and concern was shown for the future of these resources.

In 1913, after years of legislative battles over the Buzzards Bay fisheries, the Massachusetts Senate and House passed Chapter 104, which ordered an investigation of the fishery conditions in Buzzards Bay. At that time, the principal concern was over the effects of commercial netting in the bay. This controversy between hook-and-line fishermen and netters had simmered for years with many allegations on both sides with some famous figures of the times involved.

In 1891, ex-president Grover Cleveland, who was an ardent sport fisherman, addressed a meeting called by the opponents of netting in Bourne. In advocating the abolition of trap nets from the bay, he stated, "In the first place, it is conceded, I believe, that Buzzards Bay forms a nursery or spawning ground for the fish. Now, the protection of the fish in that place is only in accordance with the enlightened procedure which has been going on for years in every state in the Union, and there is no reason under Heaven why it should not be eminently a proper thing to do here in Buzzards Bay." He then went on to indicate that he considered it fortunate "... that we are not called upon in this movement which we seek to make to antagonize those who seek absolutely to gain a livelihood by catching fish. I don’t understand that we are to run against them in any way whatsoever, so that the embarrassing question which sometime arises between the livelihood of one class of our citizens and the desires of another, does not arise in this case." Thus, he sought to deflect the sportsman-vs. -

---

[5] Retired,, Massachusetts Division of Marine Fisheries.
Accepted September 26, 1990.

commercial fisherman argument and instead make his appeal for conservation.

Others, at the same meeting, were much more direct in their support of sport fishing. The secretary of the meeting, Charles Chamberlayne said, "There is not a house in this town, I venture to say, which does not derive some measure of its comfort, directly or indirectly, from the summer people, their expenditure and investment in houses and hotels, and there is hardly a dollar's worth of summer property, in hotels or otherwise, which is not directly or indirectly affected by the excellence of the fishing" (Anonymous 1892).

Apparently, these opponents of netting eventually convinced the legislature to go along with their arguments since in 1893 an act was passed that closed the entire bay to all forms of netting and fish traps. Now almost a century later this prohibition is still in effect and Buzzards Bay is one of the few areas of the Commonwealth closed to netting on a year-round basis.

The investigation of Buzzards Bay fisheries authorized by the legislature in 1913 was conducted by Dr. David Belding during 1913-1915 (Belding 1916). This study was unique in its thoroughness and scientific approach. Belding was a medical doctor who became interested in marine biological investigations and published many studies on finfish and shellfish for the Commonwealth of Massachusetts. He has been honored by the American Fisheries Society as an early pioneer in scientific approach to fisheries management. Many of his studies, particularly with regard to shellfish, are still the most authoritative in print and form the basis for many more recent studies.

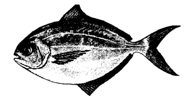
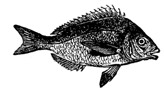
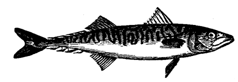
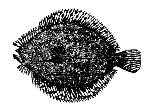
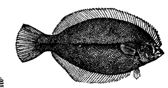
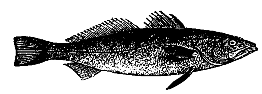
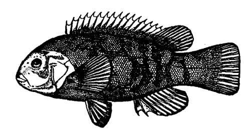
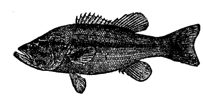
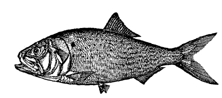
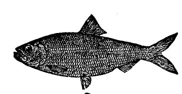
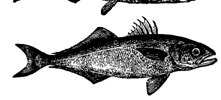
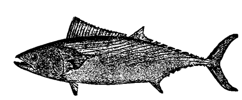
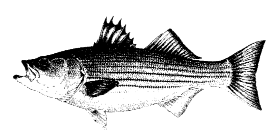
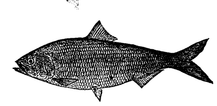
Belding pointed out in the introduction of his report to the legislature:

> *"Buzzards Bay has played an important part in development of the fisheries which have made Massachusetts famous. In colonial days its tributaries during the spawning season were crowded with shad, salmon, striped bass and alewives, while schools of mackerel, bluefish, sea bass, butterfish, scup and menhaden were found within its boundaries.*
>
> *In the early days the abundance of fish afforded a cheap and valuable food supply at the very doors of the inhabitants. Within the last two hundred years conditions have radically changed. The present supply is but a small portion of the great natural production described by historical writers – a condition which has been brought about by a variety of causes both local and general. The flourishing condition of former days may never again be attained, but by the proper regulation of our fisheries present conditions can be improved greatly."*

Unfortunately, Dr. Belding may have been overly optimistic in 1916 when he wrote of possible improvement in Buzzards Bay fisheries. Comparison of what he found then with studies conducted during the 1980s show little or no increases in most valuable species of finfish and may in fact reflect further declines in others. Belding attributed much of the decline of larger, valuable food fish such as bluefish, striped bass and squeteague (weakfish) to the decrease in abundance of alewives, which served as an attraction for the predacious migratory fish. His studies showed that alewife runs in the bay had decreased by 75%. He attributed this decline to overfishing, pollution and the careless and unnecessary obstruction of the streams by milldams and cranberry bogs. He singled out the Acushnet River as one of the most polluted streams in the state where "young fish cannot live, eggs cannot develop and fish can never spawn..." He apparently despaired of these conditions ever being changed and stated "suitable provisions should be made restricting pollution to places already affected."

Figure 4-1. Buzzards Bay.

Table 4-1. Finfish species in Buzzards Bay as reported by Belding in 1913-15 compared with present conditions.

Common Name	**Scientific Name**	**Important 1913-15**	**Commonly Present in 1980s**	**Image**
Butterfish	*Peprilus triacanthus*	x	x	
Scup	*Stenotomus chrysops*	x	x	
Mackerel	*Scomber scombrus*	x	x	
Flounders				 
Winter	*Pseudopleuronectes americanus*	x	x	
Summer	*Paralichthys dentatus*	x	x	
Squeteague	*Cynoscion regalis*	x	Rare	
Tautog	*Tautoga onitis*	x	x	
Black Sea Bass	*Centropristis striata*	x	x	
Menhaden	*Brevoortia tyrannus*	x	x	
Alewife	*Alosa pseudoharengus*	x	x	
Herring	*Clupea harengus*	x	x	
Bluefish	*Pomatomus saltatrix*	Formerly	x	
Bonito	*Sarda sarda*	Formerly	Rare	
Striped Bass	*Morone saxatilis*	Formerly	x	
Shad	*Alosa sapidissima*	Formerly	Rare	

The Buzzards Bay fisheries have suffered many environmental and regulatory impacts over the years. Probably more concern over the status of its fishery resources has been expressed in the last century than for any other coastal area of its size on the East Coast. Unfortunately, this concern has not prevented further deterioration of the bay environment. Despite continuing environmental degradation, the finfisheries of the bay are not greatly changed from what Belding found in 1913-1915. He listed ten species as being important commercially in the bay and four others that were formerly valuable. Although most commercial fishing in Buzzards Bay is now precluded by the laws prohibiting netting, most of the species Belding listed as being commercial important either at the time of his survey or before are not important to the present hook-and-line fishery in the bay or in areas near the bay where netting is allowed (see Table 4-1). The exceptions to this are shad, bonito and squeteague, none of which are consistently important in current landings from the area.

Buzzards Bay fish populations are not separate or easily differentiated from Southern New England stocks in general. This is especially true of summer migrant species such as bluefish, striped bass, scup, mackerel, summer flounder, sea bass, butterfish, sea robins and menhaden. All of these species show up in Buzzards Bay in May or June but are also summer visitors to Rhode Island, Vineyard and Nantucket Sounds and outer Cape Cod waters. Even the more resident species such as winter flounder, tautog, and skates (*Raja* sp.) move in and out of Buzzards Bay without regard to its geographical boundaries. Since the construction of the Cape Cod Canal, which began in 1912, Buzzards Bay has had an artificial opening to Cape Cod Bay. This has provided a passageway for many species of finfish and lobsters, thus affecting the movement of many species.

The prohibition of netting in Buzzards Bay, which has been in effect for almost 100 years, has not materially affected the relative abundance of commercially important finfish today. This is probably due to several reasons, not the least of which is that fish protected from netting in Buzzard Bay are subject to capture by nets in adjacent areas. Thus, any refuge provided in the bay is only temporary. In addition, the ban on commercial net fishing may have been offset in recent years by increased fishing efforts by hook and line and traps or pots.

It is arguable that the prohibition has not resulted in better sport fishing in the bay, but this point is confounded by a lack of data on sport fishing effort and success both before and after the abolishment of netting. It is reasonable to conclude that the current lack of netting provides for increased sport fishing opportunities without interference or competition from commercial netting operations.

The popularity of the area to sport fishermen since President Grover Cleveland's time has not diminished. The bay provides for an enormous and varied sports fishery from the shoreline and bridges and from thousands of powerboats that are launched or moored in many locations throughout the area. Although primarily a summer fishery, many anglers begin fishing in March or April and continue into October. In the early spring, the typical resident species such as winter flounder, eels, tautog, and cod are sought, especially from shoreline locations such as the Cape Cod Canal and the many bridges over tidal rivers. Then by May, the first of the summer migrants begin to arrive — mackerel, striped bass, bluefish, scup, black sea bass and summer flounder or fluke. By late June or early July, most of these species have become established in the area, but some others, such as mackerel, cod and winter flounder, move out of the shallower waters of the bay to cooler offshore waters. Both the Cape Cod Canal and the Vineyard and Nantucket Sounds provide passageways for the northward movement of other summer fish migrants. These migrating species can move into Cape Cod Bay, and some even migrate to Maine coastal areas. However, not all of the species that arrive in Buzzards Bay continue to the north. In many years, the arm of the Cape forms the northernmost extension of the range of many of the warmer water species.

Not all of the hook-and-line fishing in the bay is conducted for recreation. Substantial amounts of scup, fluke, striped bass and bluefish are sold to local wholesalers and markets in the area. Most of these fish are caught by small boat fishermen who use this activity to supplement their regular income from other jobs. Because of the sporadic nature of these commercial landings and the fact that some of these fishermen also fish outside of Buzzards Bay, it is not possible to assign a total value to these commercial catches. Neither is it possible to determine the total catch from the bay by sport fishermen who do not sell their catches. The collection of sport fishing statistics used to determine total effort and the catch of an area such as Buzzards Bay presents a difficult and expensive problem to fisheries managers. The Massachusetts Division of Marine Fisheries participates in a nationwide marine recreational fishery survey that, when broken down even on a statewide basis, yields estimates that have a substantial margin of error. A recent study of marine sport fishing in the Commonwealth has estimated that the total value is in excess of $800 million annually (R. Fairbanks, Massachusetts Division of Marine Fisheries, personal communication). This figure includes total expenditures by anglers for their sport as well as the value of their catch.

An assumption based on the size and popularity of Buzzards Bay for fishing can be made as to what percentage of this statewide value would apply to the bay.

Conservatively, as much as 10% appears assignable. If so, the recreational fishery value of Buzzards Bay probably exceeds $80 million annually. If the known value of shellfish and lobster landings (see other chapters of this report) are added to this figure, it seems certain that the total value of all fisheries of the bay is well in excess of $100 million annually.

This enormously valuable resource, although abused and diminished by human activities since colonial times, continues to contribute great quantities of high quality seafood and many thousands of hours of recreation. With relatively minor investments in pollution abatement, anadromous fishway construction, and other fishery management activities, it is certain that the $100 million annual value currently realized could be greatly increased. In addition, the quality of life in the area would be enhanced as those who use the area become more attuned to the environment and more responsive to the needs of other life forms of the bay.

Resource Issues

The fishes most seriously affected by human activities, in the Buzzards Bay area, are the anadromous species such as shad, alewives, Atlantic salmon (*Salmo salar*), and smelt (*Osmerus mordax*). All of these species were formerly abundant but now are rare or nonexistent except for the alewife. These fishes formerly used all of the coastal streams for spawning purposes. The erection of mill dams and later obstructions and diversions for cranberry bogs effectively eliminated from of these runs.

The Massachusetts Division of Marine Fisheries has, since the 1930s, built and maintained fish ladders and reintroduced alewives and, to a lesser extent, smelt and shad in many of these streams. By using the natural "homing" instinct of these species it is possible to re-establish spawning runs by stocking ripe adults or fertilized eggs. This provides young fish that eventually leave the stream to mature in marine waters and return several years later to their natal streams as spawning adults. Such restocking is only effective if the dams on the streams have been equipped with fish ladders and other problems such as pollution and water diversions have been mitigated. This program is ongoing, but Division budget and staffing limitations allow for only a modest effort, which is directed mostly toward alewife restoration. Despite the limited scope of this program, it has been a model for other East Coast states and it is a clear example of what can be accomplished by dedicated fishery managers working with public and local officials. On a statewide basis, more than 100 fish ladders have been constructed and are being maintained. On many coastal streams, thousands of people congregate at these fish ladders in the spring to witness the alewife runs and marvel at this annual ritual — most of them never realizing that what they are witnessing is actually a rebirth rather than an uninterrupted phenomenon.

Other anadromous species such as shad, smelt and Atlantic salmon have been the object of restoration attempts but with only limited success compared with the alewife. Of these species, shad and smelt restoration in some Buzzards Bay streams could probably be successful but it is unlikely that existing stream conditions would support self-sustaining salmon populations.

In addition to the anadromous species and other fishes now or formerly of economic importance to man, other species important to the marine food chain are found in Buzzards Bay on either a seasonal or year-round basis. In a summary of historical and recent finfish collections from the bay, Moss and Hoff (1988) list a total of 203 species of finfish taken by a variety of methods both prior to 1960 (historical) and since (recent). Their data, when broken down on a seasonal basis, show that the overall fish fauna increases markedly during the summer months, reflecting both the added presence of summer migrants and newly spawned young-of-the-year of many species.

The importance of Buzzards Bay as a spawning area for many species has already been referred to by Belding (1916) and others. Fairbanks et al. (1971), in a study of the Cape Cod Canal area, reported taking the eggs and larvae of 24 species of finfish in a one-year period. All sampling was conducted near the Canal Electric Power Plant near the eastern end of the Canal.

In a period encompassing May 1976 to March 1979, Collings et al. (1981) sampled the eggs and larvae of 47 different finfish species from seven stations including on in Cape Cod Bay, three in the Cape Cod Canal and three in Buzzards Bay (Table 4-2). A total of 1,158,422 eggs and 17,118 larvae were collected in monthly samplings in this study. Density of fish eggs and larvae peaked in June of each year of the study. The Cape Cod Bay station had the lowest density of eggs and larvae of the seven stations. Included in the 47 species taken were many baitfish species such as sand lance or sand eels (*Ammodytes* spp.), Atlantic silversides (*Menidia menidia*) and anchovy (*Anchoa* spp.).

This study documented the differences in species composition of Cape Cod Bay and Buzzards Bay, with the canal being much more similar to Buzzards Bay than to Cape Cod Bay. In general, the species complex reflected the fact that Cape Cod represents a dividing point for many Atlantic coast species, with few crossing from the temperate waters of the south or leaving the boreal waters of the north and east. Apparently, even the Cape Cod Canal, which provides a passageway through the base of the Cape, has not materially changed this overall distribution pattern.

These egg and larval studies clearly show that Buzzards Bay is an important spawning area for many finfish species. What is not as clear is whether it is any more important than some other coastal areas such as Vineyard Sound, Nantucket Sound or other areas to the south such as Narragansett Bay, Block Island, and Long Island Sounds, which have similar species assemblages. Although many of the species sampled in Buzzards Bay have no immediate economic value to man, collectively they contribute to a rich fauna and influence the seasonal presence and abundance of those other species so eagerly pursued by many thousands of anglers who fish the bay.

Environmental Issues

Unlike the situation with shellfish and lobsters, it is unlikely pollution is the most serious environmental issue facing finfish populations of Buzzards Bay. There are serious pollution problems locally but they are restricted to specific areas or species and do not impinge on utilization or survival of the overall finfish biomass. Rather, the most serious human threat to finfish has been the obstruction and diversion of tributary streams to the bay. As already described, these physical alterations have severely affected runs of anadromous fish such as alewives, shad, striped bass, salmon, and smelt. Many of the dams that closed off these streams to spawning runs were built in colonial days and rebuilt or replaced later during the period of industrial development in the 1880s. Although some concern was shown for the initial effect of these obstructions, once in place their replacement or the addition of other dams was less restricted because the fish runs had already disappeared.

Belding (1921), in his "Report Upon the Alewife Fisheries of the Commonwealth," reviewed some of the early legislative attempts to protect alewives:

> *"The first fishery law, known as the Plymouth Colony Fish Law, was enacted in 1623 for the protection of alewife. In 1682 further legislation was enacted, and in 1709 and 1727 an act was passed and amended for the prevention of all obstructions to the passage of fish in river, except mill dams. Failure to enforce these acts and the increasing number of (mill) dams, resulted in 1741 in an act which provided that a sufficient passageway be made through or around each dam from the first day of May annually, or in certain rivers for a period not exceeding sixty days."*

Table 4-2. List of eggs, larvae, and juveniles sampled at seven stations in Buzzards Bay, Cape Cod Canal, and Cape Cod Bay May 1976 - March 1979

** from Collings et al. (1981).*

Scientific Name	Common Name	Stages found
Ammodytidae - sand lances		
Ammodytes spp.	sand lance	e, l
Agonidae - poachers		
Aspidophoroides monopterygius	alligator fish	l
Atherinidae - silversides		
Menidia menidia	Atlantic silversides	l
Bothidae - lefteye flounders		
Etropus microstomus	smallmouth flounder	e, l
Hippoglossina oblonga	four-spot flounder	e, l
Paralichthys dentatus	summer flounder	e
Scophthalmus aquosus	windowpane	e, l, j
Clupeidae - herrings		
Brevoortia tyrannus	Atlantic menhaden	e, l
Clupea harengus harengus	Atlantic herring	l
Cryptacanthodidae - wrymouths		
Cryptacanthodes maculatus	wrymouth	l
Cottidae - sculpins		
Myoxocephalus spp.	sculpin	e, l
Hemitripterus americanus	sea raven	l
Cyclopteridae - lumpfishes and snailfishes		
Liparis atlanticus	seasnail	l
Liparis liparis	striped seasnail	l
Cyclopterus lumpus	lumpfish	l
Engraulidae - anchovies		
Anchoa spp.	Anchovy	e, l
Gadidae - codfishes		
Brosome brosome	cusk	
Enchelyopus cimbrius	fourbeard rockling	(e), l
Gadus morhua	Atlantic cod	e, l j
Merluccius bilinearis	silver hake	e, l
Pollachius virens	pollock	e, l
Urophycis chuss	red hake	e, l, j
Microgadus tomcod	Atlantic tomcod	l
Melanogrammus aeglefinus	haddock	e, l
Gobiidae - gobies		
Gobiosoma bosci	naked goby	l
Labridae - wrasses		
Tautoga onitis	tautog	e, l
Tautogolabrus adspersus	cunner	e, l, j
Lophiidae - goosefishes		
Lophius americanus	goosefish	e, l
Ophidiidae - cusk-eels and brotulas		
Rissola marginata	striped cusk-eel	l
Pholidae - gunnels		
Pholis gunnellus	rock gunnel	l
Pleuronectidae - righteye flounders		
Hippoglossoides platessoides	American plaice	e, l
Glyptocephalus cynoglossus	witch flounder	e, l
Limanda ferruginea	yellowtail flounder	e, l
Pseudopleuronectes americanus	winter flounder	e, l
Sciaenidae - drums		
Cynoscion regalis	weakfish	(e), l
Menticirrhus saxatilis	northern kingfish	e
Scombridae - mackerels		
Scomber scombrus	Atlantic mackerel	e, l
Serranidae - sea basses		
Centropristis striata	black sea bass	e, l
Soleidae - soles		
Trinectes maculatus	hogchoker	e, l
Sparidae - porgies		
Stenotomus chrysops	scup	e, l, j
Stichaeidae - pricklebacks		
Ulvaria subbifurcata	radiated shanny	l
Lumpenus lumpretaeformis	snake blenny	l
Leptoclinus maculatus	daubed shanny	l
Stromateidae - butterfishes		
Peprilus triacanthus	butterfish	e, l, j
Syngnathidae - pipefish		
Syngnathus fuscus	northern pipefish	j
Tetraodontidae - puffers		
Sphoeroides maculatus	northern puffer	l, j
Triglidae - sea robins		
Prionotus spp.	sea robin	e, l

Notes:
*e - egg positively identified,
(e) - egg grouped in general category,
l - larvae positively identified,
j - juvenile positively identified.

In the ensuing years since these early attempts at legislating protection for alewives, hundreds of special acts were passed by the legislature. Most of these pertained to specific streams and covered such issues as the appointment of herring committees, appointment of herring wardens, closed seasons, fishery sale provisions, and restrictions on the type and size of nets and traps.

Despite this plethora of well-meaning laws, the runs became diminished and many ceased all together. One reason for this decline was the fact that while the above-mentioned acts to protect alewives were being passed by a solicitous legislature at the same time other acts absolving dam owners of responsibility were being adopted with equal vigor! Ultimately, legislation was adopted that stated that no dam owner would be required to keep open a passageway through his dam in streams where no salmon, shad or alewives were found. Thus, a dam owner who failed to provide initial passage could be assured that once he had destroyed the run he would not be liable for fish passage in the future! Coupled with lax enforcement and insufficient penalties for those acts designed to protect the fish, these loopholes eventually resulted in insurmountable barriers on practically all of our coastal streams.

In addition to the construction of dams impassable to fish, another physical alteration that had serious consequences was the reduction in water levels because of extensive deforestation and shoreline development and stream diversion. Many natural ponds were lowered through this process and eventually became inaccessible to anadromous fish. In some instances these lower water levels eventually led to dam construction at the pond outlet in order to restore or enhance former water levels. This, of course, created yet another obstacle to passage. Even today, many natural great ponds in the Commonwealth have dams at their outlets that significantly raised their water level.

In the 1800s, another type of human alteration began to create additional problems for alewife runs, especially in Southeastern Massachusetts. The development of cranberry bogs and their need for reservoirs and ditches led to many stream diversions and obstructions that further hindered passage for the fish to their natal waters. The natural flow of many streams became diverted to new areas and was completely controlled as to flow rates.

Eventually, in addition to the problems of obstruction and diversions, the cranberry industry also presented another concern — that of pesticide contamination of the drainage from bogs. In order to control various insects and other organisms associated with cranberry culture, bog owners adopted a very intensive, multi-chemical spray regime that, if not properly controlled, could be very toxic to downstream fish populations.

According to Massachusetts Division of Marine Fisheries records, at least six fish kills associated with cranberry bog pesticide runoff in the Buzzards Bay area were documented in the period 1970 to 1984 (Fiske, personal communication). These kills were attributed to a variety of chemicals including parathion, Guthion, Sevin, and diazinon. Besides the problem of immediate mortality, there are other potential impacts that may be serious although not as easily determined. These include the effects of pesticide residues on the growth and survival of eggs and larvae and the overall issue of bioaccumulation in the environment.

In recent years, better water level control, reduced use of long-lasting chlorinated hydrocarbons, and more accurate spray application through the irrigation systems have reduced the possibility of fish kills from cranberry culture. Bog owners are much more aware of the potential problems and in keeping with the general public concern of the use of pesticides have become more responsive with regard to their use of these compounds.

Industrial pollution in the Buzzards Bay area is not restricted to only a few problem areas. The Acushnet River, which empties into New Bedford Harbor, has a long history of severe problems from mill wastes. Belding (1916) cited it as "one of the most polluted streams in the state" and "no longer is of any particular value." He doubted that it could ever be adequately restored and instead urged that the pollution be restricted to places already affected."

Unfortunately, the Acushnet River pollution has continued into recent times, and eventually climaxed with the PCB contamination that led to the area being named as the first marine Superfund site in the United States. PCBs were apparently released from two industries located along the river and now contaminate the bottom soils and overlying waters. Fish, shellfish and lobsters in the inner harbor area have been shown to have measurable and in some cases excessive concentrations in their organs and tissues. Parts of the New Bedford/Fairhaven area have been closed to the taking of all shellfish, lobsters, and finfish because of this contamination (Figure 4-2).

In addition to this extreme case of industrial contamination, Buzzards Bay is the recipient of sewage contamination, which results in local bacterial contamination and nutrient overloading. This pollution is more of a problem with shellfish than with finfish, although the overall impact of nutrient overloading may result in long-term changes that can be serious. Fish kills, often occurring in the upper, shallow portion of bays and estuaries such as Buttermilk Bay during warm weather may be one manifestation of toxic conditions. High nutrient levels may lead to sudden oxygen depletion and subsequent mortality of species such as menhaden and winter flounder.

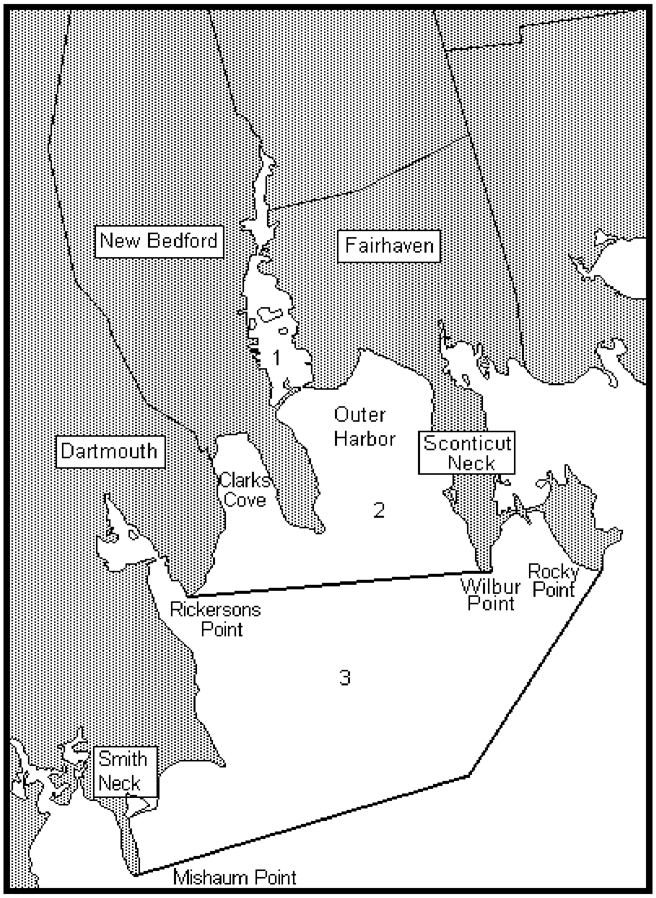


Figure 4-2. Areas subject to PCB closures.

1. Waters closed to all fishing activities. 2. Water closed to the taking of lobsters, eels, flounders, scup and tautog. 3. Water closed to lobstering only.

Buzzards Bay has been the recipient of many oil spills in recent times. As indicated earlier, barge and tanker traffic through the Cape Cod Canal is extremely heavy since most of the heating oil used in New England is shipped through this area. The first well-documented oil spill that had serious impacts on marine life in the area occurred in September 1969 when the barge Florida went aground off West Falmouth Harbor. Approximately 174,000 gallons of No. 2 oil were spilled. A strong southwest wind that prevailed for several days thoroughly mixed the oil throughout the water column and resulted in heavy mortality of even bottom-dwelling organisms throughout the 1000-acre area affected by the spill (Grice, 1969).

Subsequently, detailed studies of the impacted area were carried out by private researchers at the Woods Hole Oceanographic Institution by Blumer et al., 1970 and others. These studies and marine life restoration efforts by the Massachusetts Division of Marine Fisheries documented the serious and long-lasting effects of oil in the coastal environment. More than $300,000 was paid by parties responsible for this spill to the state and Town of Falmouth to finance these investigations and fishery restoration efforts.

In the period October 1974 to December 1977, eleven oil spills in Buzzards Bay or the Cape Cod Canal were recorded by the Bourne Natural Resources Director, Burke Limeburner. He estimated that more than 765,000 gallons were involved in these spills. In some cases, he stated that no official reports were made and that to date (December 1977) no fines had been paid, and only two spills resulted in legal action (Cape Cod Times, December 1977).

There is a large body of evidence that very low levels of hydrocarbons and other contaminants in the sediment and food chain can produce deleterious effects in fish. These include carcinogenesis, reduced egg viability, and decreased growth of embryos and larvae (Black et al., 1988).

Another human activity that poses potential problems for finfish is the dumping of dredge material at coastal dumpsites. Figure 4-3 shows the locations of three current or former disposal sites in Buzzards Bay. These locations were the recipient of an average of 22,500 cubic yards of material annually in the period 1979 to 1984. In 1985, 73,800 cubic yards were disposed, but since that date, no dumping has occurred. A U.S. Army Corp of Engineers study of these disposal sites did not disclose any serious finfish problems associated with this activity but concluded that in order to minimize impacts, proper techniques such as disposal project evaluations, project sequencing, and disposal site monitoring were imperative (Anonymous, 1989).

Of all the effects of these environmental impacts on the bay, probably the most difficult to assess may be the effect of the public's perception of contamination of seafood from the area. In recent years the news media has emphasized the pollution of our waterways and shorelines. This exposure has led many people to question the wholesomeness of seafood in general and has reduced sales in some areas. A prime example of this occurred in the summer of 1988 when the problem of medical wastes washing ashore on East Coast beaches led to reduced demand and sales even though there was no evidence of health problems from fish in the marketplace, most of which were caught offshore.

Despite the acknowledged benefits of low-cholesterol, low-fat seafood in our diets, these highly publicized occurrences can have substantial deleterious impacts on consumers. Not mentioned in these alarming news stories is the fact that fresh fish is one of the few truly natural foods left in the market — no hormones or other additives such as is the case with meat and poultry and no direct pesticide

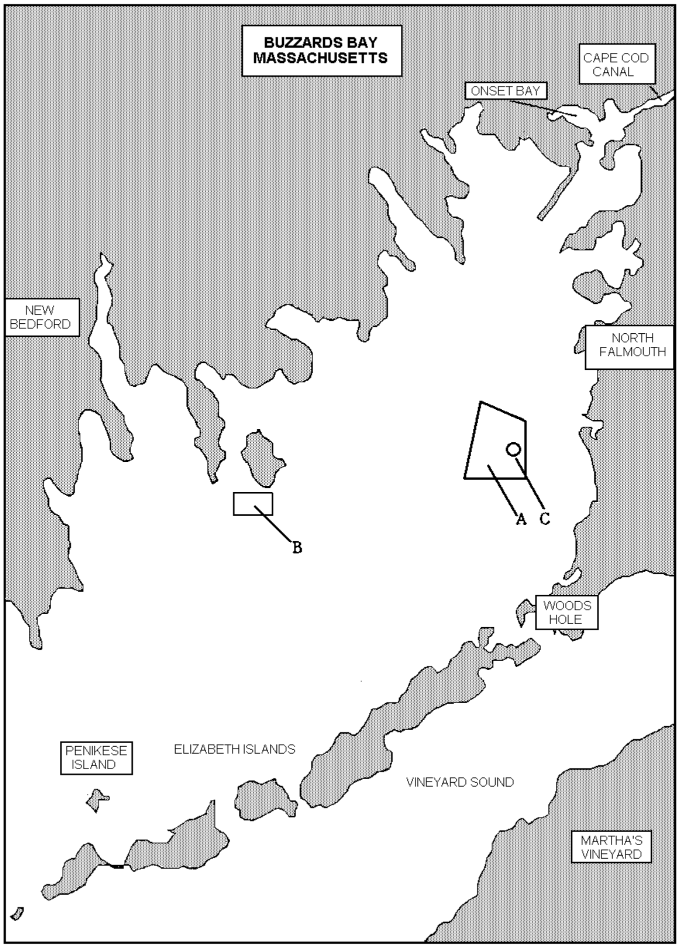


Figure 4-3. Current or former disposal sites in Buzzards Bay.

applications as occur on fruits and crops. Americans have a much lower per capita consumption of seafood that do many other nationalities. They could benefit from more fish in their diet as a substitute for fattier foods.

Management Issues

As already reported, Buzzards Bay is unique in that its waters have been closed to netting for many years. Although the initial reason for this closure, which went into effect almost 100 years ago, was largely self-interest on the part of hook-and-line fishermen, there are now some logical arguments for retaining this prohibition.

Throughout New England coastal and offshore waters there has been a dramatic increase in commercial fishing efforts in the last ten to fifteen years. Within the territorial limit (out to 3 miles from a baseline along the shore) the states have jurisdiction over fishery stocks. In 1976, the federal government assumed control out to 200 miles. When foreign fishing was curtailed in the 1970s, the New England offshore fleet expanded so rapidly that excessive fishing pressure developed and over-exploitation of many stocks quickly followed. In this area, the New England Fisheries Management Council is charged with developing fishery management plans and regulations to control the fisheries in the 200-mile zone. The Council has been reluctant to control the number of domestic vessels fishing or the amount of effort they can exert on the various species. In contrast, tight controls on all foreign fishing in these waters has essentially eliminated foreign vessels.

Although the finfish resources of Buzzards Bay are not identical to those of the New England offshore areas, some of the same species and stocks are involved so that both areas are affected by excessive exploitation in either area. As already pointed out, Buzzards Bay stocks are part of a resident and migrant fish population that moves freely throughout the southern New England waters. Some species come into inshore areas for spawning and many others utilize the bay as a nursery area during their juvenile stages.

Thus, effective management of either area must take into account what transpires in the other. The current excessive fishing effort in the offshore area, particularly on stocks such as yellow tail flounder, winter flounder, fluke, scup and butterfish, makes the protection afforded in the Buzzards Bay area even more important from a conservation point of view. The Commonwealth has a major interest in the offshore fisheries of New England, so it is appropriate that the state coordinate management efforts in both areas. It should use its substantial membership on the New England Fisheries Management Council to ensure that management plans reflect conservation needs rather than short-term economic gains.

The ban on netting in Buzzards Bay does not completely preclude commercial fishing activities. Hook-and-line fishing tends to be more selective than netting and therefore less destructive to non-target species. It is labor-intensive and does not require substantial capital investment. Because of this and the accessibility of the bay, this fishery lends itself to a seasonal, part-time operation that can produce quantities of high value fresh fish on a day-to-day basis.

In order to achieve the most effective management regime, the professional fisheries managers of the Division of Marine Fisheries should be allowed to regulate the fishery rather than the legislature, which has neither the expertise nor the available time to serve in such a capacity. The Division can insure proper public input through its Marine Fisheries Advisory Commission and appropriate public hearings.

With regard to the management of anadromous species and especially the alewife, the Division of Marine Fisheries should continue to delegate management authority to the cities and towns that show an interest and capability of managing their local fishways. This does not mean an abdication of the state's overall responsibility but rather a partnership with local on-site involvement by the towns, which is so necessary to the successful operation of fish ladders and the regulation of the catch in the streams. With such local control and involvement, there is more concern and responsibility for long-term management and a higher participation by the public in the process. The Division should also continue to work with both the U.S. Fish and Wildlife Service and the National Marine Fisheries Service on the restoration of anadromous species to insure coordination throughout the range of these and other migrant species.

In summary, the bay's fisheries must be managed as part of a larger process that includes southern New England and even larger areas to the south, west, and east. Although the bay itself is entirely within the Commonwealth's management jurisdiction, its fisheries are dependent upon movements of species from these other areas. Because of the value and importance of these resources to the bay and to Massachusetts in general, the Commonwealth should take a major role in the regional and national effort to effectively manage these stocks.

Recommendations

The finfish resources of Buzzards Bay are varied and abundant. Throughout our history, they have been an important asset for both food and recreation. Despite over 300 years of the destructive effects of stream obstructions, pollution, and often inappropriate legislation, these resources continue to produce their benefits at very little cost to the public. While there is still time to restore and enhance these remaining stocks, the following recommendations are offered to provide responsible stewardship of these marine resources:

1. The Division of Marine Fisheries should develop a comprehensive anadromous fisheries restoration plan for the Buzzards Bay area.

An intensive evaluation of the potential for restoration of fish runs to all of the coastal streams draining into Buzzards Bay should be undertaken in the near future. It has been more than twenty years since such a survey was conducted on a statewide basis. Part of this effort should consist of a physical and biological examination of each stream to determine such factors as obstructions to fish runs, stream flow rates, pond water levels, pollution, condition of fish populations and control over any existing fisheries.

Following this field survey a list should be developed that would indicate the priority and cost of re-establishing or enhancing fish runs on each stream. Owners of dams or other water diversions and major sources of pollution should be identified and their responsibilities documented. Engineering plans for the construction of fishways or the removal or alteration of obstructions should be included.

2. In order to provide a more comprehensive management system for the state's marine resources including those in Buzzards Bay, a marine sport-fishing license should be adopted by the Commonwealth to help finance the management program and provide data on fishing effort, catch and its value.

It is estimated that sport fishing in the bay currently generates more than $80 million annually. Better statistics would provide for more precision in these estimates and form the basis for specific management measures to protect and enhance these values. More information on such issues as seasonality, species preference, methods of fishing, and accessibility are all critical to intelligent management and effective regulation. The adoption of a marine sport fishing license system on a statewide basis would provide the basis for such a system and at the same time help finance the entire management effort. For the overall cost of one striped bass lure, sport fishermen could ensure that the resource their sport depends upon would be adequately represented and managed.

3. The Commonwealth of Massachusetts should continue to take a leadership role in regional and national programs to conserve and manage anadromous, migrant, and offshore stocks of fish important to our area.

Through active participation in the New England Fisheries Management Council and the Atlantic States Marine Fisheries Commission, the Commonwealth should ensure that the fishery interests of the state are protected and perpetuated. Massachusetts fishery landings constitute more than 50% of the total New England landing values. New Bedford is the leading fisheries port on the East Coast. Annually the fishing industry pumps millions of dollars into the local economy without any subsidy and very little government support.

The Buzzards Bay sport fishery generates more than $80 million annually as part of the total state value in excess of $800 million. In order to protect these values, Massachusetts should use its pre-eminent position to insist on effective regional and national fisheries management programs.

4. The Division of Marine Fisheries should continue and expand its fishery investigations to determine the status of important finfish species and the impact of human activities on Buzzards Bay and other coastal areas.

The Division currently has an effective but financially and manpower-limited program that should be expanded to include all aspects relating to marine resources and their utilization by the public.

These state efforts are a critical supplement to federal offshore assessments because areas such as Buzzards Bay are the nursery grounds for many important species and therefore are the first to show trends in species abundance.

.

References

Anonymous, 1892. Buzzards Bay Fisheries. Account of a Meeting, the Protection of the Fisheries. Printed for the Old Colony Club, Falmouth, Massachusetts, 15 pp.

Belding, D. L. 1916. Special Report of the Board of Commissioners and Game Relative to the Fish and Fisheries of Buzzards Bay. House No 1775, 75 pp.

Belding, D. L. 1921 (reprint 1964). A Report Upon the Alewife Fisheries of Massachusetts. Massachusetts Division of Fisheries and Game. 135 p.

Black, D. E., D. K. Phelps, and R. L. Lapan. 1988. The Effects of Inherited Contamination on Egg and Larval Winter Flounder. Marine Environmental Research, 25, pp. 45-62.

Blumer, M., J. Sass, G. Souza; H. L. Sanders; J. F. Grassle; and G. R. Hampson. 1970. The West Falmouth Oil Spill. Tech Report Reference No. 70-44. Woods Hole Oceanographic Institution, 31 pp.

Collings, W. S., C. Cooper-Sheehan, S. C. Hughes, and J. L Buckley. 1981. The Effects of Power Generation on Some of the Living Marine Resources of the Cape Cod Canal and Approaches. Massachusetts Division of Marine Fisheries.

Davis, R. B. 1989. Historic Profile: Buzzards Bay and New Bedford Waters. Unpublished report, submitted to Camp, Dresser and McKee. City of New Bedford, 27 pp.

Fairbanks, R. B., W. S. Collings, and W. T. Sides. 1971. An Assessment of the Effects of Electrical Power Generation on Marine Resources in the Cape Cod Canal. Massachusetts Division of Marine Fisheries, 49p.

Fiske, J. P., J. R. Curlew, and R. P. Lawton. 1968. A Study of the Marine Resources of the Westport River. Monograph Series No 7, Massachusetts Division of Marine Fisheries, 37 pp.

Grice, F. 1969. Marine Fisheries Investigation of Falmouth Oil Spill. Report to the Commissioner and the Board of Natural Resources (unpublished), 3pp.

Hoff, J. G., and R. M. Ibara. 1977. Factors Affecting the Season Abundance, Composition and Diversity of Fishes in a Southeastern Massachusetts Estuary. Estuaries and Coastal Marine Science 5 (5): 665-678

Howe, A. B., and B. T. Estrella. 1978. Fisheries Resource Assessment: Winter Flounder and Other Species. National Marine Fisheries Service, Report No. NOAA 78082301. Gloucester, Massachusetts, 81 pp.

Howe, A. B. 1989. Coastwide Fishery Resource Assessment. Massachusetts Division of Marine Fisheries.

Kolek, A., and T. Currier. 1980. Feasibility of a Pot Fishery for Scup (*Stenotomus chrysops*) in Buzzards Bay. Massachusetts Division of Marine Fisheries, Publication No 11986-25-100-7-80-CR. 24 p.

Moss, S., and J. Hoff. 1988. The Finfish Resources of Buzzards Bay. Unpublished report for EPA CX812850-01-0, 68 pp.

Smith, H. M. 1898. The Fishes Found in the Vicinity of Woods Hole. Fisheries Bulletin.

5. Waterbirds of Buzzards Bay

By Alan Poole[6]

Introduction

Seventeenth century European explorers were apparently impressed by the abundance and variety of birds they found in Buzzards Bay because they named this estuary after a bird of prey (probably the Osprey) and their logbooks contain numerous references to various species of "fowles". Although now greatly reduced in numbers, and somewhat reduced in diversity, birds remain an important component of the Buzzards Bay ecosystem. For the ecologist or ecosystem manager, their importance is twofold.

First, birds are aesthetically important – the bay's most visible living resource. Birdwatchers rival fishermen in numbers, contributing significantly to local economies. Second, birds can be excellent environmental indicators. Their status and distribution provide key signs of the overall health and productivity of an ecosystem, even on a local scale. This is especially true of the coastal birds of Buzzards Bay, most of which eat fish or shellfish. Knowing where waterbirds concentrate, therefore, and knowing the size of their wintering flocks or breeding populations, helps to reveal productive "hotspots" within the bay, areas where benthic invertebrates or migratory fish abound. In addition, because birds accumulate and are often sensitive to certain toxic chemicals, avian health, and breeding success can reflect the fates and persistence of environmental contaminants.

For all of these reasons, an historical assessment of the birds of Buzzards Bay, focusing on their current status and distribution, seems desirable. No such overview exists today. This chapter provides such an assessment, relying on existing data and published literature. In addition, I have consulted people actively involved in the local management of these species to gain perspective on the problems birds face in our region, on how humans are helping to solve these problems, and on what lies ahead for different populations. Six species or groups of species will be the focus of this assessment: (1) terns and gulls; (2) Piping Plover; (3) Double-crested Cormorants; (4) Ospreys; (5) herons and egrets; and (6) waterfowl, especially sea ducks. I choose these species because, of all the birds dependent on Buzzards Bay waters, they are the most numerous, the most heavily impacted by man (both by management practices and ecosystem perturbations), the best indicators of ecological change, and the best studied to date. In addition, I include a short section on pollutants – levels of contaminants in Buzzards Bay waterbirds and impacts on the birds themselves.

Terns and Gulls

Terns: Description, Ecology, and Natural History

Three species of terns breed along Buzzards Bay shores in significant numbers: common tern *(Sterna hirundo*), Roseate Tern *(E. dougallii*), and Least Tern (*E. albifrons*). Only a few Arctic Terns (*Paradisaea*) have nested here (Nisbet, 1973a); their main breeding range being farther north. Thus, Commons, Roseates, and Leasts will be the focus of this section.

Terns are medium sized seabirds that superficially resemble small gulls but are slimmer, more graceful, and more buoyant in flight, with narrower wings and bills. Common and Roseate Terns are often difficult to tell apart — as breeders, they share silvery-gray plumage above, creamy-white plumage below, black cap and blood red bill (usually tipped with black), forked tails with long white streamers, and orange-red feet and legs. Roseates, however, are somewhat paler than Commons, their underparts are suffused with pink ("roseate"), their tail streamers are longer and more flexible, their bills are usually blacker, and their outer primaries more frosted. The calls of these two species are quite different and immediately recognizable from a distance: Roseates utter a sharp but musical "chi-vik" while in flight or on the breeding grounds, along with a harsher, more grating aaaach" (alarm call). (It is often possible to recognize Roseates at night by voice alone; I regularly hear them overhead on summer nights in Woods Hole and Falmouth as they commute from their Bird Island [Marion] nesting colony to sandy shoals in Vineyard Sound, where they find abundant fish). Commons give a low, piercing, distinctive "kee-ar-r-r-r" as their alarm call, with "kik-kik-kik" notes as their contact (flight) call. Within each species, sexes are identical in plumage and voice, and can be distinguished in the field only by behavior.

Least Terns are smaller than Commons and Roseates by almost half. In addition, their yellow bills and feet and their white foreheads make them one of the easiest terns to recognize. Calls include high-pitched, bell-like "kip" or "kit-tic" notes and a harsh "chir-ee-eep." Flight is rapid and even more buoyant than that of the larger terns.

[6] Manomet Bird Observatory, Manomet, MA. Accepted September 26, 1990.

Commons have a wide Holarctic distribution, nesting south to northern Africa and the Greater Antilles. In the New World, most Commons breed in north central and northeastern North America, with the largest colonies along the coast. Atlantic coast populations nest as far north as southern Labrador and as far south as North Carolina. Most of these birds, including those that nest along Buzzards Bay shores, winter along the northeast coast of South America, as do most Massachusetts Roseates (AOU 1983; Nisbet and Reynolds 1984).

Roseates, a worldwide species, breed in two discrete areas of the Western Hemisphere: (1) the northeast coast of the USA, NY state to the Canadian Maritimes; and (2) Caribbean Islands. Unlike Commons, which sometimes live near lakes, Roseates are exclusively marine, nesting on small islands and occasionally among sand dunes along barrier beaches. Here in the northeast, Roseates always share nesting colonies with Common Terns, although the two species prefer different microhabitats (see below) (USFWS 1989). Least Terns breed only in the New World. One subspecies nests along the California coast, another along interior US river systems, and a third along the Atlantic and Gulf coasts (including Buzzards Bay) from Maine to Texas (Spendelow and Patton, 1988). The northeastern Atlantic population winters from Florida and the Gulf coast south to Brazil (AOU 1983).

All three species of Buzzards Bay terns arrive back from winter quarters in late April or early May and quickly begin to court, form pairs, and establish nesting territories; many start laying two to three weeks after returning to the area (Nisbet 1973b). Colonies of Common Terns show a distinct peak in laying, generally during late May and early June, while Roseates usually lay over a more prolonged period (Nisbet 1973a). These species rarely lay eggs after the first or second week of July, however; only young, new breeders lay then, although older, established pairs will sometimes relay in July if their first clutches are destroyed by storms or predators. Early Commons generally lay three eggs, late Commons two, while most early Roseates lay two and most late Roseates one; eggs laid June 1 fledge young by mid-July (USFWS 1989). Once fledged (flying), young Commons and Roseates continue to be fed by their parents for many weeks. These family groups disperse throughout the breeding area, often concentrating on outer beaches in flocks of thousands during August. Roseates and Commons migrate south in late August and early September; nearly all leave Buzzards Bay by September 15.

In Massachusetts, Least Terns nest on a roughly similar schedule, but more erratically and with less pronounced peaks in laying. Least tern nests are especially vulnerable to tidal flooding and to predation, so pairs are often forced to move and relay, reducing nesting synchrony within and between colonies.

Terns are specialist feeders on small schooling fish, which they catch by plunging into the water and seizing in their bills. Commons and Roseates usually feed over open water, often in tidal channels and rips, or over sandbars where currents bring fish into shallow water. They also follow schools of predatory fish such as Bluefish (*Pomatomus saltatrix*), feeding on the baitfish driven to the surface from below. In such circumstances, the terns often form large feeding flocks (Duffy 1986); sport fishermen use these flocks as indicators of where their prey are located – a service all too often taken for granted. Leasts tend to feed closer to shore, often in estuarine waters and usually singly or in small flocks. Coastal ponds seem to be their preferred habitat, perhaps because they often nest nearby. Commons and Roseates also choose, when possible, to nest near primary foraging areas, but these bigger terns can commute long distances for food, flying back with fish in their bills to mates or young at the nest. Locally, the diet of all three species is made up of juvenile fish such as herring and mackerel, minnow-like fish such as sand lance (*Ammodytes americanus*), and small shrimp (Nisbet 1973b).

Because terns eat fish, a mobile, transitory food source that cannot be easily defended, they usually defend only the immediate area around their nest, allowing pairs to nest close together in breeding colonies. In addition, Commons, Roseates, and Leasts lay their eggs on the ground, building minimal nests – often just small scrapes in sand or gravel. These two behaviors, coloniality and ground nesting, are major influences on the breeding ecology of these species. As ground nesters, terns are vulnerable to predators (e.g., foxes, raccoons, and skunks) and to human disturbance, and so are forced to nest on remote islands or isolated mainland beaches where these threats are absent or reduced. Within habitats, Commons typically place eggs in open or sparsely vegetated areas (generally dunes and upper beaches), while Roseates, which often share the same habitat, prefer to nest near or under cover – plants, rocks, flotsam (Spendelow and Patton 1988; USFWS 1989). Leasts prefer the most exposed habitat, nesting on coarse sand and gravel beaches, usually just above the high tide line in areas swept clear by winter storms. Such habitat, especially that favored by nesting Commons and Roseates, is also favored by the ground-nesting Herring and Black-backed gulls (*Larus argentatus* and *L. marinus*) – larger, more aggressive birds that easily displace the terns. The history of Buzzards Bay terns, discussed below is largely a history of such competition with gulls, although human persecution was also a major factor influencing breeding numbers and distribution. Before turning to this history, however, we take a brief look at the ecology of the two gull species that have adversely affected terns so dramatically.

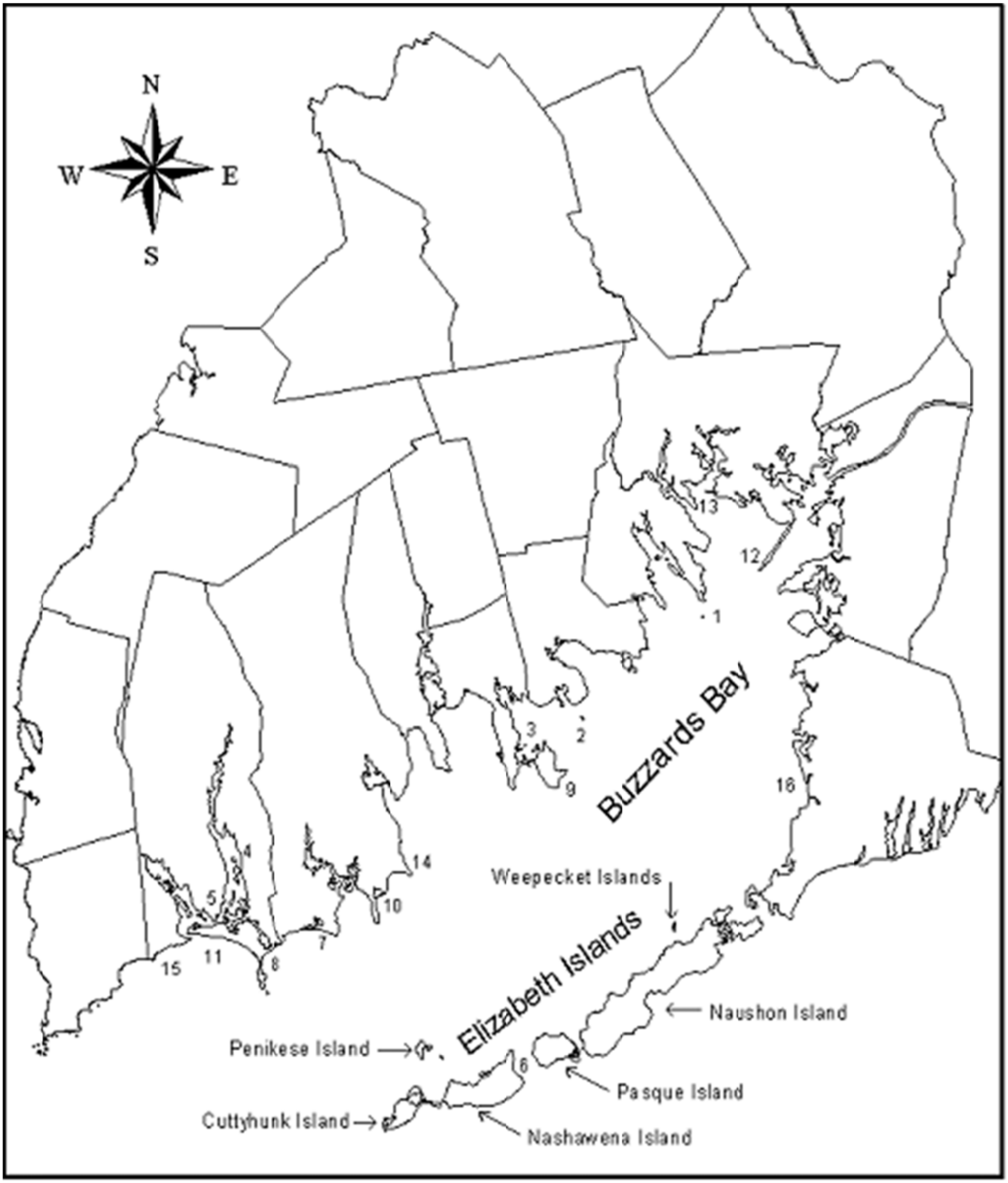


Figure 5-1. Locations of waterbird breeding colonies in Buzzards Bay.

1. Bird Island, Marion 2. Ram Island, Mattapoisett, 3. Fish Island, Fairhaven 4. Speaking Rock, Westport 5. Ram Island, Westport, 6. Nashawena Island, 7. Barneys Joy/Little Beach, Dartmouth 8. Gooseberry Neck, Westport 9. West Island, Fairhaven 10. Salters Point, Dartmouth 11. Horseneck Beach, Westport 12. Stony Point Dike, Wareham 13. Long Beach Point, Wareham 14. Round Hill, Dartmouth 15. Acoaxet Beach, Westport 16. Sippewissett, Falmouth.

Compared to terns, Herring and Black-backed gulls differ ecologically in many important ways: they nest earlier, they have a much broader diet, they undergo no long distance migrations, and they are large and aggressive – in short they have distinct advantages over terns. In part because they do not migrate, the gulls set up nesting territories early (April) and are well established by the time the terns arrive in early May. As opportunistic scavengers, gulls can survive on garbage at landfills all winter (boosting survival rates and thus breeding numbers) and even feed their young on such refuse. Moreover, Herring and (especially) Black-back Gulls eat tern eggs and chicks, when possible, so the terns tend to move their colonies in response to colonization by gulls.

Gulls: History and Current Assessment of Buzzards Bay Breeding Colonies

Although some historical information is available back to the late 19th century, careful monitoring of Buzzards Bay gull and tern populations began only about 1970, with a few local exceptions. Nisbet (1973a and unpublished) has thoroughly assessed this history, along with that of other Massachusetts terns, and his work should be consulted by all who wish more details, especially concerning census methods and their reliability. Drury (1973-1974) covers historical changes in New England gull populations. Keep in mind, however, that historical counts, although often vague and inaccurate, were generally adequate to determine overall trends in numbers.

The Weepecket Islands (Figure 5-1), one of the major gull and tern colonies in Buzzards Bay, were monitored sporadically from 1896 to 1915 and yearly from 1925 to 1945 (Crowell and Crowell 1946). Table 5-1 summarizes the excellent data gathered there during those years. Although a thriving tern colony (Roseates and Commons) up to the 1930s, the arrival of Herring Gulls in the mid-1930s displaced nearly all the terns in just a few years. Indeed, the speed of this displacement is typical, a clear example of the sensitivity of nesting terns to the presence of gulls in their midst. The Crowells (1946) concluded that direct damage to tern eggs and young, although a potential threat, was not the major cause of desertion. Faced with nesting gulls, the terns simply abandoned nests or never bothered to settle, apparently moving elsewhere.

Herring and Black-backed Gulls have become common nesting species in southern New England only in the last few decades. Although there were scattered records of Herring Gulls nesting in Buzzards Bay during the last half of the 19th century, these birds had disappeared as breeders by 1900; people regularly shot gulls and took their eggs for food (Forbush 1925; Drury 1973). Herring Gulls recolonized the Cape and Islands in the 1930s, beginning a period of explosive growth; by 1941, 4700 pairs were

Table 5-1. Estimated numbers of terns and Herring gulls nesting on the largest of the three Weepecket Islands, 1896 to 1945.

Year	Terns	Gulls
1896	200*	0
1902	900	0
1903	1500	0
1905	2500	0
1915	4000	0
1925	200	0
1930	2500	0
1935	1500	4
1940	1000	400
1941	4	400
1942	10	1000
1943	0	1000
1944	<10	500
1945	<10	250

Numbers shown are individuals, not pairs. Similar trends were seen among smaller populations nesting on the two outer Weepecket Islands. Terns were roughly 75% Commons and 25% Roseates, except in 1896. Data from Crowell and Crowell 1946.

*150 of these were Roseates

breeding this area and by 1965 nearly 20,000 pairs (Drury 1973).

Black-Backs came later, with only 20 pairs breeding on the Cape and Islands in 1951, and 1325 in 1972. Black-blacks are now outcompeting Herring Gulls on nesting islands in our region, and Herring gull numbers appear to be leveling off (Table 5-2). The Weepecket gull colonies continue to grow (Table 5-2), although current numbers appear somewhat reduced compared to the highs of the early 1940s. Great Black-backed Gulls have been especially successful here, increasing more than 400% between 1977 and 1984.

Penikese Island, nearly seven times larger than the nearby Weepeckets (Figure 5-1), was once the largest tern colony in Buzzards Bay. Two to three thousand pairs of terns (mostly Commons, but about 10%-20% Roseates) nested here around 1900, their numbers swelling to 5,000 - 7,500 pairs in the 1930s and 7,000 - 10,000 pairs in the early

Table 5-2. Gull nesting colonies in Buzzards Bay, 1977-1989

Colony	1977	1984	1989
Weepecket Island	450 H 25 BB	658 H 130 BB	
Nashawena Island	675 H 0 BB	930 H 200 BB	
Penikese Island	1650 H 300 BB	380 H 8 BB	200 H 0 BB
Ram Island	350 H 20 BB	500 H 90 BB	405 H ? BB

Data show estimated numbers of breeding pairs. H = Herring Gull; BB = Greater Black-backed Gull. Data from Erwin and Korschgen 1977 and from B. Blodget 1980-1989.

1950s, thanks in large part to protection – wardens were there beginning in 1897 (references in Nisbet 1973a). Gulls first colonized this island at about the same time as they did the Weepeckets, but Commons and Roseates managed to coexist with the gulls because the latter nested in a separate part of the island (Crowell and Crowell 1946). By the late 1950s, however, gulls had overrun Penikese; no terns were found there in several visits between 1962 and 1972 (Nisbet 1973). A 1977 survey found about 1650 pairs of Herring Gulls and 300 pairs of Great Black-backed breeding on the island, but those numbers dwindled substantially during the 1980s (Table 5-2), apparently in response to a red fox that was released on the island around 1980.

Penikese continues to have tremendous potential for nesting terns; it is a colony waiting to happen. Tide rips and shoals — feeding grounds for terns — bound nearby, and plenty of nesting space is available if the remaining gulls (and of course the fox) can be removed. Simple, proven, and cost-effective management practices for removing gulls are now available, and terns are quick to respond to such a vacuum. In addition, naturalists from the ongoing Penikese Island School, who live on the island all summer, have expressed interest in serving as wardens for any tern colony that can be re-established there; public access is limited anyway, so human disturbance would be minimal. In short, with time and a little management effort, Penikese could easily become the spectacular tern colony that it once was, supporting tens of thousands of Commons and perhaps several thousand Roseates. Such a breeding colony would be a landmark in Buzzards Bay and help to bolster threatened tern populations throughout the area.

Ram Island (Mattapoisett) and Bird Island (Marion) Figure 5-1) have held significant numbers of breeding terns off and on since the 1930s. Austin (MS) recorded a gradual increase in the size of these colonies during the 1940s. Between 1964 and 1966, they were overrun by gulls, but by the late 1960s Common and Roseate terns had become re-established on both islands, thanks to local gull control efforts (Nisbet 1973a). Ian Nisbet, then of Mass Audubon, began annual studies here in the early 1970s, studies which continue today. As a result, census data for these colonies is unusually thorough. Although the Bird Island colony has grown nearly 400% since 1970, gulls re-invaded Ram Island during the 1970s and the terns left, many of them presumably for Bird Island (Table 5-2 and Table 5-3). In an effort to re-establish terns (especially the endangered Roseate) on Ram Island, the MA Division of Fisheries and Wildlife Endangered Species Program began a gull control program there in 1989, and plan to continue this in 1990.

Three facts are worth noting about the Ram and Bird Island tern colonies. First, while the Bird Island Commons have nearly tripled in number since 1980, Roseates have

Table 5-3. Numbers (pairs) of terns nesting in various colonies in Buzzards Bay, 1970 to 1989.

Colony	1970	1980	1985	1989
Ram Island	300 C 700 R	0 0	0 0	0 0
Bird Island	250 C 600 R	600 C 1400 R	1040 C 1450 R	1880 C 1473 R
Nashawena Island	100 C 0 R	86C 0	118 C 1	150 C 0
Cuttyhunk Island	0 C 0 R	0 0	0 0	8 0
Fish Island	0 C 0 R	0 0	? ?	20C 0
Speaking Rock	? C ? R	? ?	15 C 0 R	20 C 0 R
Total	650+ C 1,300+ R	686+C 1,400+R	1,173 C 1,451 R	2,078 C 1,473 R

C = Common Tern; R = Roseate Tern. Data from Nesbit 1973a and B. Blodget – MA Dept. of Fisheries and Wildlife. See Figure 5-1 for colony locations.

remained steady; Commons now outnumber Roseates there (Table 5-3), apparently outcompeting them. Second, roughly 50% of North America's Roseate Terns nest on Bird Island (USFWS 1989), as do 93% of all Massachusetts Roseates (Blodget 1989), a potentially vulnerable reproductive concentration for any species or population. This is why gull control was initiated on Ram Island and why it is so long overdue on nearby Penikese. Third, in most years terns breed successfully at Bird Island (Nisbet, pers. comm.; Hecker 1987), suggesting that this area is relatively free of predation and disturbance.

Other Common and Roseate colonies in Buzzards Bay have been small compared to those discussed above (Table 5-3). Nashawena Island, which has supported about 90 to 150 pairs of Commons in the past two decades, is the largest of these satellite colonies. It is interesting to note that Nashawena's Commons have managed to co-exist with gulls despite their proximity (Erwin and Karschgen, 1979;), but this is clearly a vulnerable situation for the terns. None of these satellite colonies seems to have much potential for expansion.

Although Least Terns were "... common to abundant" nesters along Buzzards Bay shores during the19th century, they have always been more abundant on the outer Cape, on Nantucket, and on Martha's Vineyard (Nisbet 1973a). In even the best of circumstances, however, Least Tern colonies tend to be small and shifting (and thus their numbers hard to count) compared to the larger terns. This contrast has been especially evident in Buzzards Bay during the 1900s (Nisbet 1973a; Table 5-4), probably because our region holds few large, sandy islands or remote, predator-free beaches, preferred habitat for large colonies. Along Bristol County shores, for example, Leasts dwindled from about 50 pairs in the 1920s to 10 pairs in 1972 (Nisbet, 1973a). During the past two decades, Nashawena Island has been the only Buzzards Bay colony to hold more than 50 pairs of Leasts (Table 5-4), but even that one has declined alarmingly in recent years, apparently due to predation. In short, Buzzards Bay Least Terns, probably never very abundant, are barely holding their own today. Careful management, discussed below, could help to stabilize numbers.

Management Recommendations

1. Encourage a program of gull control on Ram and Penikese Islands, as discussed above. This would involve both the poisoning of breeding adults at the nest with an appropriate avicide, and the destruction of eggs and nests. Such programs have proven remarkably effective along the coast of Maine (Blodget 1988). Buzzards Bay Roseates, now federally endangered, would gain most from gull control, but the more numerous and aggressive Commons would also gain extra security.

2. Facilitate other recommendations listed in the Roseate Tern Recovery Plan (USFWS 1989).

3. Protect nesting habitat of Least Terns, as outlined by Becker (1987). Particularly important measures are: building predator exclosures around nesting colonies, regulating vehicle use, dogs, and other human disturbance on nesting beaches, and maintaining overwash and similar open sand nesting areas by discouraging dune stabilization programs (e.g., with Christmas trees). In addition, gull and other predator control programs, applied near threatened Least tern colonies, would give that species a local boost.

Table 5-4. Least Tern nesting colonies in Buzzards Bay, 1980 – 1989. Data show estimated numbers of breeding pairs. Data from B. Blodget (1980-1989). NA = not active. P = present but not censused.

Colony	1980	1985	1989
Nashawena Island	108	75	16
Barney's Joy	50	27	39
Gooseberry Neck	15	12	NA
Long Island, Fairhaven	P	12	NA
West Island, Fairhaven	P	12	NA
Richmond Pond, Westport	NA	NA	16
Salters Point, Dartmouth	?	NA	3
Horseneck Beach, Westport	?	NA	2+

Current Research and Management Activities

1. Ian Nisbet's study of Bird Island Commons and Roseates, mentioned above, has been active since 1970. This study involves censuring, ecological, and behavioral research, and population modeling.

2. Within Buzzards Bay, the U.S. Fish and Wildlife Service's (1989) Roseate Tern Recovery Plan focuses mostly on Bird Island but also peripherally on Nashawena Island (three pairs nested there in 1988) and Ram Island (due to its potential for reestablishing a Roseate colony). Gull control on Ram Island, recommended by the recovery plan, is being coordinated by the MA Division of Fisheries and Wildlife.

3. Annual monitoring of Massachusetts terns is coordinated by Mass Fisheries and Wildlife under the direction of Bradford Blodget, State Ornithologist. Mass Audubon personnel and volunteers have collected much of this data. Blodget's database extends back to the early 1970s. Mass Audubon continues to oversee many tern colonies in the state, including Bird Island. Management includes limited gull control, clearing vegetation, and wardening on summer afternoons (Hecker 1987).

Piping Plover

Description and Natural History

Piping Plover (*Charadrius Melodius*) are small, sand-colored shorebirds that frequent Atlantic coast beaches from Newfoundland to North Carolina. Pale orange legs, a dark narrow breast band (complete only in breeding males), and a haunting, flute-like call distinguish it from other North American plovers, most of which breed in the arctic. When visiting summer beaches, one hears this plover far more often than one sees it; its plumage is beautifully camouflaged against dry sand. In addition, when disturbed, these birds often crouch low and freeze in "false incubation," making detection of both individuals and their nests exceedingly difficult.

Piping Plover are beach nesters, favoring open habitat in sparsely vegetated dunes or just above the high tide line, habitat similar to that chosen by nesting Least Terns. In fact, the two species often share nesting grounds. And like the terns, the plovers lay eggs on the ground in just a rudimentary nest, a small scrape lined with a few sticks or broken shells. Unlike the terns, however, Piping Plover are not colonial breeders but space their nests at least 50-100 meters apart, usually more. Even though these nests are solitary and well-camouflaged, the eggs are vulnerable to ground predators such as foxes, skunks, and raccoons — unless the nests are enclosed by fence. And once the young hatch and are moving about, they become vulnerable to gulls and other aerial predators. (Plover chicks are precocial; they follow their parents and pick food from the ground hours after they hatch).

Piping Plover eat a variety of small marine invertebrates – worms, crustacean and amphipods – plus beach insects, all of which they snatch from portions of the upper beach, especially decaying wrack lines. In southern New England, individuals arrive and pair up in April, lay first clutches (usually 4 eggs) in May and June, and fledge their young about one month after hatching (J. Lyons, pers. comm.). Although pairs will often relay if their first clutch is destroyed, successful pairs never produce a second clutch because they have not enough time to raise a second brood. Family groups linger along August beaches, sometimes forming small, loose flocks; individuals usually depart for wintering grounds (beaches: S. Carolina to West Indies) by mid-September, although a few (perhaps transients from further north) may still be found here in late fall.

History and Current Status in the Buzzards Bay Region

Compared to our terns and gulls, few census data are available for Piping Plover in southern New England prior to the 1980s. Their early history is especially vague. Forbush (1925) writes that this species was severely reduced by spring and summer shooting in the late 19th century, becoming rare where it was once abundant. State protection in the early 20th century brought it back; by the 1920s it was "abundant and increasing." Griscom and Snyder (1955) found this plover "common and widely distributed" during the early 1950s, "nesting on virtually every beach in the state." Although they are still widespread, Piping Plover are now far from common in the Buzzards Bay region; only 15 to 30 pairs have nested here annually during the past six years (Table 5-5). Predation and human disturbance have undoubtedly contributed to this scarcity. As nearshore development and beach use have accelerated in recent decades, plover nesting beaches have been plagued by scavenging predators (red fox, raccoons, striped skunk) attracted by human garbage. Proof of the impacts of predation come from areas where nest sites have recently been fenced against predators; such nests show higher reproductive success than they did before fencing.

Along Buzzards Bay shores, several plover breeding concentrations — "hotspots" — became evident when censusing began in the 1980s: Cuttyhunk Island, Horseneck Beach, and Little Beach/Barneys Joy (Table 5-5). Cuttyhunk is thought to have few predators, so this may account for the plovers' success there. More young Piping Plover have fledged at Horseneck Beach in the past few years than at any other spot in the state except one; 18, for example, fledged from 7 Horseneck nests in 1989, nearly double the average reproductive success for Massachusetts plovers during the past few years (Blodget 1980-1989). This suggests that Piping Plover can thrive despite human disturbance, for Horseneck Beach attracts thousands of

Table 5-5. Locations and numbers of Piping Plover nesting around Buzzards Bay, 1984 – 1989.

Site Name	1984	1985	1986	1987	1988	1989
Stony Point Dike, Wareham	2	ND	0	2	1	1
Long Beach Point, Wareham	1	ND	ND	0	ND	0
West Island, Fairhaven	2	2	1	2	1	0
Round Hill Beach, Dartmouth	ND	ND	ND	ND	1	1
Salters Pond, Dartmouth	ND	ND	ND	ND	0	1
Little Beach-Barney's Joy, Dartmouth	3	4	9	8	17	7
Gooseberry Neck, Westport	ND	1	1	0	1	1
Horseneck Beach	4	6	7	5	3	7
Acoaxet Beach, Westport	ND	2	1	1	2	2
Richmond Pond, Westport	2	3	3	2	3	2
Bay Point, Swansea	ND	ND	ND	ND	0	0
Sippewissett, Falmouth	1	ND	1	1	2	0
Pasque Island	3	4	3	2	0	1
Nashawena Island	1	1	2	0	2	3
Cuttyhunk Island	3	3	4	6	6	5
TOTALS	22	26	32	29	39	31

Numbers shown are pairs. Data from Blodget (1980-1989). Upward trend in totals is due mostly to increasing observer effort.

human visitors (many with dogs) on hot summer days, but apparently few predators anytime. At Little Beach and Barneys Joy, by contrast, human disturbance is minimal but a red fox reduced 1989 reproductive success to about 20% that found at Horseneck. In short, predation seems to be a major limiting factor for these birds, and undoubtedly influences their breeding distribution as well.

Management and Research: Current and Recommended

The Piping Plover, currently "threatened" in Massachusetts, is just beginning to benefit from management. Many of the techniques that help Least Terns also help the plover. Predator exclosures, for example, are producing tremendous results, boosting reproductive success significantly. Such enclosures, simple rings or triangles of snow fence 20-30 m across, are not difficult to install around nests, although the effort of finding the nests can be time consuming. Volunteers, however, often participate in these projects, reducing the costs to management agencies. Little Beach is an obvious priority for 1990 enclosure efforts. At Horseneck Beach, symbolic fencing (flagging) around nests seems to have helped the plovers, but snow fence enclosures will be needed where human traffic is most intense.

The MA Division of Fisheries and Wildlife plans to continue monitoring Piping Plover until the species is no longer threatened. It will be delisted when it is better distributed and reproductively stable. Fish and Wildlife will also help to co-ordinate exclosure efforts, although so far this has depended largely on local initiative (e.g., the Lloyd Center in the Dartmouth/Westport area). The Buzzards Bay Project might help to generate interest in Piping Plover by publicizing management and censusing efforts; beach users are generally not receptive to having areas closed off for a small, inconspicuous bird.

Finally, dredge spoil islands make ideal nesting habitat for plovers and terns (Spendelow and Patton 1988). When considering the environmental impacts of dredging in the bay, the Buzzards Bay Project should be aware of this fact.

Double Crested Cormorants

Description and Natural History

In *Paradise Lost*, Milton chose the cormorant as one of several transmutations for his character Satan. A quick glimpse at these creatures shows why. A large, black waterbird with setback legs, long neck, and long hooked bill, cormorants look like elongated, awkward geese. To complete the picture, their calls are a series of harsh croaks and guttural grunts (heard mostly at breeding colonies), they fly in loose, ragged V's or lines, and they spend considerable time perched on rocks and trees with their wings spread, drying soaked feathers. Whatever awkwardness these birds show on land or in the air, however, is quickly lost in the water. They are superb swimmers and divers, highly adapted for pursuing fish (their main prey) underwater.

Only one species of cormorant breeds in Buzzards Bay: the Double-crested Cormorant (*Phalacrocorax auritus*). This species is distinguished from others of its genus by a large, rounded, orange throat patch (facial skin), which is present year-round, and by small dark crests atop its head (seen only on breeders). Like other cormorants, this species often swims partially submerged (just the head and neck showing), diving from the surface after fish and eels and re-emerging with prey in its bill, which it then subdues and swallows whole. Although restricted to just two breeding colonies in Buzzards Bay, Double-crested Cormorants have a wide (if disjunct) distribution in North America, nesting along the Atlantic coast from Newfoundland to the Bahamas and wintering from southern New England (a few) to the West Indies (AOU 1983).

Visiting a cormorant breeding colony is a memorable experience, although not one to be encouraged for the casual visitor because it disrupts nesting. Nests, which are mounds of seaweed, twigs, and wrack line trash, are usually built on the ground on predator-free islets, often packed in side by side; thousands of pairs will nest on a tiny narrow islet just a few hundred meters long. A cacophony of grunts and croaks greets the intruder, the stench of decaying fish fills the air (young are fed by regurgitation), and excrement whitewashes rocks above the tide line. Newly hatched young are naked, coal-black, and resemble rubber toys, although they are soon covered with dense black down; eggs (3-4) are pale blue with a chalky covering.

Buzzards Bay cormorants eat a great variety of fish, but mostly non-schooling species from rocky substrates (e.g., Cunner [*Tautogolabrus adspersus*], Hatch, 1983). In addition, sand lance have been important in recent years. Rarely are species of any commercial value taken, although fishermen often view this bird as a competitor and have killed it indiscriminately in the past (Drury 1973).

History and Current Status in Buzzards Bay

Hatch (1984) has reviewed the history of the Double-crested Cormorant in Massachusetts through 1982. Although this bird's early range and history in our region are little known, bones from Indian middens suggest that it apparently nested on islands near present-day Boston around 1500. After being extirpated from New England in the 19th century (partly by shooting for food), it recolonized many of its old haunts in the 1940s, including the Weepecket Islands in 1946. Starting about 1970, this colony, like others in southern New England, saw rapid growth, increasing from 150 breeding pairs in 1971 to 520 pairs in 1978 to 1050 pairs in 1981 (Hatch 1984). Most nesting in this period occurred on the two small, rocky, outlying Weepeckets, but as these became saturated the cormorants tried to expand onto the largest islet. There, a combination of gulls and human disturbance have kept the cormorants from gaining much of a foothold, although they still persist. Due to this habitat saturation, Weepecket cormorant numbers have grown slowly in recent years; the last effective survey (in 1984) found 1135 nesting pairs, and Hatch (pers. communication) suggests that little growth has occurred since then.

Until recently, the Weepeckets were the only Double-crested cormorant colony in Buzzards Bay. In 1986, however, a new colony sprang up on Ram Island (Figure 5-1), perhaps due to spillover from the Weepeckets. Although still small (ca. 100 pairs), this new colony hints that cormorant numbers may continue to expand in Buzzards Bay, although most growth is now occurring farther south. In our region, Double-crests prefer rocky islets for nesting, but they do colonize sandy or vegetated islands as well (Spendelow and Patton 1988). Reproductive success at both existing colonies has been good, although no precise data have been gathered (J. Hatch, pers. comm.).

Management and Research: Current and Recommended

Continue surveys every five years of new and existing colonies. Formerly (in 1977 and 1984) these surveys have been coordinated by the U.S. Fish and Wildlife Service, although their interest seems to be waning (e.g., no survey in 1989). If Buzzards Bay surveys cannot be coordinated with others in the state (or in New England), then local censusing would be appropriate and could be contracted out at minimal cost. Surveys of cormorants could be combined with those of other coastal waterbirds. (2) Gather occasional data on reproductive success in these colonies; no such data exist today. This information could prove valuable because reproductive rates of Double-crested Cormorants are sensitive to certain environmental pollutants (refs. in Hatch 1984).

Ospreys

Description and Natural History

Curious readers are referred to Poole (1989) for more details. The Osprey (*Pandion haliaetus***)** is a large bird of prey, about the size of a small eagle or a large hawk, although narrower winged than either of these. Seen in flight from below, the Osprey's salient features are its white or slightly mottled underparts, the pronounced crook in its long wings, and its dark "wrist" patches. Seen perched from a distance, the Osprey's white breast usually first catches attention. Seen up close, the Ospreys bright yellow eye, mottled breast band, and chocolate brown back and eye stripe are most prominent. Males sometimes lack breast mottling, are generally smaller than females (by about 20%) and more buoyant on the wing. Both sexes, when perched, have an almost feline look about them, an impression enhanced, perhaps, by their small, narrow heads.

You hear Ospreys as often as you see them. Calls vary considerably (Poole, 1989), but a slow, whistled guard call ("kyew, kyew, kyew") is heard most often, especially when other Ospreys are nearby. Courting and territorial males display with fish in their talons, a high, undulating flight accompanied by a screaming call.

Traditionally, Ospreys have built their large stick nests high in dead trees or, when they find predator-free islands, on the ground. Where safe nest sites are plentiful, pairs often nest in colonies, with nests just a few dozen meters apart. (Pairs nesting solitarily breed just as successfully as those nesting in colonies do.) In recent decades, however, as natural nest sites have dwindled, as the coastline has become more crowded, and as predators have proliferated, Ospreys have discovered that artificial structures – buoys, power poles, and specially designed platforms atop poles – often make safe, sturdy nesting locations. Nearly all of the 152 nests active in Massachusetts in 1989 were built on artificial structures.

Ospreys nest along rivers, lakes, and seas throughout the northern hemisphere, and in Australia. The Atlantic coast, Labrador to Florida, holds more than half of the North American population, with the largest colonies found in southern New England, Chesapeake Bay, and Florida. New England Ospreys winter in northern South America (Poole, 1989).

Ospreys are fish hawks, their diet restricted almost exclusively to live fish. They catch their prey by diving feet first into the water and grasping the fish as it tries to escape. Because they cannot dive deep, they thrive best in shallow water environments – bays, estuaries, and shorelines, or where surface schooling fish are plentiful. Buzzards Bay Ospreys feed mostly on winter flounder (*Pseudopleuronectes americanus*), various herring (*Alosa* spp.*)*, and Menhaden (*Brevoortia tyrannus*).

History and Current Status

Ospreys undoubtedly nested abundantly along the shores of Buzzards Bay during the l8th and 19th centuries, and probably before this, but we lack accurate historical records for confirmation. As mentioned in the introduction to this report, early explorers in Buzzards Bay probably named this body of water after the Osprey ("Buzzards") they found here. Ideal, shallow estuarine habitat would certainly have been plentiful here.

Forbush (1925) and Bent (1931) describe the Ospreys of Bristol County around 1900 and give some rough estimates of population size (75 nests), but few specific locations of nesting pairs. Most were apparently along the coast (Buzzards and Narragansett Bays) and many had adapted to artificial nesting structures – poles erected by local farmers. The first reports for Buzzards Bay come from the late 1960s and early 1970s, by which time pesticides had severely reduced breeding numbers. The Westport River held only about 5-8 active pairs at that time, and was the only nesting concentration in the region. One or two other unsurveyed nests may have existed then along Buzzards Bay shores, but certainly not more than that. By 1979, a decade after use of DDT ceased in our region, the Westport population had grown to 20 active nests (all but one on artificial platforms), Wareham held one active nest (on a power pole), and sub adults were showing up in the Dartmouth area. A decade later, Westport had jumped to 69 active nests and Ospreys were reappearing throughout the bay: four pairs in Dartmouth, one in Fairhaven, two in Wareham, one in Bourne, one in Falmouth (on the bay side), and two on Naushon. Westport remains the center of concentration, mostly because of the tremendous effort that local residents Gil and Jo Fernandez have put into building nesting platforms. Availability of safe, sturdy nest sites is a key limiting factor or this species (Poole 1989).

Research and Management

MA Fisheries and Wildlife continues to monitor Osprey populations in the state, and to coordinate efforts to build nesting platforms in appropriate locations. The Osprey was recently delisted as a species of special concern in the state, however, so official monitoring may no longer continue. I plan to continue my own research on Westport River Ospreys into the 1990s.

One area of concern with this species in our area is the tremendous proliferation of nesting platforms, many of which are being built by inexperienced people in inappropriate locations (e.g., where the birds are vulnerable to predators). In such cases, the nests serve as Osprey "sinks", dooming breeding attempts to failure and exposing the adults to predation. We need better regulation of the construction and siting of these nesting poles.

Black-Crowned Night Herons and Snowy Egrets

Description and Natural History

Two species of wading bird (family *Ardeidae*) are known to nest along Buzzards Bay shores: Black-crowned Night Herons (*Nycticorax nycticorax*) and Snowy Egrets (*Egretta thula*). Several other waders roost and feed here, but none have been confirmed as breeders.

Snowys are a relatively small white heron, easily distinguished by their black legs and contrasting bright yellow feet. Black-crowns are about the same size overall, but chunkier, with breeders showing pearly-grey upper wings and neck, black crown and back, and elegant white plumes trailing from their hindneck. Juveniles are mottled brown and white above with streaked puffy breasts. While Snowys are generally silent, Black-crowns utter a harsh, guttural "woe" when disturbed, and even when flying together in small flocks, a familiar sound to those who frequent nighttime shores and marsh. This distinctive call has given the Black-crown its colloquial name in New England – the "woo."

Like most other *Ardeidae*, Snowys and Black-crowns are shallow water and shoreline feeders that concentrate on small fish and crustaceans, which they seize in their bill with a quick, vigorous stab. The night heron, as its name implies, is a crepuscular animal, most active at dawn, dusk, and even at night. It tends to wait quietly and alone for its prey, poised along a stream or marsh. Snowys, by contrast, are active daytime feeders, often stirring up prey with their feet and chasing after them in small, seemingly frantic flocks. *Fundulus* and *Crangon* shrimp are favored prey of Snowys in southern New England; the birds forage for them over flooded mud flats and, at higher tides, in among the salt marsh grasses. Black-crowns seem to prefer fresh and brackish waters, often taking small anadromous fish like herring as these migrate to and from estuarine waters (K. Parsons, pers. comm.). These herons, however, will also raid tern colonies and eat the eggs and young; their diet is broad.

Both species are restricted largely to coastal breeding habitats in southern New England, but both are adaptable in their choice of nesting sites, building in high trees, low shrubs, and even on the ground, depending on available vegetation (Spendelow and Patton 1988). Because their nests are vulnerable to ground predators, however, these birds (like all the other waterbirds examined in this report) like to nest on small, predator-free islands. Both species breed only in colonies, often in company with other herons and egrets. In such mixed heronries, Snowys, and Black-crowns generally nest well below the canopy, just a meter or two away from their nearest neighbor (Burger 1978).

Such dense breeding colonies, sometimes holding hundreds or thousands of pairs, are one of the marvels of the natural world. Forbush (1925) describes one he camped beside on Cape Cod in 1908:

"The heronry was in a hollow among wooded hills, where there had been a pool in the spring which was now dried up. The borders of the place were hedged about with thorny smilax and poison ivy, but inside the heronry the ground was comparatively clear. Here, well up on the trees, the large straggling nests were placed, from three to six nests on each tree. Young herons are inured to hardships from the first. Resting on the hard sticks which compose their crude unlined nests, exposed to every wind that blows over and through the ramshackle structure, they must become hardened or perish. The windless air was stagnant and fetid, swarms of stinging midges, deer-flies and mosquitoes attacked at will; and vicious wood ticks, hanging from the vegetation, reached for me with their clinging claws, and crawled upon my limbs, seeking an opening to bury their heads in my flesh."

"Croaks and calls, flat cries and choking gasps filled the air, as the great flocks of the heronry took flight, flapping and wheeling overhead. Here was a beautiful and stirring sight! Hundreds of waving plumes, pale, delicately tinted breasts, great red eyes, and widespreading pinions sailing over me just above the trees. The young birds, homely, awkward, speckled things with staring yellow eyes were now out of the nests and had climbed to the tree tops high above that pestilential hole to a place where they could escape the mosquitoes, feel the breeze and get a breath of the free air of heaven.... In the 24 hours that I remained within hearing, there was not a minute when the sound of their voices was stilled, and there were always birds flying away to sea, shore or marsh, and others returning. They were quietest just after noon, and noisiest about all night ... the babel of sounds increased as the night grew darker, until a nervous person might have imagined that the souls of the condemned had been thrown into purgatory and were bemoaning their fate."

The Wading Bird Colonies of Buzzards Bay

Our region can boast no colony as large and active as that described above. Although there is little historical data available for the herons and egrets of Buzzards Bay, it seems clear that all our colonies, past and present, have been small. Apparently nesting habitat is submarginal, because salt marsh feeding habitat is plentiful; I regularly see foraging herons and egrets here.

Snowy Egrets have only recently colonized southern New England. Once abundant to the south (Mid-Atlantic States to Florida), these birds were threatened by plume hunters in the 1880s and 1890s (Ryder 1978). This shooting restricted nesting distribution, but subsequent protection allowed the species to re-occupy its former range and expand to the northeast. The first pair of Snowys nested in Massachusetts in 1955 (Erwin and Korschgen 1979); prior to that, the species had been "an accidental straggler," only six individuals reported in the state from 1926-1947 (Griscom and Snyder 1955). By 1968, 45 pairs were breeding in the Commonwealth; by 1976, 600 pairs, but apparently few around Buzzards Bay (Erwin and Korschgen 1979). Table 5-6 lists the only documented nesting locations used by these (or any other) waders in our region during the recent past.

Black-crowned Night Herons have been an abundant coastal Mass. resident, at least since the late 19th century when colonies of several thousand were known from north of Boston. For some reason, perhaps increased predation or disturbance, these colonies broke up in the early 20th century and the species redistributed itself around the state in smaller, more numerous colonies (Erwin and Korschgen 1979). However, there are no confirmed, published records from Buzzards Bay prior to 1977 (Table 5-6). Forbush (1925), for example, mentions 15 eastern Massachusetts towns were Black-crowns bred in the early 20th century; none was within the Buzzards Bay watershed except North Falmouth. It seems unlikely that any large colonies existing in our region during historical times would have gone unrecorded.

Table 5-6. Breeding locations and numbers (pairs) of Snowy Egrets and Black-crowned Night Herons around Buzzards Bay, 1977 and 1984.

Colony Site	1977	1984
Weepecket Island		
Snowy	1	a few
B-crown	a few	a few
Nashawena		
Snowy	30	?
B-crown	25	20
Ram Island, Westport		
Snowy	11	?
B-crown	40	?

The years 1977 and 1984 were the only years for which records exist. The Westport colony may have contained 10-20 pairs of Little Blue Herons as well. Data from Erwin and Korschgen 1979; B. Blodget; and J. Hatch. Other possible, but unconfirmed historical sites for the breeding of these species in our region include Devils Foot/Ram Island, Woods Hole; Piney Island, Woods Hole (prior to '38 hurricane); and Pasque Island.

Management and Research: Current and Proposed

Given the marginal status of breeding herons and egrets in our region (both past and present), future censusing and research is probably not a top priority. Nevertheless, these (and any new) Buzzards Bay colonies could be covered during routine monitoring of other local waterbirds. It should be noted, however, that these birds are difficult to count from the air. Their nests are generally well hidden, so ground surveys are more effective. Such surveys, even every five years, would be adequate to document the status and range expansion of these and other waders. Current trends suggest that new colonies of Snowys and Black-crowns will spring up in our region, perhaps including other species such as Little Blues. How such surveys could be initiated and coordinated has previously been discussed.

Wintering Waterfowl

Ecology and Natural History

At least 20 species of waterfowl (Family *Anatidae* – swans, ducks, and geese) are found on Buzzards Bay waters, far too many to provide here even a brief natural history for each species. It is possible, however, to generalize about these birds. Most are winter residents in southern New England, arriving each fall and returning to northern (often arctic and sub-arctic) breeding grounds each spring. We can distinguish two broad categories of these waterfowl: (1) sea ducks such as Common Eiders (*Somateria mollissima*), Oldsquaw (*Clangula hyemalis*), and White-winged Scoter (*Melanitta fusca*) and (2) estuarine species such as Canada Goose (*Branta canadensis*), Canvasback (*Aythya valisineria*), and Black Duck (*Anas rubripes*). Some species, such as Greater Scaup (*Aythya marila*), spend time in both marine and estuarine environments, but most are faithful to one. The estuarine species tend to feed on benthic plant material in shallow water, diving or just tipping up (dabbling) to reach it, while the sea ducks often congregate near offshore ledges and dive for benthic invertebrates and fish. Blue Mussels are a staple for many of these sea ducks wintering on Buzzards Bay. The natural history of waterfowl is described in mere detail by Pough (1951).

Status and Trends in Buzzards Bay

It is difficult to get a clear and accurate estimate of waterfowl numbers in Buzzards Bay because counts, mostly done from shore with binoculars and telescope, vary greatly with weather (e.g., amount of shoreline ice) and with observer effort and competence. This is especially true for the Audubon Christmas Bird Count, which relies entirely on volunteer bird watchers. Yet these counts have proven useful in providing a broad, semi-quantitative snapshot of waterfowl in the bay. Keep in mind, of course, that even where accurate censuses can be achieved, annual fluctuations in waterfowl numbers may reflect ecological events on distant breeding grounds, rather than changes in the health and productivity of the local waters where these animals winter. Nevertheless, it can be argued that local differences in waterfowl numbers are useful qualitative indicators of productivity within Buzzards Bay. Areas where these birds winter and feed in greatest concentration are likely to have a rich and productive benthos or abundant fish.

Examining local trends in waterfowl numbers during the past two decades (Table 5-7 and Table 5-8), a few species deserve comment. Mute Swan (*Cygnus olor*), for example, are a feral, introduced species that has spread rapidly along

Table 5-7. Total number of waterfowl seen on Lloyd Center winter surveys, 1988 and 1989, along the southwestern shore of Buzzards Bay.

Area	**1988 Jan. 30**	**1988 Dec. 4**	**1989 Jan. 29**
Apponagansett Bay	895	364	422
Nonquitt Marsh	224	240	81
Meadow Shores	20	17	2
Salters Pond	0	66	115
Cow Yard Pond	0	0	6
Little River	105	117	231
Slocums River	596	66	55
Georges Pond	0	76	77
Allens Pond	786	590	960
Westport River	4891	1738	2616

Data from Christiansen et al. (in press).

Table 5-8. Trends in numbers of representative species of waterfowl censused during Christmas bird counts in upper Buzzards Bay – the shoreline from Angelica Point, Mattapoisett to Woods Hole, 1974-1989.

Species	**1974**	**1975**	**1986**	**1988**	**1989**
Mute Swan	56	61	60	59	79
Common Goldeneye	715	1327	837	609	480
White-wing Scoter	273	554	575	198	166
Canvasback	493	818	190	90	123
Black Duck	1009	1477	1243	2024	1761
Brant	0	0	493	29	117

Data from Dick Harlow, Marion, MA, pers. comm.; also published in American Birds, Christmas Bird Count issue for each of the years listed.

the east of southern New England. These large birds feed voraciously on the same rooted aquatics that our native waterfowl need to overwinter. Since the early 1970s Mute Swan numbers have risen dramatically in the southwest portion of the bay (Table 5-9), less so in the upper bay (Table 5-8). Canvasback, by contrast, have dropped noticeably throughout (Table 5-8 and Table 5-9), probably due to drought and less of habitat on their prairie pothole breeding grounds. Black Duck, threatened throughout much of their breeding range by habitat degradation, seem to be holding their own here in Buzzards Bay, and are generally the most numerous waterfowl in level estuarine counts.

The counts do show definite "hotspots" within the bay where waterfowl gather to feed and roost. One of these areas is the Westport River, where at least 300% more waterfowl were seen in recent winter counts than in any other portion of the southwest shoreline (Table 5-7). Allens Pond and Apponagansett Bay were lesser, but important, feeding areas (Table 5-7). In the upper bay, three areas stand out: (1) Piney Point/MA Maritime (Bourne), where nearly all of the upper bay's Brant and about half its Black Duck are counted each winter; (2) outer Sippican Harbor (Marion), where nearly 35% of the Greater Scaup and Goldeneye are found; and (3) Wings Cove (Bourne), where nearly half the Scaup reside in mid-winter (R. Harlow, pers. comm.). In addition, Woods Hole and the neighboring West Falmouth shore held significant concentrations of Common Eider and Oldsquaw Duck. Two areas with potentially large numbers of waterfowl that have not been surveyed are the north shore of the Elizabeth Islands and the shallower portions (ledges) of the central bay. New Bedford Harbor needs better coverage as well.

Management and Research

The Lloyd Center has instituted a model survey for wintering waterfowl along the southwest shore of Buzzards Bay (Table 5-7). Conducted twice each winter, this survey reduces the weather and seasonal biases of the single annual Audubon Christmas count. The Buzzards Bay Project should encourage expansion of this survey to include the entire bay. Data gathered from such expanded surveys would sharpen our estimates of the bay's waterfowl populations, provide useful information for local waterfowl managers – responsible for many of these game species – and warn the coastal ecologist, interested in areas of high productivity within the bay, of large scale changes that may be occurring. In addition, the Lloyd Center's waterfowl database, now just two years old, could be bolstered by adding historical data from the bay's Christmas Bird Counts. If such data were added to files on an area-by-area basis, so that we knew how many of each species were found in each locale during any one count, we could project a time-lapse ecology of Buzzards Bay waterfowl and better determine trends in numbers of different species.

Table 5-9. Trends in numbers of representative species of waterfowl censused during Christmas bird counts in lower Buzzards Bay – the shoreline from new Bedford Harbor to Allens Pond, 1971-1988.

Species	1971	1972	1986	1988
Mute Swan	14	0	65	44
Common Goldeneye	146	506	631	239
White-wing Scoter	283	544	294	46
Canvasback	0	8	18	1
Black Duck	350	419	416	354

Data from Joe Fernandez, Dartmouth MA, pers. comm.; also published in *American Birds*, Christmas Bird Count issue for each of the years listed.

In addition, I think occasional aerial surveys of the bay's waterfowl would be useful. Such surveys could provide coverage of the Elizabeth Islands and offshore ledges, areas currently unsurveyed, and could back up and refine shoreline surveys in other areas. Aerial surveys could be flown at very modest cost.

Finally, the Buzzards Bay Project should encourage better enforcement of waterfowl hunting regulations. In areas such as the Westport River, for example, bag limits and species restrictions are notoriously neglected by hunters (pers. obs.). In addition, the Buzzards Bay Project might encourage a program of Mute Swan control in our region. These feral birds, despite their popularity with the bird-feeding public, are detrimental to our native waterfowl and are likely to continue rapid population growth. At present, there is no hunting season on these birds. Rhode Island has an effective program of swan control on its coastal ponds that could serve as a model for the Buzzards Bay region.

Pollutants

In general, Buzzards Bay waterbirds appear to have suffered little from environmental pollutants. That stated, two exceptions jump to mind: Ospreys and, to a lesser extent, Common Terns. Both species experienced hatching failure due to organochlorine contaminants, but only Ospreys lost enough young to affect subsequent populations of breeding adults.

Ospreys, an apparently abundant breeder along the Buzzards Bay coastline prior to 1950, decreased by more than 50% during the 1950s and 1960s (Poole 1989). Numbers dropped because pairs reproduced poorly; their eggs often broke or failed to hatch. DDT, which thinned shells and killed embryos, was directly implicated (refs. in

Poole 1989). Pesticides-induced mortality of adults was probably a less significant factor in this population decline.

Local use of DDT ceased during the mid to late 1960s (Nisbet and Reynolds 1984), and Osprey reproduction revived about a decade later (Poole 1989). Recent (1979-84) monitoring of contamination in Westport River Osprey eggs showed low levels of DDE (mean = 1.8 ± 1.2 ppm wet wt.), but fairly high PCBs (mean = 18.8 ± 5.8 ppm wet wt.; N = 18) (Poole and Farrington MS). Nevertheless, these Ospreys reproduced at near record levels, with fledging rates as high as Ospreys anywhere in the world. As with many other waterbirds, PCBs apparently have little impact on Osprey reproduction, at least at the levels measured here.

Other studies have found a similar pattern among the waterbirds of Buzzards Bay. During the 1970s, Nisbet and Reynolds (1984) monitored organochlorines in the prey and eggs of Common Terns from Bird and Ram Islands and other coastal MA locations. Early in the 1970s, they found higher levels in Buzzards Bay eggs than in those from elsewhere in the state. They also documented a significant drop in levels during the 1970s, "associated with the declining use of most insecticides during the 1960s, the banning of most uses between 1969 and 1975, and the reduction in discharges of PCBs during the 1970s." At Bird Island, "hatching failure in Common Terns was associated with elevated residues of DDE in one sample, but population effects of DDE were only marginal after 1971". Further testing of local Roseate Terns in 1981 revealed low levels of organochlorines and minimal shell-thinning (Custer et al., 1983). As noted above (Table 5-3), Bird Island terns have grown significantly in number since 1970. Recently (1988-89), however, several Roseates with high levels of PCBs in body tissue have been picked up dead on Bird Island; Roseates and other terns sometimes feed in nearby New Bedford Harbor (I. C. T. Nisbet, pers. comm.). Because the Bird Island population is closely monitored, however, this worrisome trend will no doubt be followed.

To my knowledge, no other Buzzards Bay bird has been analyzed for pollutants. Black-crowned Night Herons from nearby Martha's Vineyard, however, showed generally low levels of organochlorines in eggs during the late 1970s; despite marginally reduced hatching rates, these birds produced young at very close to normal levels for the species (Ohlendorf et al., 1978). Individuals foraging closer to New Bedford Harbor, of course, might fare very differently.

References

AOU (American Ornithologists Union). 1983. Check-list of North American birds, 6th ed. Allen Press, Inc., Lawrence, Kansas. 877 pp.

Bent, A. C. 1937. Life histories of North American birds of prey order Falconiformes (Part 1). US Natl. Museum Bull. 167.

Blodget, B. G. (ed.). 1980-1989. MA tern inventory. MA Dept. Fisheries & Wildlife.

Blodget, B. G. 1988. The half-century battle for gull control. Massachusetts Wildlife 38(2): 4-10.

Burger, J. 1978. The pattern and mechanism of nesting in mixed-species heronries. In: Audubon Research Report No. 7 (A. Sprunt et al. (eds.). Natl. Audubon Society, New York.

Christiansen, D., J. O. Hill, M. J. Mello. in press. Lloyd Center estuarine winter waterfowl census. Bird Observer of Eastern MA. [JEC: Subsequently, Hill, J. O., and M. J. Mello. October 1993, Bird Observer Vol. 21, No. 5]

Crowell, E. M and S. Crowell. 1946. The displacement of terns by Herring Gulls at the Weepecket Islands. Bird-Banding 17: 1-10.

Custer, T. W., I. C. T. Nisbet, and T. W. Krynitsky. 1983. Organochlorine residues and shell characteristics of Roseate Terns, 1981. J. Field Ornithol. 54: 394-400.

Drury, W. H. 1973-1974. Population changes in New England seabirds. Bird-banding 44: 276-313 and 45: 1-15.

Duffy, D. C. 1986. Foraging at patches: interactions between Common and Roseate Terns. Ornis Scand. 17: 47-52.

Erwin, R. M. and C. E. Korschgen. 1979. Coastal waterbird colonies: Maine to Virginia, 1977. An atlas showing colony locations and species composition. U. S. Fish & Wildlife Service, Biological Services Program, FWS/OBS-79/08.

Forbush, E. H. 1925. Birds of Massachusetts and other New England states. MA Dept. of Agriculture.

Gochfeld, M. 1983. Colony site selection by Least Terns: physical attributes of sites. Colonial Waterbirds 6: 205-213.

Griscom, L. and D. E. Snyder. 1955. Birds of Massachusetts, Peabody Museum, Salem, MA.

Hatch, J. J. 1983. Diet of an expanding population of Double-crested Cormorant. (abstract) Colonial Waterbirds 6: 71.

Hatch, J. J. 1984. Rapid increase of Double-crested Cormorants nesting in New England. American Birds 38 (6): 984-988.

Nisbet, I. C. T and L. M. Reynolds. 1984. Organochlorine residues in Common Terns and associated estuarine organisms, Massachusetts, USA 1971-1981. Marine Environmental Research 11: 33-66.

Nisbet, I. C. T. 1973a. Terns in Massachusetts: present numbers and historical changes. Bird-banding 44: 27-55.

Nisbet, I. C. T. 1973b. Courtship-feeding, egg size, and clutch size in Common Terns. Nature 241: 141-143.

Ohlendorf, H. M., E. E. Klaas, and T. E. Kaiser. 1978. Environmental pollutants and eggshell thinning in the black-crowned Night Heron. In: Audubon Research Report No. 7 (A. Sprunt et al., eds.). Natl. Audubon Society, New York.

Poole, A. F. 1989. Ospreys: a natural and unnatural history. Cambridge University Press. 250 pp.

Pough, R. H. 1951. Audubon water bird guide. Doubleday & Co. 352 pp.

Ryder, R. A. 1978. Breeding distribution, movements, and mortality of Snowy Egrets in North America. In: Audubon Research Report No. 7 (A. Sprunt et al., eds.). Natl Audubon Society, New York.

Safina, C., J. Burger, M. Gochfeld, and R. H. Wagner. 1988. Evidence for prey limitation of Common and Roseate Tern reproduction. Condor 90: 852-859.

Spendelow, J. A., and S. R. Patton. 1988. National atlas of coastal waterbird colonies in the contiguous USA: 1976-1982. US Fish and Wildlife Serv. Biol. Report 88 (5)/

USFWS (US Fish and Wildlife Service). 1989. Roseate Tern Recovery Plan - Northeast Population. USFWS, Newton Corner, MA 78 pp

.

6. Mammals of Buzzards Bay

By P. Michael Payne[7], Colleen Coogan[8], Fred Wenzel[9], Mary Ann Buehler[10], and Alan L. Hankin[11].

Introduction

Buzzards Bay is bordered by the mainland of Massachusetts on the north and northwest, and Cape Cod and the Elizabeth Islands to the east and southeast. It opens to Rhode Island Sound to the southwest forming a natural cul-de-sac. This natural geographical entrapment results in a reduced, albeit diverse, seasonal fauna of marine mammals. The objectives of this report are as follows:

1) To provide a species account (and data sources) and natural history of the marine mammals and turtles which have been observed or which have stranded in Buzzards Bay.

2) To describe the spatial and temporal distribution, and abundance, of all the marine mammals and turtles found in Buzzards Bay relative to the population status of each species in the shelf waters of the northeastern United States, with emphasis on the Gulf of Maine and southern New England regions.

Methods

To obtain the information presented in this synthesis we surveyed readily available, relevant published works, including scientific papers, books, reports, and popular articles. We also examined some periodical literature, notably newspaper clippings. Stranding reports and personal logs or records provided the most useful information on the diversity of species that have occurred within the Buzzards Bay study area.

Published Literature Surveys

Cetaceans

Since 1978, two-large-scale surveys have provided estimates of abundance, and temporal/spatial distribution patterns of cetaceans in the shelf waters of the northeastern United States north of Cape Hatteras, North Carolina. The Cetacean and Turtle Assessment Program (CeTAP), University of Rhode Island, provided the first quantitative estimates of cetaceans by season and region in this study area (see CeTAP 1982 for greater detail). This series of aerial surveys occurred from November 1978 through December 1981 and the results have been published in a series of reports and manuscripts.

Since May 1980, the National Marine Fisheries Service, Northeast Fisheries Center (NMFS/NEFC) has placed an observer onboard NMFS/NEFC research vessels conducting standardized fisheries-plankton surveys in shelf and shelf-edge waters of the northeastern United States. The observers, using standardized line transect methodologies, have continuously recorded marine mammal and seabird sightings along the cruise track of the vessel (Payne et al., 1984). These shipboard surveys were designed to provide NMFS/NEFC with a long-term, continuous assessment of the distribution and abundance of cetacean and seabird populations, which can be compared directly to the distribution of fish stocks by region and season (see Payne et al., 1984; Smith et al., 1988 for greater detail).

Published data are also available from cetacean surveys conducted generally within Cape Cod Bay (Mayo 1982; Mayo et al., 1988; Watkins and Schevill 1982; Schevill et al., 1981, 1986). Sighting data and information from these surveys were also used when the information furthered the discussion relative to Buzzards Bay.

There has not been any cetacean survey conducted specifically within the waters of Buzzards Bay. However, the CeTAP and NMFS/NEFC programs stratified the shelf waters of the northeastern United States into regions, each having its own characteristic oceanographic features and species assemblages. The Buzzards Bay study area is located between the base of the Gulf of Maine (including Cape Cod Bay) and the southern New England (including eastern Long Island Sound) regions. Therefore, the seasonal occurrence and movements of the cetacean fauna represented within Buzzards Bay can be best described from stranding data, and from the sighting data and published results of surveys that have occurred in each of the adjoining, larger regions.

Pinnipeds

Since 1980, the Manomet Bird Observatory has conducted a harbor seal research program throughout southern New England (south of Maine) focused on the distribution, abundance and selected prey of seals in this region. During January and February, 1983-1986, Payne and Selzer (1989)

---

[7] Manomet Bird Observatory, Manomet, MA. Accepted January 31, 1991.

[8] National Marine Fisheries Service, Northeast Regional Office, Gloucester, MA

[9] Plymouth Marine Mammal Research Center, Plymouth, MA

[10] New England Aquarium, Boston, MA

[11] Lloyd Center for Environmental Studies, So. Dartmouth, MA

conducted aerial surveys from the Isles of Shoals on the Maine-New Hampshire border to the Massachusetts-Rhode Island border. Relevant survey data (that applying to Buzzards Bay and the Elizabeth Island chain) have been incorporated into this report.

In addition, since 1986 personnel from the Lloyd Center for Environmental Studies have conducted two forms of seal surveys in the immediate Buzzards Bay study area:

Near-weekly surveys of Gull Island and Pease ledge (a low tide rock outcropping between Gull Island and Cuttyhunk Island) have been conducted by vessel during November-May, 1986-1989.

Weekly counts of harbor seals were also conducted on the northwest (mainland) side of Buzzards Bay between January-April 1986 and March-April 1989.

These unpublished data have been collected in a systematic manner, generally, as part of an undergraduate requirement, or a volunteer-based research effort, and can be used to monitor the abundance of seals in the immediate area (similar to Payne and Schneider 1984). These data, combined with the results of Payne and Selzer (1989) provide a near continuous index of harbor seal abundance in Buzzards Bay since 1933.

Turtles

The CeTAP surveys provide the only detailed quantitative information on the abundance and seasonal/temporal distribution of marine turtles in the shelf waters of the northeastern United States. The results of these surveys are provided in Shoop et al. (1981) and CeTAP (1982).

Periodical Literature

Newspaper articles or private journals have also been cited where the information would further the discussion. The use of newspaper clippings is generally limited to anecdotal statements, or as a possible verification of sighting or stranding if the information is not available in a literature source.

Stranding Programs

There have been several stranding networks on the eastern coast of the United States since the mid-1970s, all of which have reported marine mammal and sea turtle strandings.

The National Museum of Natural History (Smithsonian Institute) has recorded all strandings and unusual phenomenon reported to them under the Scientific Event Alert Network (SEAN). This network has been modified, since its beginnings and several name changes have occurred prior to the 1980s. Information published in these reports (primarily cetacean strandings) has been included in this report.

The New England Aquarium (NEA), Boston, Massachusetts has also operated a marine mammal and sea turtle stranding and salvage program since the mid-1970s. Their records provide information on all strandings or beached animals north of Long Island Sound. The marine mammal stranding data eventually became incorporated into the SEAN reports, therefore we were careful not to duplicate any stranding records from the two separate networks. The sea turtle strandings recovered by the NEA network become incorporated into a National Marine Fisheries Service/Southeast Fisheries Center Sea Turtle Stranding and Salvage Network (STSSN). This network is the repository for all turtle sighting and stranding data along the east coast of the United States and the Gulf of Mexico.

Strandings are often listed by latitude-longitude, as well as common-name location (e.g. Buzzards Bay, Monument Beach, and Horseneck Beach). We have tried to provide as much information on the location of the stranding as the combined information allows.

Strandings of harbor seals have not been discussed in this report. The number of strandings of this species throughout New England has increased concurrent with an overall increase in abundance of this species throughout New England (Payne and Schneider 1984). We have restricted any discussion of harbor seals in Buzzards Bay to known levels of seasonal abundance, and haulout locations.

Results and Comparisons

The Comparison of Known Cetacean High-Use Habitats Relative to Buzzards Bay: An Overview

The Buzzards Bay study area is not considered a high-use cetacean habitat (as defined by Kenney and Winn 1986). Preferred or high-use habitat (areas of greatest density, animals/km^2) for cetaceans have been described by CeTAP 1982 Haim et al., 1985; Kenney and Winn 1986; Payne et al., 1984, 1986; Selzer and Payne 1988). The greatest concentrations of baleen whales occur in the southwest Gulf of Maine, spring through fall. The southwest Gulf of Maine includes waters from Jeffreys Ledge and Stellwagen Bank south along the 100-meter contour outside Cape Cod to, and including, the Great South Channel. Species that characterized this area are primarily piscivorus, and include the humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*) and minke (*B. acutorostrata*) whales, and white-sided dolphin (*Lagenorhynchus acutus*) (Kenney et al., 1981 Kenney and Winn 1986; Mayo 1982; Payne et al., 1986, 1990a).

The central basin of the Great South Channel (water depths generally >100 meters) is also a center of the Northern right whale (*Eubalaena glacialis*) distribution in the spring (Brown and Winn 1989; Kraus 1985; Kraus et al., 1986;

Winn et al., 1986; Wishner et al., 1988). The right whale subsists primarily on dense swarms of calanoid copepods, notably *Calanus finmarchicus*, in the North Atlantic (Kenney et al., 1986; Winn et al., 1986; Wishner et al., 1988).

A second important region for cetaceans is along the edge of the continental shelf (CeTAP 1982; Hain et al., 1985; Kenney and Winn 1987). This cetacean community is much more diverse than the Gulf of Maine community, and consists primarily of toothed whales (the sperm whale [*Physeter macrocephalus*], pilot whales [*Globicephala* spp.], grampus [*Grampus griseus*], bottlenose [*Tursiops truncatus*], common [*Delphinus delphis*], striped [*Stenella coeruleoalba*], and spotted dolphins [*S.* spp.]). The species more characteristic of the Gulf of Maine are also observed in this region, but less frequently.

Although spatially disjunct, the high-use areas of the southern Gulf of Maine and along the shelf-slope edge have at least one common physical characteristic that sets them apart from Buzzards Bay; they are both areas of high bottom-relief. Hui (1979, 1985) formulated a Contour Index (CI) that describes the degree of bottom relief or slope within a specified area. The CI incorporates, into a single number, both the change in depth and the maximum depth of a given unit area, thereby representing a percent change in depth in the sample area. The CI ranges from 0.00 (no slope or uniform depth) to 99.99 (maximum change in depth within an area) and any CI value >80 characterizes an area as having a high degree of bottom-relief. The areas described by Kenney and Winn (1986) and Payne et al. (1984) as high-use habitat all have CI values >80.00. Selzer and Payne (1988) demonstrated that the white-sided dolphin (primarily a Gulf of Maine species) and the common dolphin (a midshelf to shelf-edge species) occupy ecologically similar habitat (similar CI values) within their respective ranges. Few cetacean species occupy regions of little or no bottom contour. The exceptions to this are primarily for plantiverous species (such as the right whale) whose principal prey (copepods) are concentrated by currents within or adjacent to central portions of basins (Winn et al., 1986; Wishner et al., 1988), rather than along more high-energy areas (such as the edges of banks, or shelf-edges).

Buzzards Bay Contour-Index Relative to Cetaceans

The maximum depth within Buzzards Bay is approximately 30 meters (north of Cuttyhunk Island). An approximate CI value for the central portion of Buzzards Bay is calculated

$$CI = \frac{\text{approximate maximum} - \text{functional minimum depth}}{\text{approximate maximum depth}}$$

or

CI = (30m - 10m)/(30m)

as follows,

with a resulting Contour Index = 66.00, or an area of medium bottom relief. The Buzzards Bay CI value indicates that within the mid portion of Buzzards Bay (north of Cuttyhunk Island), there are few rapid changes in depth. Intuitively, the correlation between the distribution of cetaceans and sea floor relief is related through links in the food web; i.e. mesoscale oceanographic features that affect prey distribution are important to the distribution of cetaceans although it is unlikely that these relationships are strictly causal. Rather, factors that concentrate prey may secondarily affect the distributions of Cetacea. Feeding by cetaceans in areas where prey are concentrated would improve foraging efficiency, thus whales and dolphins would be expected to aggregate in such areas.

The absence of large concentrations (or even lesser concentrations) of whales and dolphins in Buzzards Bay (both historically and at present) likely reflect the absence of any topography or oceanographic features which tend to concentrate prey. Therefore Buzzards Bay (independent of any other physical variables (e.g. a shallow mean depth), is not considered a high-use area for baleen whales and dolphins because it lacks the oceanographic features which indirectly control the feeding distribution of cetacea.

However, Buzzards Bay is adjacent to major feeding locations (e.g. Stellwagen Bank-Cape Cod Bay, the Great South Channel, and Cox Ledge-eastern tip of Long Island). Because of this close proximity to whale concentrations, a number of cetacean species have been observed within the boundaries of the bay, either as seasonal transients generally moving into preferred feeding locations, or as strandings. The following is an account of those species that have been documented within Buzzards Bay.

Species Accounts

Fourteen species of cetacean and two species of pinniped (the harbor seal [*Phoca vitulina]* and gray seal

[*Halichoerus grypus]*) have been observed, or have stranded within the Buzzards Bay study area. Also four species of marine turtle (the leatherback [*Dermochelys coriacea]*, loggerhead [*Caretta caretta*], hawks-bill [*Eretmochelys imbricata]*, and the Kemp's or Atlantic ridley *[Lepidochelys kempi*]) have been reported within Buzzards Bay. The Kemp's ridley, because of its critical status, recent, significant population declines, and the real potential that Buzzards Bay, historically, was and possibly remains an important foraging area for juvenile ridleys, is discussed in some detail.

Cetaceans

Baleen Whales (Family Balaenopteridae and Balaenidae)

Fin Whale (*Balaenoptera physalus*)

The fin whale is present in coastal Massachusetts waters year around. The two regions of greatest fin whale abundance in the Gulf of Maine-coastal Massachusetts waters occurs along a corridor from the Great South Channel (southeast of Nantucket) north along the 100 meters contour outside of Cape Cod to Jeffreys Ledge, and from Montauk Point, Long Island, eastward (over Cox Ledge) to south of Gay Head, Martha's Vineyard (Hain et al., 1981; CeTAP 1982; Payne et al., 1984). Since the mid 1970s sandlance has been a principal prey of baleen whales in both of these feeding locations. Both of these feeding areas extend into shallower waters seasonally. During March-April and then again in late summer to mid-autumn, the seasonal movements of fin whales bring them into the vicinity of the Buzzards Bay study area. Historically, Atlantic herring (*Clupea harengus*) and Atlantic mackerel (*Scomber scombrus*) have also been important prey of fin whales in this region as indicated by the following excerpt from Allen (1916):

> *1874. During the latter half of October in this year "large schoo1s of whales" (probably mostly Finbacks) were reported seen from Noman's Land, Gay Head, and Cuttyhunk, Mass. "In Vineyard Sound large numbers were seen near the shores and the lightboat off Sow and Pigs. On October 23rd, ten were seen at one time. One, a Finback, was shot with a bomblance near Cuttyhunk. In all four were shot, but they sunk and were not recovered. It was said that the great shoals of herring then in the Sound spawning had attracted the whales.*

Fin whales have washed ashore on Cuttyhunk Island and Nomans Land, and they have been observed below Cuttyhunk west to below Narragansett Bay; however, fin whale sightings within Buzzards Bay are considered uncommon to rare.

Fin whales are likely limited by the physical characteristics of Buzzards Bay. Although they have been observed in water depths from 27 to >2000 meters (average 149 meters) and in water temperatures ranging from 60° to 22. 6°C (average 12.8), the average depth at sighting (149m from CeTAP 1982) is significantly greater than that found within Buzzards Bay. It is also likely that prey concentrations and availability in Buzzards Bay are not sufficient enough (when compared to other locations) for this species to forage in an energetically efficient manner. Therefore, Buzzards Bay is not considered an important area for fin whales.

Minke Whale (*B. acutorostrata*)

The distribution of minke whales has been described (by CeTAP 1982) as a large "U" which extends from Montauk Point southeast to Nantucket Shoals then northward through the Great South Channel, along the outside of Cape Cod north to Jeffreys Ledge. This is very similar to that of the fin whale except that more emphasis is placed on the area between Montauk Point to below Nantucket Shoals.

The range of this species expands north into the Gulf of Maine into the summer and contracts mid-winter. Minke whale sightings occur regularly between Block Island and Gay Head, Martha's Vineyard and from September to November minke whales have been observed below and west of Cuttyhunk Island (waters generally >30 meters) (Hain et al., 1981; CeTAP 1982; Payne et al., 1984) Since they are present throughout coastal Massachusetts (and adjacent islands) waters year round, it seems very possible that a few individuals are present below and west of Cuttyhunk throughout winter, but not detected. Their occurrence in Buzzards Bay appears irregular and transient during late-spring and summer. The inherent difficulty in detecting this whale (due to its small size and lack of a distinctive exhalation or "spout" during surfacing sequences) makes its occurrence during the remainder of the year difficult to determine.

Minke whales have not been reported within the central portions of the bay although it is unlikely that the physical characteristics of Buzzards Bay are limiting to this species. Minke whales have been observed in waters depths as shallow as 3 meters (CeTAP 1982) and depth at sighting <20 meters is not atypical. However, limited prey concentrations would restrict the occurrence of this species on a year round basis. Therefore, this species does have a seasonal occurrence near Cuttyhunk Island but, generally, Buzzards Bay is not considered an important area for minke whales.

Humpback Whale (*Megaptera novaeangliae*)

The largest feeding aggregations of humpback whales in the shelf waters of the northeastern United States also occur in the southwest Gulf of Maine from the Great South

Table 6-1. Right whale sightings in Buzzards Bay and immediately adjacent waters, 1955-1980 (source: Schevill, et al. 1981).

Number	Date	Location and Comments
6	3-6 April 1956	Between Quicks Hole and Menemsha Bight (multiple sightings)
3	April 1958	Quicks Hole
1	25 March 1959	1.3 mi northwest of Gay Head, between Gay Head and Cuttyhunk
3	April 1959	Between Quicks Hole and Menemsha Bight
1	April 1959	Between Quicks Hole and Menemsha Bight (multiple sightings)
1	28 March 1961	North of Menemsha
1	29 March 1961	Menemsha Bight
2	4 April 1961	Menemsha Bight
1	9 April 1961	Menemsha Bight
1	11 May 1973	Off Cuttyhunk Island
1	8 May 1973	Gay Head
2	28 June 1975	1 mi south of Cuttyhunk Island
2	4 July 1975	courtship display, off Menemsha Bight

Channel north along the 100-meter contour to Stellwagen Bank and Jeffreys Ledge (Kenney et al., 1981; CeTAP 1982; Mayo et al., 1985; Payne et al., 1984). The distribution of humpback whales within that region has been dependent upon the spatial distribution of sandlance (Kenney et al., 1981; Payne et al., 1986, 1990a), their preferred prey in the southwest Gulf of Maine (Overholtz and Nicolas 1979; Hain et al., 1982; Mayo 1982; Mayo et al., 1988), since the mid 1970s. Although one humpback whale was observed on 27 August 1981 west of Naushon Island (by an MBO observer aboard the NMFS/NEFC research vessel DELAWARE II), Buzzards Bay does not appear to be a preferred area for humpback whales. The humpback seems to require dense aggregations of prey over areas of rugged floor relief, in order for foraging to remain energetically advantageous to this species (as suggested by Payne et al., 1986). The gradually sloping bottom profile of Buzzards Bay is not characteristic of humpback whale foraging areas.

Right Whale (*Eubalaena glacialis*)

It is generally considered by all that the right whale represents that most seriously threatened large whale species in the North Atlantic. Current estimates for the northwest Atlantic generally range between 300-400 individuals (Winn et al., 1981; CeTAP 1982; Kraus 1985; Kraus et al., 1982, 1986; Winn et al., 1981, 1986). Despite this low abundance, their seasonal distribution in the Gulf of Maine-southern New England regions is well documented and aggregations of right whales may be observed in several locations adjacent to the Buzzards Bay study area. During spring (late February-May) the Great South Channel and Cape Cod Bay are consistently inhabited by this species (Brown and Winn 1989; Kraus 1985; Winn et al., 1986; Wishner et al., 1988) where social behavior and has been observed. The copepod, *Calanus finmarchicus*, is the preferred prey of right whales in the western North Atlantic. From June through October the center of the right whale distribution generally moves northward in the vicinity of the Bay of Fundy and the southern Scotian shelf (Arnold and Gaskin 1972; Kraus et al., 1982; Kraus 1985; Mitchell et al., 1986; Stone et al., 1988; Munson and Gaskin 1989). The only recorded exceptions to this seasonal pattern occurred during the early 1970s (Watkins and Schevill 1979) and in 1986 (Payne et al., 1990b) during periods of low finfish biomass in local areas of Cape Cod Bay-Stellwagen Bank and regional copepod maximums (Wishner et al., 1988; Payne et al., 1990b).

Between December and February at least part of the population overwinters along the coast from North Carolina to Florida (Kraus et al., 1986). However, small numbers of right whales have also been observed in waters of the lower Gulf of Maine (Reeves et al., 1978; Schevill et al., 1981; Watkins and Schevill 1982; Mayo 1982) including Cape Cod Bay and adjacent areas. Right whales have been observed swimming in the immediate waters of Buzzards Bay and through the Cape Cod Canal, although dates and specific information are not readily available (William A. Watkins, WHOI, pers. comm.).

Right whales have traditionally been considered coastal and historically were the focus of shore-based whaling in the Cape Cod Bay-southern New England regions (Allen 1916; Little and Andrews 1982). These inshore sightings generally correspond to known movement patterns of right whales around the eastern tip of Long Island (Reeves and Mitchell 1986), and into southern New England waters by mid-spring. Seasonal right whale movements take at least a part of the population across the entrance to Buzzards Bay at this time. Right whales have been frequently observed between Cuttyhunk and Gay Head-Menemsha Bight area of Martha's Vineyard from March to May during the spring movement northward (Table 6-1). At this point these animals generally move eastward, either below Nantucket Island or through Nantucket Sound, toward the Great South Channel. Movements of right whales into and through

Table 6-2**.** Known strandings of cetaceans in Buzzards Bay by Species, number stranded, date, location (latitude-longitude where available and common place name, and reference (accession location and number)[1]

Species	Number	Date	Reference	Location
Common Dolphin (*Delphinus delphis*)				
	1	March 13, 1967	Marion	MC051913
	1	July 17, 1974	Buzzards Bay	00504107
	1	June 6, 1975	N. Falmouth	00550041
	1	February 12, 1976	Cuttyhunk	SEA N1047
	1	January 25, 1983	Fairhaven	MME00477
	1	December 22, 1985	Falmouth (Old Silver Beach)	MME-01355
	1	April 29, 1986	Falmouth (Old Silver Beach)	MME02125
	1	September 26, 1986	N. Falmouth	MME02117
Grampus (*Grampus griseus*)				
	1	September 9, 1983	N. Falmouth	MME0726
	1	September 21, 1989	N. Falmouth	NEA
White-sided Dolphin (*Lagenorhynchus acutus*)				
	1	September 28, 1951	Buzzards Bay	Waters and Rivard (1962)
	1	July 5, 1975	Pasque Island	USNMNH-00504292
	1	April 28, 1976	Marion	SEAN 1084
	1	June 1986	Cuttyhunk	STR 05170
Killer Whale (*Orcinus orca*)				
	1	August 6, 1986	Nomans Island	MME-01745
	1	July 8, 1989	Dartmouth	NEA-MH89-515
Striped Dolphin (*Stenella coeruleoalba*)				
	1	February 13, 1974	N. Falmouth (41º33' 70º37')	00504080
	1	January 22, 1960	Buzzards Bay	Harvard MCZ-#49. 633 (skull only)
	1	January 10, 1963	Marion	MC-051763
	1	September 19, 1975	Wareham	00550043
Bottlenose Dolphin (*Tursiops truncatus*)				
	1	October 5, 1956	Buzzards Bay (Penzance Point)	MC048565
Pilot Whale (*Globicephala melaena*)				
	45	September 30, 1907	Monument Beach	CCMNH
	1	September 6, 1944	Marion	W. F. Nye
	1	December 28, 1951	Buzzards Bay	Waters and Rivard (1962)
	3	Winter 1952	Pocasset	CCMNH
	1	May 23, 1964	Fairhaven	New Bedford Standard Times
	1	July 16, 1966	Horseneck Beach	New Bedford Standard Times
	1	1973	Cuttyhunk	STR-02556
	1	November 30, 1977	Nashawena	SEAN2424
	1	December 15, 1978	Woods Hole (Faye Beach)	SEAN-3439
	1	January 25, 1979	Fairhaven (41º37' 70º52')	SEAN-4007
	1	April 23, 1980	Nashawena	SEAN-5138
Harbor Porpoise (*Phocoena phocoena*)				
	1	December 11, 1986	Pasque Island	MME-02009
	1	December 11, 1986	Woods Hole	MME-02119
	1	January 9, 1989	Westport	NEA-MH89-412

1 References:
NEA: New England Aquarium, Boston, MA
W. F. Nye: William F. Nye Company, New Bedford, MA file records.
CCMNH: Cape Cod Museum of Natural History.
All other references refer to file collections at the National Museum of Natural History, Washington, DC

Buzzards Bay are considered transient and resident time is generally considered a few days or less.

Dolphins (Family Delphinidae)

In the shelf and shelf-edge waters of the northeastern United States dolphin spp., and harbor porpoise (*Phocoena phocoena*) distribution patterns have been separated by physical oceanographic characteristics (Edel et al., 1981; Hain et al., 1985; Selzer and Payne 1988) and were considered by Hain et al. (1981) to be of three basic types as follows:

Type I. Represented by a single species, the harbor porpoise. The distribution is widespread throughout the Gulf of Maine, waters in the vicinity of Cape Cod *and over western Georges Bank. This distribution does not appear to extend southwest beyond Nantucket.*

Type II. Represented by several species of baleen whales, but by only one common odontocete, the white-sided dolphin (Lagenorhynchus acutus). This distribution is widespread throughout the entire Gulf of Maine-Georges Bank regions. There are also more scattered sightings south to Cape Hatteras than found in the Type I species. While some of the whales are sighted along the shelf edge at times, the general tendency of this type is to occupy the shelf proper.

Type III. The general pattern for the remainder of the odontocetes is from mid-shelf to shelf-edge and slope waters. Several of the species have nearshelf seasonal movements, but generally, there is a linear distribution along the shelf-edge from the southern edge of Georges Bank south to Cape Hatteras.

Generally, dolphin species are found in areas of high bottom-relief, which potentially concentrate prey species (independent of Hains distribution patterns). Therefore, for reasons similar to those already discussed for baleen whales, Buzzards Bay is not considered a year-round high-use area (as defined by Kenney and Winn 1986) for any species of dolphin.

Species which have been observed or stranded in Buzzards Bay, and which belong to Distribution Types I and II (species whose normal range might include Buzzards Bay), are the white-sided and white-beaked (*L. albirostris*) dolphins, and the harbor porpoise.

White-beaked Dolphin (*Lagenorhynchus albirostris*) and White-sided Dolphin (*L. acutus*)

Two species of *Lagenorhynchus* dolphins occur in shelf waters of the Gulf of Maine, white-beaked and white-sided dolphins.

White-beaked dolphin are considered the more northerly of the two *Lagenorhynchus* species. Within the Gulf of Maine, most sightings occur in the southwest Gulf of Maine, generally north of Cape Cod Bay (CeTAP 1982). Sixty-eight percent of all sightings by (CeTAP 1982) also occurred between November-April. Although most sightings occur east of Nantucket northward along the outside of Cape Cod to Jeffreys Ledge, several sightings have also occurred between Martha's Vineyard and the Elizabeth Island chain, and on 6 June 1979 five white-beaked dolphin were observed inside Buzzards Bay (CeTAP 1982). This species has not stranded inside Buzzards Bay.

The white-sided dolphin is presently the more common of the two *Lagenorhynchus* species and the most abundant dolphin in the Gulf of Maine (Scott et al., 1981). However, it is apparent that the distribution of this species has changed significantly during the past several decades. The first confirmed report of white-sided dolphin from Cape Cod was by Schevill (1956) and it is generally agreed that the white-beaked dolphin was the more abundant *Lagenorhynchus* species during the mid 1950s. An increase in sightings of white-sided dolphin from the Gulf of Maine north to the Gulf of St. Lawrence combined with an increase in the number of mass strandings (Sergeant et al., 1980) and incidental takes (Katona et al., 1978) during the 1970s support a recent increase in abundance of this species in shelf waters. Prior to the 1970s, there were no reported mass strandings of this species.

The present center of the distribution of white-sided dolphin is in the southwest Gulf of Maine-Great South Channel regions where they are abundant year around (CeTAP 1982; Payne et al., 1984; Selzer and Payne 1988). During mid-summer to October, this distribution expands northward to the Bay of Fundy and into the central portions of the Gulf of Maine. During mid-winter large aggregations of white-sided dolphin are found in the Hudson Canyon, and their range continues southward to at least the mouth of the Chesapeake Bay (Testaverde and Mead 1980).

Since white-sided dolphin are the most common delphinid throughout the Gulf of Maine-southern New England regions, they are potentially present in the Buzzards Bay study area in all seasons. However, given the lack of any apparent seasonality to the strandings which have occurred for this species in Buzzards Bay (Table 6-2) and the absence of any reported sightings, we conclude that white-sided dolphin are in Buzzards Bay only in low numbers for short periods of time.

Pilot Whale (*Globicephala melaena*)

The distribution of pilot whales generally follows the shelf edge between the 100-meter and 1000-meter contour from Cape Hatteras (3°00N latitude) to the northeastern portion of Georges Bank (CeTAP 1982; Payne et al., 1984; Waring et al., 1990). However, seasonal intrusions occur onto the shelf during fall. At this time, the largest concentrations of pilot whales occur generally along the southwestern edge of Georges Bank and into the Great South Channel.

It is between October and December that the distribution of pilot whales is the most widespread throughout the Gulf of Maine-Cape Cod Bay regions. It is also during this period that the inshore, southern movement of pilot whales (generally combined with a gale-force wind from the northeast) has resulted in all of the mass-strandings on Cape Cod between 1981 and 1986 (data from Greg Early, New England Aquarium, reported in Waring et al., 1990). Seven of the ten strandings within Buzzards Bay (from Table 6-2) have also occurred September through January. One mass stranding occurred in Buzzards Bay in 1907

(Table 6-2). Some of the individuals from this event, as well as the pilot whale which stranded in Marion in 1940 (from Table 6-1) were taken to the William F. Nye Company in New Bedford and processed for oil as part of the shore-based New England "blackfish fishery" (records from the William F. Nye Company).

Killer whale (Orcinus orca)

Katona et al. (1988) summarized known sightings and strandings of killer whales in the North Atlantic during this century (through 1987) from the Bay of Fundy south to the equator. In the western Gulf of Maine, killer whales are most commonly reported between mid-July and September from the Stellwagen Bank-Cape Cod regions (Katona et al., 1988). They are thought to follow schools of bluefin tuna (*Thunnus thynnus*) which move into these waters during late summer as part of their annual migration.

During the period reviewed by Katona et al., there were no recorded strandings or sightings within Buzzards Bay although one stranding did occur on Nomans Land 6 August 1986 (original source MMEP-01745) and several were reported on Nantucket and within Martha's Vineyard-Nantucket Sound. Since 1986, one stranding has occurred within Buzzards Bay on 8 July 1989 (Table 6-2).

Other Delphinidae spp.

Four other species of delphinids, the bottlenose dolphin (*Tursiops truncatus*), the common dolphin (*Delphinus delphis*), and two species of Stenella (*S. coeruleoalba* and *S. plagiodon*) have stranded within the boundaries of Buzzards Bay. All of these species have a mid-shelf (depth >50 meters) to shelf-edge (>100 meters) distribution north of Long Island (Type III from Ham et al., 1981) and are considered stragglers, uncommon to rare, in Buzzards Bay.

The bottlenose dolphin is common between the 100 meter and 500 meter contours from southeast of Long Island along the southern edge of Georges Bank from March to October (CeTAP 1982; Payne et al., 1984). During late summer and fall their range extends onto the shelf east of Long Island to south of Martha's Vineyard. The northward extension onto the shelf generally follows water temperature increases to above 20°C. They have been observed at the eastern entrance to Long Island Sound during this time and it is at this time that the distribution of this species comes closest to the southern edge of Buzzards Bay. Although sightings and strandings have occurred in the Gulf of Maine (Mairs and Scattergood 1958; MBO data, unpublished), they are considered a rare straggler into Buzzards Bay.

Common dolphin are present in a broad band from mid-shelf seaward throughout shelf waters of the northeastern United States (especially north of 39º00" N latitude) throughout the year. Within this broad range, they have pronounced seasonal/regional shifts in distribution. From March through June, they are the most widespread. During mid-summer common dolphin move northeast onto the Scotian Shelf resulting in a decreased abundance in southern New England-Georges Bank regions (Kenney et al., 1981). From October through December, common dolphin again move southward onto Georges Bank, and continue to move southwest into southern New England waters. During November-December their distribution is notably inshore from their spring, mid-shelf to shelf edge distribution and common dolphin are abundant from Montauk Point to below Cuttyhunk and Martha's Vineyard. Again, in March through June (during the northward spring movement) common dolphin are abundant in this region.

Given the widespread abundance of common dolphin throughout most of the year, the unlikely occurrence or an occasional stranding within Buzzards Bay can occur during any season. This is apparent in the stranding record (Table 6-2). Eight strandings have been recorded in the study area, each in different months.

Within southern New England-Georges Bank waters, striped dolphin are generally found in large aggregations only along the shelf-edge waters (generally >200 meters). Although striped dolphin strandings are fairly frequent inside Cape Cod Bay, the Gulf of Maine is not considered their preferred habit. The average depth at sighting for this species (from CeTAP 1982) was 2076m. At no time does their distribution approach Buzzards Bay. The stranding events of striped dolphin are seasonal (September through January) and follow a tendency for striped dolphin to follow warm water intrusions (Gulf Stream influenced) onto regions of the shelf, normally considered outside their normal range.

Dolphins (Family Monodontidae)

Beluga (*Delphinapterus leucas*)

One beluga was observed at the Buzzards Bay entrance to the Cape Cod Canal in Spring 1972 (Reeves and Katona, 1980). Although considered rare in Buzzards Bay, "extralimital" sightings of beluga have been observed from the Maritimes south to New Jersey (Connor 1971; Fisher and Sergeant 1954; Goode 1884; Mairs and Scattergood 1958; Sergeant and Brodie 1975; Sergeant and Fisher 1957; Waters and Rivard 1962). At least 10 sightings have been seen in Massachusetts waters since the mid-1800s (summarized in Reeves and Katona 1980). Sergeant and Brodie (1969) and Sergeant et al. (1970) suggested that beluga from the St. Lawrence subpopulation follow the cold Gaspe Current to clear the coast of Cape Breton. Therefore, animals seen in Buzzards Bay (Table 6-2) may have come from the St. Lawrence Estuary, where an isolated population of several hundred resides (Sergeant and Brodie 1975).

Beluga eat a wide spectrum of food and a large proportion of sightings in New England are from individuals captured in herring weirs (Reeves and Katona 1980) suggesting that at least for the period of time they are in New England waters, they may be preying on schools of herring or mackerel.

Katona and Reeves show that no strandings of beluga have occurred along the eastern seaboard in spite of numerous inshore sightings south of the expected range of this species. They suggested that long migrations, which include extended movements up freshwater rivers (500-2000 km) and changes in water temperature (from pack ice to 12-18º C estuarine water within the span of less than 1 hour, Brodie [1975]) are not uncommon for this species. Therefore if left unmolested, it is likely that beluga are not adversely affected by extended stays in New England, considerably southward of their normal range.

Porpoises (Family Phocoenidae*)*

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise, *Phocoena phocoena,* is locally abundant in the Bay of Fundy and northern Gulf of Maine in summer, where they are classified as "abundant" in comparison with all other areas examined (Gaskin 1977 and 1984). During mid-summer and early fall, the northern Gulf of Maine-Bay of Fundy may support as much as 80% of the total summer population of the species in Canadian waters south of the Gulf of St. Lawrence (Prescott and Fiorelli, 1980). During the high abundance levels of summer in the northern Gulf of Maine, sightings throughout the southwest Gulf of Maine-Cape Cod Bay are rare (Prescott and Fiorelli 1980; CeTAP 1982). Sightings south of 40º 00' N latitude in coastal waters increase during winter and early spring.

In Cape Cod Bay-southern New England waters harbor porpoise are common from early March through May and then again from early October through mid-December. These periods correspond to seasonal movements northward into the upper Gulf of Maine-Bay of Fundy in spring (Gaskin et al., 1975; Gaskin and Watson 1985), and then a southern movement into the mid-Atlantic region and possibly offshelf during winter. Seasonal movements of this species are correlated quite closely with those of herring, the main food species (Smith and Gaskin 1974) and an increase in water temperatures to at least 8°C (Gaskin et al., 1975). This species is most abundant in coastal southern New England waters during winter and the strandings reported in Buzzards Bay (Table 6-2) are related to this seasonal movement.

Pinnipeds

Seals (Family Phocidae)

Harbor Seal (*Phoca vitulina*)

The harbor seal is the most abundant marine mammal in coastal New England waters (including Buzzards Bay). The present seasonal distribution has changed considerably south of Maine, having been affected directly by wildlife and fisheries policies since the mid 1800s. In 1888 Massachusetts began offering a bounty on seals (Public Statutes of Massachusetts, 1882-1888, Chapter 287) which lasted until 1962 (Laws and Resolves of Massachusetts, 1962, Chapter 222). Seals were/are considered predators of commercially important fish and therefore competitors with local fishermen. Pressure from the Massachusetts (and Maine) bounties significantly reduced seal numbers in local areas thereby limiting the southward dispersion of seals from Maine pupping areas (Payne and Schneider 1984). This eventually led to their present seasonal occurrence (Payne and Schneider 1984) and the extirpation of breeding activity south of Maine (Katona et al., 1983). Complete protection of seals was not provided until implementation of the Marine Mammal Protection Act of 1972.

Since protection, harbor seal numbers have more than doubled throughout southern New England (Payne and Schneider 1984). Between 1972 and 1982 the number of harbor seals wintering in southern New England increased approximately 11.8% per year (Payne and Schneider 1984) to the present estimated population of approximately 4,500 seals (Payne and Selzer 1989).

Present Distribution of Harbor Seals in Buzzards Bay

Temporal Distribution

The harbor seal occurs in southern New England (south of Maine) seasonally from late September through late May. Harbor seals in Buzzards Bay follow a slightly bimodal seasonal pattern of occurrence between mid-October and early May (data from the Lloyd Center for Environmental Studies, unpubl.) characteristic of other haulout sites in Massachusetts (see Schneider and Payne 1983). The number of seals immigrating into the area during late fall-early winter from the larger concentrations in coastal Maine-outer Cape Cod regions increases until early January. During mid-January through February, the number of harbor seals in Buzzards Bay either remains constant or slightly decreases as immigration into the area decreases and seals continue to move southeastward into eastern Long Island Sound. The maximum number of seals counted at major haulout sites in eastern Long Island Sound

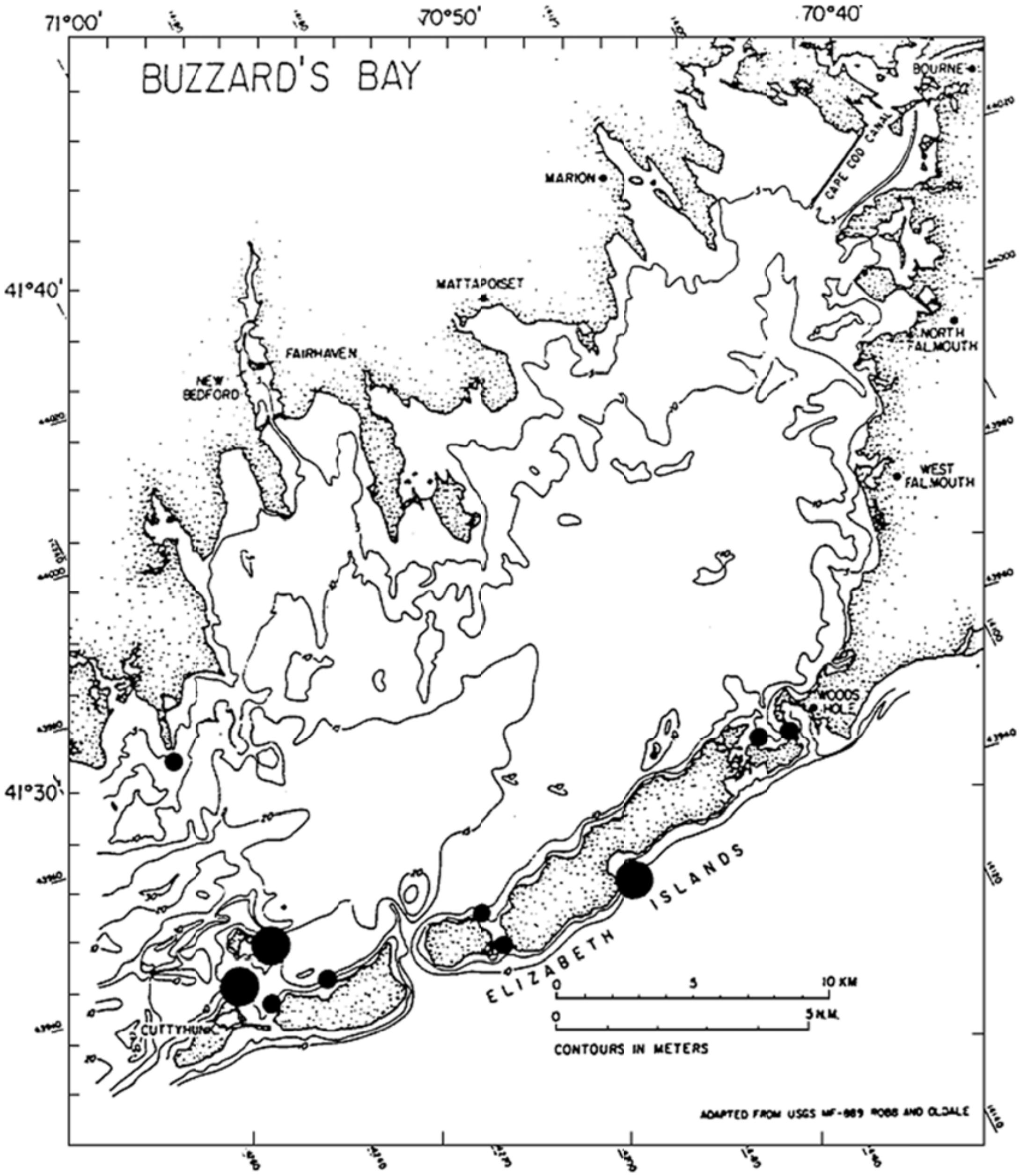


Figure 6-1. Known haulout locations of harbor seals in Buzzards Bay (including the Elizabeth Islands).

The maximum number of seals counted at each location during aerial surveys, 1983-1986 are as follows: 1-50 seals per count (small circles); >50 seals per count (large circles).

generally occurs during mid-February to March (Knapp and Winn 1978).

Seal numbers again increase in Buzzards Bay during mid-March through early April. This second peak is followed by a rather rapid decline in numbers to near-zero by early May. A few individuals are seen throughout the year (Knapp and Winn 1978), however most harbor seals move north to Maine by mid-May to early June prior to the pupping season (Schneider and Payne 1983). Although a few pups are born each year in Massachusetts waters, there are no established harbor seal rookeries south of Maine.

Spatial Distribution and Abundance

The maximum number of seals counted in Buzzards Bay (including the Elizabeth Island chain) during each of the 1983-1986 aerial surveys (from Payne and Selzer 1989) ranged from 157-253 seals. The largest haulout site was generally Gull Island, a small island-gravel spit located north of Cuttyhunk Island (Figure 5-1). This single location generally contained between 50-90% of all the seals counted in the Elizabeth Island-Buzzards Bay study area. Only one location on the northwest side of Buzzards Bay (Mishaum Point at the mouth of the Slocum's River) was used by seals for hauling-out during the 1983-1986 surveys.

The maximum number of seals observed during any of the near-weekly vessel surveys of Gull Island and Pease Ledge during November-May, 1986-1989 was 280 in March 1988. These numbers are comparable to those found during the aerial surveys 1983-1986 and reflect a continued increase in the number of seals that haul-out in the Elizabeth Island chain. Given the number of seals that use these two locations (relative to the remainder of the Elizabeth Island-Buzzards Bay area) it is reasonable to assume that between 300-400 seals now use the Elizabeth Islands as haulout locations during mid-winter.

During the January-April 1986 and March-April 1989 weekly seal counts conducted on the northwest (mainland) side of Buzzards Bay, only a small number (7-9) were observed at Mishaum Point during 1989. Based on the results of all surveys, 1983-1989, it is apparent that the rock-outcroppings and ledges along the mainland coast of Buzzards Bay are not suitable as haulout locations for harbor seals.

Gray Seal (*Halichoerus grypus*)

The gray seal is also a regular, but far less common, visitor to Buzzards Bay than the harbor seal. Two gray seals were observed during the winter 1982-1983 (unspecified location in Dartmouth) and another was on West Island (Fairhaven) in the winter 1986-1987 during weekly harbor seal counts (Lloyd Center for Environmental Studies, unpublished data).

The southern New England component of the gray seal population ranges from Cape Cod (Monomoy Island) south and east to at least Montauk Point, Long Island. The major haulout sites are found within Nantucket Sound (Monomoy Island, the shoals west of Nantucket, Muskeget, and Tuckernuck Islands) and Wasque Shoal, a sand bar southeast of Martha's Vineyard (Schurman 1983a, 1983b). Although their range does include Buzzards Bay, there are no major haulout locations used extensively by gray seals within the Buzzards Bay study area (including the Elizabeth Islands).

Throughout the 1940s and 1950s, gray seals were killed in Massachusetts for their bounties. In March 1965, the State of Massachusetts provided special legislation protecting the few remaining gray seals in these waters (Laws and Resolves of Massachusetts, Acts 1965, Chapter 129). Because they are not considered endangered or threatened throughout their North Atlantic range, the State of Massachusetts now considers them a "species of special concern" (French and Cardoza, in press).

Andrews and Mott (1967) reported that during the 1940s and early 1950s, approximately 40 gray seals were killed for their bounty with at least 10 seals killed in each of two years during this period. Between 1958 and the mid-1960s (prior to Andrews and Mott), bounties had been paid on at least 25 seals. In 1962 (when the bounty was repealed) the Muskeget gray seal population was 15-17 individuals (Schurman, 1983a).

The annual cycles for gray seals are significantly different from for the harbor seals. The breeding season starts in mid-December and lasts until mid-February (Beck 1983). The peak of the pupping season occurs late December through late January. Females nurse their pups for approximately 17 days and come into estrus 15 days postpartum, just before weaning their pups. Peak breeding activity generally occurs during January to mid-February.

Between 1964 and 1970, one pup was born each season. Between 1971 and 1979, no pups were found and the total number of gray seals decreased to nine individuals (Schurman 1983a; 1983b). Since 1980 the number of seals >age 0 (pup) has increased each year from 18 (in 1980), to the low 20s during 1982 and 1983, to >100 in 1986, and >200 by 1989. During January 1990, six gray seal pups were observed at Monomoy Island (reference, Boston Globe). During February a seventh pup was born (reference, Cape Cod Times), the largest number recorded since the early 1950s.

These large increases in the number of gray seals in Massachusetts have been the direct result of an increased gray seal production at Sable Island, Nova Scotia, and subsequent immigration from that location to southern New England. Between 1962 and 1980, the number of pups at Sable Island increased from 350 to 3,500 (Beck 1983) and the number continues to increase. Many of the individuals observed within Massachusetts waters are branded or marked (Gilbert et al., 1977; Schurman 1983a, 1983b) indicating that they have come from Sable Island. Observations of branded seals on Sable Island indicate that most return there to breed (Beck, 1983). Therefore, in Massachusetts we have had a significant increase in subadult and adult gray seals (in the mid 1980s), with little local reproduction. Recent increases in the number of local pups would indicate that, either gray seal pups born in Massachusetts in the early 1980s are returning to pup and breed, or Sable Island seals are expanding their breeding range south into Massachusetts, or both. A few branded seals with white-coat (newborn) pups in Massachusetts (Schurman 1983a) would indicate that both possibilities might be occurring simultaneously as none of the adults that pupped in January-February 1990 appeared marked or branded.

Factors Affecting the Present Distribution of Seals in Buzzards Bay

Disturbance

The present distribution of harbor seals in Buzzards Bay reflects the distribution of suitable haulout locations. Factors other than tidal level and the interplay between tide and time of day have been shown to affect the distribution of haulout sites and haulout behavior. Harbor seals have been shown to select haulout sites based on topography and degree of wind exposure (Sullivan 1980; Schneider and Payne 1983), tide and degree of isolation from human disturbance. Human disturbance has been the major factor shown to deter or eliminate haulout behavior and pupping activity at specific locations (Bartholomew 1949; Newby 1973; Paulbitski 1975; Schneider and Payne 1983; Allen et al., 1984). Newby (1973) attributed the abandoning by harbor seals of a site in Puget Sound in part to increased disturbance from recreational boating. Paulbitski (1975) documented a change from diurnal to nocturnal hauling-out patterns in harbor seals in response to increased disturbance levels. A South San Francisco Bay seal "population" described by Bartholomew (1949) as being disturbed by boats and landfill development, no longer exists. Human disturbance has also been shown to deter harbor seals from pupping (Allen et al., 1984). Andrews and Mott (1967) thought mid-winter duck hunting curtailed haulout behavior and possibly pupping of gray seals on Muskeget Island.

It seems apparent that mainland locations within Buzzards Bay will continue to be avoided, at least generally, by seals of both species. There is no indication (given continued protection) that the number of harbor seals throughout the Elizabeth Island chain will decrease. However, the current rate of increase may decrease due to increased competition for space or food-availability near current haulout sites resulting in emigration from Buzzards Bay to other locations.

Impact of Coastal Pollution

Reports on Polychlorinated Biphenyls (PCBs) in the marine environment are numerous and the role of environmental pollution in relation to reproductive success in marine mammals has been examined (Addison and Brodie 1977; Andersen and Rebsdorff 1976; Bowes and Jonkel 1975; Gaskin et al., 1973, 1971 1974,1979 1983; O'Shea et al., 1980; Risebrough et al., 1968; Taruski et al., 1975). PCBs have been implicated in reduced pup production and consequently in the reduction of total numbers in the Wadden Sea (Netherlands) population of harbor seal (Reijnders 1982; 1984), the Baltic Sea population of ringed seals (*Phoca hispida*) (Bergman et al., 1981; Helle 1980) and the California sea lion (*Zalophus californianus*) (Leboeuf and Bonnel 1971; DeLong et al., 1973; Gilmartin et al., 1976; Martin et al., 1976).

Documented studies on the interrelationships between pollutants and lowered reproductive success in pinnipeds indicated several direct manners in which pollutants (primarily PCBs) can limit reproductive potential:

- premature pupping resulting in abortions, stillbirth and high pup mortality.
- implantation failure-PCBs interfere with required hormone levels at the end of the implantation-delay period in pinnipeds resulting in implantation failure and non-pregnancy.
- female sterility and occurrence of uterine occlusions. Helle (1976a, 1976b) correlated a reduction in the pregnancy rate of sexually mature ringed seals, gray seals and harbor seals with significantly higher levels of PCB and DDT in non-pregnant females compared with the pregnant ones, and suggested a causal relationship between those contaminants and pathological changes in seal uteri.

Gilmartin et al. (1976) and Drescher (1977) also provided evidence for an indirect interrelationship between environmental contaminants and disease agents. It is likely that PCBs may indirectly contribute to infection through strong immunosuppressive capacities (Drescher 1977; Reijnders 1980). Drescher (1977) reported skin lesions in the harbor seals of the Wadden Sea and suggested that disturbance of pups resulted in inflammation of the umbilical region. Drescher further inferred that due to a transfer of toxic burdens from mother to pup, increased levels of PCBs resulted in a total reduction in pup immunity making them more vulnerable to infection after physical injury.

The mean level of PCBs in harbor porpoise are also notably higher immediately before and during the onset of sexual maturity (Gaskin and Blair 1977). Gaskin and Blair (1977) suggested that this period is accompanied by a significant increase in feeding and an increased intake of organochlorinated hydrocarbon residues through the food web. Holden (1972) suggested that marine mammals (principally seals and porpoises) might be useful as "indicator species" to monitor accumulation levels of contaminants in the marine environment.

The accumulation of heavy metal (nickel, mercury, cadmium, lead, and chromium) concentrations in soft seal tissues vary in relation to maternal levels and generally reflect the tendency for some metals to show an age accumulation in certain tissues (Heppleston and French 1973; Gaskin et al., 1983). However, increased heavy metal concentrations in pinnipeds and harbor porpoise have not resulted in a clear connection between increased body or tissue burden from these compounds and a demonstrated reduction in reproductive potential or health of the animals (Drescher 1977).

Turtles

Family Cheloniidae and Dermochelyidae

Five species of sea turtles occur in United States waters, the leatherback *(Dermochelys coriacea)*, the loggerhead *(Caretta caretta)*, the Kemp's ridley *(Lepidochelys kempi)*, the green turtle *(Chelonia mydas)*, and the hawksbill *(Eretmochelys imbricata)*. All of these species are listed as endangered, except for the loggerhead, which is threatened. Prior to the CeTAP surveys marine turtles were known off the northeastern United States primarily from strandings, anecdotal comments, or opportunistic reports of sightings at sea (Babcock 1919; Bleakney 1965; Lazell 1976). The leatherback turtle is the sea turtle that is most frequently encountered within the Buzzards Bay study area. Two other species have also been observed and have a high probability of occurring within Buzzards Bay: the loggerhead and the Atlantic or Kemp's ridley. The hawksbill turtle has also been reported in Buzzards Bay, and green turtles may occur here occasionally, but these turtles appear to have a more tropical distribution. The seasonal distribution of all sea turtles found in the northeast is confined almost exclusively to the summer and fall, when area waters are warm enough to sustain them. Therefore, the seasonal expansion and reduction of this species range correlates directly with the warming and cooling of the surface water temperatures.

Leatherback Turtle (*Dermochelys coriacea*)

The leatherback is the sea turtle most often found in Buzzards Bay. The majority of Buzzards Bay sightings and strandings occur from July through early November (Table 6-3). While specific seasonal movements are unknown CeTAP sightings occurred most frequently in southern New England in water depths <60 meters (Shoop et al., 1981).

Leatherback turtles feed principally on jellyfish (Carr 1952; Bleakney 1965; National Fish and Wildlife Laboratory 1980a), and Lazell (1980) links the turtle's seasonal inshore movement to concentrations of the jellyfish *(Cyanea capillata*) their preferred prey in the Gulf of Maine (Bleakney 1965; Lazell 1976) which also move into shallower, nearshore waters of southern New England during warmer months.

Causes of leatherback mortality in Buzzards Bay are rarely reported due to low observer effort and the advanced state of decomposition of most of the carcasses. Cold stunning, a common cause of mortality for some species of sea turtles in the northeast, does not affect leatherbacks. They are temperate water sea turtles, found as far north as Newfoundland and adapted to colder waters. The leatherback eats a variety of nonfood items that they apparently mistake for food. Items reported include plastic debris (strips, pieces of plastics, plastic bags) rope and tar-balls. Leatherbacks are reported to have died of intestinal blockages after eating floating plastic bags, which they mistake, presumably, for jellyfish. It is clear that floating debris, particularly plastics, and oil presents a serious threat to sea turtles in their feeding and migratory habit. Reports of entanglement in lobster pot lines and in other fishing gear have been received from Cape Cod Bay, and entanglement may be a cause of mortality for leatherbacks in areas of Buzzards Bay where lobstering still occurs. Leatherbacks have been reported with prop cuts into their carapaces, but it is difficult to determine whether they were hit before or after death.

Loggerhead Turtle (*Caretta caretta*)

The loggerhead turtle is the most abundant sea turtle in the shelf waters of the northeastern United States (Shoop et al., 1981; CeTAP 1982). They are most widespread throughout shelf waters (the mode of water depth at sighting was 37 meters, CeTAP 1982) in summer and fall and are rarely observed free-swimming within the Gulf of Maine. Juvenile loggerheads apparently come inshore to forage on various species of crabs, jellyfish, and a variety of benthic invertebrates that are found throughout inshore northeast waters.

Between 1980 and 1988, 23 loggerhead strandings were reported in Massachusetts (STSSN, unpublished data). Only one stranding was reported in Buzzards Bay (Table 6-3) although this may under-represent the occurrence of loggerhead turtles in this area due to low observer effort and the low visibility of juvenile loggerheads.

The average water temperature at loggerhead sightings (based on CeTAP 1982) was 22.4°C. Unlike leatherback turtles which can tolerate a decrease in water temperature as their distribution extends northward, loggerheads move northward as the shelf water temperature increases to approximately 20-23°C (CeTAP 1982). The loggerhead generally becomes dormant at temperatures below 15°C, although juveniles may be active in temperatures to 7-80°C. Prolonged exposure to seawater temperatures below these thresholds causes cold-stunning, immobilization, and death. This may be the most common cause of natural mortality for juvenile loggerheads. Other factors that are implicated in their mortality in the northeast are ingestion of plastics, entanglement in fishing gear, and boat hits.

Table 6-3. Known strandings of marine turtles in Buzzards Bay by species, number stranded, date, location (latitude-longitude where available and common place name, and reference (accession location and number)[1]

Number	Date	Location	Reference
Leatherback Turtle *(Dermochelys coriacea)*			
1	1891	Buzzards Bay (fish trap near Woods Hole)	Babcock 1935
1	27 September 1984	Buzzards Bay (410301 710031)	STSSN/NMFS
1	1 October 1985	Buzzards Bay (410351 700551)	STSSN/NMFS
1	2 October 1985	Gooseberry Neck (410291 710021)	STSSN/NMFS; NEA
1	4 October 1985	Horseneck Beach (410301 710031)	STSSN/NMFS; NEA
1	10 October 1985	Gooseberry Neck (410291 710021)	STSSN/NMFS; NEA
1	18 October 1985	Naushon Island	NEA
1	20 October 1985	Horseneck Beach (410301 710031)	STSSN/NMFS; NEA
1	11 November 1985	Buzzards Bay (410301 710031)	STSSN/NMFS
1	24 August 1986	East Beach, Westport (410401 700401)	STSSN/NMFS; NEA
1	7 September 1987	Barneys Joy Beach, S. Dartmouth (410301 700591)	STSSN/NMFS; NEA
1	7 October 1987	Barneys Joy Beach, S. Dartmouth (410301 700591)	STSSN/NMFS; NEA
1	29 October 1987	Barneys Joy Beach, S. Dartmouth (410301 700591)	STSSN/NMFS; NEA
1	3 November 1987	Mishaum Beach, S. Dartmouth (410311 700571)	STSSN/NMFS; NEA
1	25 November 1987	Barneys Joy Beach, S. Dartmouth (410301 700591)	STSSN/NMFS; NEA
Loggerhead Turtle *(Caretta caretta)*			
1	27 August 1985	Horseneck Beach (410301 710031)	STSSN/NMFS
Hawksbill Turtle *(Eretmochelys imbricata)*			
1	1909	Buzzards Bay (vicinity of Woods Hole)	Summer 1909
Kemp's Ridley *(Lepidochelys kempi)*			
1	12 May 1965	Gay Head, Martha's Vineyard	Carr 1967
"dozens'	1930's	Buzzards Bay Multiple strandings and "flotilla"	Carr 1967
3		Buzzards Bay (Quissett Harbor to Popes Island)	Lazell 1976
1	?	Nonamesset, Naushon	Lazell 1976

1 References:
STSSN/NMFS: Sea Turtle Sighting and Stranding Network/National Marine Fisheries Service/Southeast Fisheries Center
NEA: New England Aquarium, Boston, Massachusetts

Hawksbill (*Eretmochelys imbricata*)

Summer (1909) reported a hawksbill turtle from Buzzards Bay. The account (published in Babcock, 1937 suggests that the hawksbill "not infrequently reaches the coast of southern New England." (from Babcock 1937 p. 17).

A specimen ten or twelve inches long was taken among floating sargassum by Mr. Edwards in August, 1908, and was kept for some time in the shark pool of the station {Biological Laboratory of the Bureau of Fisheries]. I learn from Mr. Edwards that individuals as large as eighteen inches long are not infrequently captured.... It is now, therefore, included in the fauna of the ‘waters of Woods Hole and vicinity.

There is a small specimen, less than six inches in length, from the vicinity of Woods Hole in the Biological Laboratory museum. It is reported to be more common in Buzzards Bay than the loggerhead...

We now believe that hawksbill turtles are extremely rare north of North Carolina, certainly less common than loggerheads. Hawksbill turtles have stranded on Cape Cod but are considered extremely rare in Massachusetts (including Buzzards Bay).

Atlantic or Ridley’s Turtle *(Lepidochelys kempi)*

Historically, the Kemp's ridley was not considered a species, but rather a hybrid between the hawksbill and the loggerhead (Carr 1952). It was not until the early 1930s that museum specimens in Massachusetts were re-examined and re-classified (DeSola 1931; Dodge 1944). However, the most remarkable record of ridley distribution (up to the date of the following correspondence) involved the Kemp's ridley and Buzzards Bay. The following correspondence between William E. Schevill (WHOI) and Archie Carr is extracted from Carr (1967, pp. 142-145). The significance of this record will be discussed further, therefore merits a reasonably full accounting at this time.

....The greatest concentration of positively identified Atlantic ridleys that I ever heard of (away from Tamaulipas) occurred in just about the most unlikely place that anybody could imagine. It was Martha's Vineyard, Massachusetts.... I was told about the Martha's Vineyard ridleys by William Schevill of the Woods Hole Oceanographic Institution.... Some years ago Bill wrote to say he was sending me a pickled ridley that had been picked up on May 12, 1956 at the foot of Gay(s) Head cliffs, on Martha's Vineyard. Unless dead ridleys are very buoyant, this one must have come in quite close to the beach before dying, and must have crossed some very cold water in doing so. Cogitating on the degree of cold tolerance implied by its arrival, Bill got himself interested in the strangely numerous ridley records for Massachusetts waters that seemed to be turning up at the time. This interest led him to the discovery that a number of yearling sea turtles caught in Buzzards Bay some years before, and exhibited as loggerheads at Woods Hole for two summers, were actually ridleys. That was a time when, after sixty years of not having believed in the reality of the ridley as a separate kind of turtle, museum curators had been persuaded that it was in fact a valid species and had begun dragging out their old sea turtle specimens, re-examining them and often finding those labeled loggerhead to be really ridleys. Finding the Buzzards Bay turtles seemed to Bill to be a continuation of the tendency for all old Massachusetts sea turtle records to turn out to be based on misidentified ridleys.

"It seems as if this is real ridley country," Schevill wrote. "Maybe they breed on Penikese or Cuttyhunk."

The latter remark was a joke. I had been looking for ridley nesting for years. In a later note Bill had this afterthought.

Just talked to Mr. McGinnis of MBL [Marine Biological Laboratory]. He says that about 20 years ago a whole fleet of such turtles came into Woods Hole, carcasses littering the beaches. He fished half-a-dozen sea turtles out of his barrels. All ridleys. Says he has a few more. What is this, a Yankee turtle?

Bill went on to say that Mr. McGinnis, even after talking it over with old-time colleagues, could fix the date no more closely than "about 20 years ago." He remembered that the time of year was midsummer; that the stranded carcasses, although there "by dozens," were only a small fraction of the original school; and that the live turtles had passed outward from Buzzards Bay into Vineyard Sound.

These were pretty eerie observations. I could see no shred of sense in a flotilla of ridleys turning up so far north, and much less in their being found swimming seaward out of an inland bay. I wrote Bill this and though his answer was, as his answers often are, a bit tainted with levity, at least it shed light on the odd course the turtles were taking when discovered. His explanation was as follows:

So as not to confuse you unduly (a little is ok), perhaps I should let on that our tidal circulation in Buzzards Bay and Vineyard Sound may be considered as somewhat clockwise; so that it is quite reasonable to imagine a chunk of water containing, for example, a passel of ridleys, coming in from the sea between Block Island and the Vineyard, being inhaled into Buzzards Bay (where the flood begins some three hours earlier than in Vineyard Sound), and then being sucked through the Hole an hour or so after the beginning of flood in Buzzards Bay, and a couple of hours before the current turns eastward (let's call it flooding) in Vineyard Sound... How do you feel now pilot?

The main way I felt was, how did the ridleys get to Massachusetts to start with? Schevill being after all predominantly a cetacean man, went happily on to say:

> *I am inclined to reverse my irreverent hypothesis that ridleys breed on Cuttyhunk. Seems more likely that it's further up-maybe Scraggy Neck or Buzzards Bay...*

By then I wasn't sure whether Bill was advancing a facetious hypothesis or a serious one. But in any case, I was an old hand at deflating such spacious ridley theories as that.... it was not thinkable that they [inhabitants of Buzzards Bay] would have let ridleys dig their beaches for centuries and never have said a word about it...

-End of reference from Carr (1967)

At this time, considerably more is known of the status of the Kemp's ridley than at the time of this conversation. The adult Kemp's ridley appears restricted to the Gulf of Mexico (National Fish and Wildlife Laboratory 1980b). The entire Kemp's ridley population breeds simultaneously at one location in Mexico, which makes it unlike any other sea turtle in the world. In 1947, an estimated 40,000 were observed nesting on the beach. This number decreased to 2,000 in 1966, and for the last 8 years 200-750 females have come to nest each year (Meylan 1986).

Ironically, the ridley is the most common marine turtle reported on shores (stranded) within Cape Cod Bay. Approximately 88 ridleys were found between 1976 and 1985 (Meylan 1986). Thirty-seven individuals were reported during 1986 and 1987 (from STSSN unpublished data). Stranded immature ridleys are regularly found from Massachusetts and North Carolina waters (Lazell 1976; STSSN, unpubl. data). Partly because of the high numbers of strandings of *L. kempi*, in view of their much-reduced worldwide number, Lazell (1980) requested that New England waters be considered critical habitat for that species.

Prior to 1986 only three records of kemp's ridleys were available for the entire state of New York (Meylan 1986). Meylan feels this is a case of misidentification and poor record keeping, rather than a true lack of ridleys. Since 1985 Morreale et al. (1989) have encountered more than 280 sea turtles in Long Island Sound waters. The loggerhead and Kemp's ridleys are the two species most often stranded in Long Island Sound (Morreale et al., 1989) and Cape Cod Bay (STSSN). The turtles are all juveniles, approximately the same size and in good health. There is a heavy concentration of ridleys on the northeastern shore of Long Island in August when water temperatures range from 20-25°C (Burke et al., 1989). The turtle strandings are most numerous in late fall months, with a peak in December. This was due to the passive movement of floating cold-stunned turtles at water temperatures below 13°C, small Kemp's ridleys die at 5°C. Burke et al. found that wind direction is a major influence in determining the number of cold-stun related strandings of Kemp's ridleys turtles in Long Island Sound.

The Peconic Bay System (north side of Long Island) is considered a critical foraging location for juvenile and subadult ridleys turtles beginning in mid-summer and continuing through the period prior to cold-stunning. The food of the Kemp’s ridley turtle is primarily crabs (National Fish and Wildlife Laboratory 1980b; Plotkin 1969) which are found in shallow water. In Long Island Sound the slow-moving spider crab (*Libinia spp*.) and the blue crab (*Callinectes sapidus*) were the most common prey items (Standora et al., 1989). The prey abundance and species composition, and the physical and biological features of Buzzards Bay are very similar to the Peconic Bay System (which characterize it as an important foraging area for juvenile turtles).

Kemp's Ridley Turtles in Buzzards Bay?

Since the "flotilla" of ridleys was observed in the 1930s, there have been no further records of this species in Buzzards Bay. It is obvious that they cannot withstand the winter in Buzzards Bay. By November water temperatures begin to fall rapidly and by early December conditions in Buzzards Bay are lethal (below 5°C) to Kemp's ridleys and remain in the lethal range until April. However, that such numbers (100s) occur in Long island Sound annually and the most frequently stranded turtle in Cape Cod Bay is the ridley, it seems inevitable that this species does occur (at some level) in Buzzards Bay from late summer until a decrease in water temperature forces them southward, possibly into eastern Long Island Sound.

If this is possible, why have they not been encountered in greater numbers? Ridley turtles were virtually unknown in eastern Long Island Sound until 1986. It is apparent from the stranding record that the ridley is not "rare" in Massachusetts coastal waters. There are three immediately obvious reasons why ridleys could go undetected in Buzzards Bay.

1) The small size and pale gray color of ridley makes them extremely difficult to detect in the water and easy to overlook on the beach.

2) The stranding locations in eastern Long Island Sound and Cape Cod Bay are all located on the north side of a natural barrier that could prevent the turtles from moving southward as the water temperatures decrease in late fall. The configuration of Buzzards Bay would allow a turtle to move southward as water temperatures decrease. Therefore, cold-stunning and eventual stranding within Buzzards Bay is unlikely, or at least minimized. The northeast wind, which pushes cold-stunned turtles onto the northern shores of Long Island and Cape Cod, would tend to push turtles out of Buzzards Bay southwest towards Block Island and Montauk Point. Even an immobilized turtle could drift out of the bay.

3) Most live-captured ridleys in eastern Long Island Sound have been taken out of pound-traps or weirs. Within Buzzards Bay net-fishing (weirs, pound-nets, trawls) has not been permitted for many decades; therefore the possibility of detection through live-capture (as in eastern Long Island Sound) does not exist.

Therefore the lack of ridley sightings and strandings in Buzzards Bays does not mean they are not present during late summer and fall. Given the critical survival status of this species, the possibility that Buzzards Bay is an important foraging area for juvenile ridleys during late summer and fall should not be dismissed until this possibility is further examined.

References

Addison, R. R., and P. F. Brodie. 1977. Organochlorine residues in maternal blubber, milk, and pup blubber from grey seals (*Halichoerus grypus*) from Sable Island, Nova Scotia. J. Fish. Res. Board Can. 34: 937-941.

Allen, G. M. 1916. The whalebone whales of New England. Mem. Boston Soc. Nat. Hist. 8: 107-322.

Allen, S. G., D. G. Ainley, G. W. Page, and C. A. Ribic. 1984. The effect of disturbance on harbor seal haulout patterns at Bolinas Lagoon, California. Fish. Bull. 82: 493-500.

Anderson, S. H., and A. Rebsdorff. 1976. Polychlorinated hydrocarbons and heavy metals in harbour porpoise (*Phocoena Phocoena*) and white beaked dolphin (*Lagenorhynchus albirostris*) from Danish waters. Aquatic Mammals 4: 4-20.

Andrews, J. C., and P. R. Mott. 1967. Gray seals at Nantucket, Massachusetts. J. Mammal. 48: 657-658.

Arnold, P. W., and D. E. Gaskin. 1972. Sight records of right whales (*Eubalaena glacialis*) and finback whales (*Balaenoptera physalus*) from the lower Bay of Fundy. J. Fish. Res. Board Can. 29: 1477-1748.

Babcock, H. L. 1919. The turtles of New England. Memoirs Boston Soc. National Hist. 8: 325-431.

Babcock, H. L. 1937. The sea turtles of the Bermuda Islands, with a survey of the present state of the turtle fishing industry. Proc. Zool. Soc. Lond. 107: 595-601.

Bartholomew, G. A. 1949. A census of harbor seals in San Francisco Bay. J. Mammal. 30: 34-35.

Beck, B. 1983. The grey seal in Canada. Underwater World. Dept. of Fisheries and Oceans, Ottawa. 4 pp.

Bergman, A., H. Olsson, and L. Reutergardh. 1981. Lowered reproduction rates in seal population and PCB concentration. Internat. Counc. Explor. Seas (ICES) C. M. 1981/N: 10. l0pp.

Bleakney, J. S. 1965. Reports of marine turtles from New England and Canadian waters. Can. Field-Naturalist 79: 120-128.

Boston Globe. 1990. Gray seals come back to the Cape. pp. 61 In The Boston Sunday Globe, 28 Jan 1990.

Bowes, G. W., and C. J. Jonkel. 1975. Presence and distribution of polychlorinated biphenyls (PCBs) in arctic and subarctic marine food chains. J. Fish. Res. Board Can. 32: 2111-2123.

Brodie, P. F. 1975. Cetacean energetics, an overview of intraspecific size variation. Ecol. 56: 152-161.

Brown, C. W., and H. E. Winn. 1989. Relationship between the distribution pattern of right whales, *Eubalaena glacialis*, and satellite-derived sea surface thermal structure in the Great South Channel. Cont. Shelf Res. 9: 247-260.

Burke, V. J., E. A. Standora, and S. J. Morreale. 1989. Environmental factors and seasonal occurrence of sea turtles in Long Island, New York. pp. 21-22 *In* Eckert, S. A., K. l. Eckert, and T. H. Richardson (Compilers). Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Tech. Memo. NMFS-SEFC-232. 306 pp.

Cape Cod Times. 1990. Seventh gray seal pup born in Chatham. pp. 3 in Cape Cod Times, 3 Feb 1990.

Carr, A. 1952. Handbook of Turtles. Comstock Publ. Assoc., Ithaca, N. Y. 542 pp.

Carr, A. 1967. So Excellent a Fishe. Natural History Press, Garden City, N. J. 249 pp.

CeTAP. 1982. A characterization of marine mammals and turtles in the mid- and north Atlantic areas of the U. S. outer continental shelf. Final Report of the Cetacean and Turtle Assessment Program, Bureau of Land Management, Contract No. AA551-CT8-48, U. S. Dept. of Interior, Wash. DC. 450 pp.

Connor, P. R. 1971. The mammals of Long Island, New York. New York State Museum Scientific Services, Univ. of New York, Albany, New York, Bull. Number 416. 78 pp.

DeLong, R. L., W. G. Gilmartin, and J. G. Simpson. 1973. Premature births in California sea-lions: Associations with high organochlorine pollutants residue levels. Science 181: 1168-1170.

DeSola, R. 1931. The turtles of the northeastern states. Bull. N. Y. Zool. Soc., 34: 131-160.

Dodge, E. S. 1944. Status of the ridley turtle in Massachusetts waters. Copeia 2: 120-121.

Drescher, H. E. 1977. Organochlorines and heavy metals in the harbour seal *(Phoca vitulina)* from the German North Sea coast. Mar. Biol. 41: 99-106.

Edel, R. K., M. Cagan, J. H. W. Ham, P. W. Sorensen. 1981. Correlations between cetacean sightings and selected environmental variables. Chap VII In A characterization of marine mammals and turtles in the mid- and north Atlantic areas of the U. S. outer continental shelf. Ann. Rept. 1979, CeTAP Program, Univ. of Rhode Island, prepared for Bureau of Land Mgmt., U. S. Dept. of Interior, Washington, DC.

Fisher, H. D., and D. E. Sergeant. 1954. A white whale in the Bay of Fundy. Canadian Field-Naturalist 68: 138-139.

French, T. W., and J. E. Cardoza. Endangered, threatened, and special concern vertebrates of Massachusetts. Univ. Massachusetts Press, Amherst, MA (accepted for publication).

Gaskin, D. E. 1977. Harbour porpoise *Phocoena phocoena (L.)* in the western approaches to the Bay of Fundy 1969-75. Rep. Int. Whal. Comm. 27: 487-492.

Gaskin, D. E. 1984. The harbour porpoise, *Phocoena phocoena (L.)*: Regional populations, status, and information on direct and indirect catches. Rep. Int. Whal. Comm. 34: 569-586.

Gaskin, D. E., O. J. D. Smith, and A. P. Watson. 1975. Preliminary study of movements of harbor porpoises (*Phocoena phocoena*) in the Bay of Fundy using radiotelemetry. Can. J. Zool. 53: 1466-1471.

Gaskin, D. E., and A. P. Watson. 1985. The harbor porpoise, *Phocoena phocoena*, in Fish Harbor, New Brunswick, Canada: occupancy, distribution, and movements. Fish. Bull. 83: 427-441.

Gaskin, D. E., and B. A. Blair. 1977. Age determination of harbor porpoise, *Phocoena phocoena (L.)* in the western North Atlantic. Can. J. Zool. 55: 18-.

Gaskin, D. E., K. I. Stonefield, P. Suda, and R. Frank. 1979. Changes in mercury levels in harbour porpoises from the Bay of Fundy, Canada, and adjacent waters during 1969-1977. Arch. Environ. Contam. Toxicol. 8: 733-762.

Gaskin, D. E., M. Holdrinet, and R. Frank. 1971. Organochlorine pesticide residues in harbor porpoise from the Bay of Fundy region. Nature 233: 499-500.

Gaskin, D. E., R. Frank, M. Holdrinet, K. Ishida, C. J. Walton, and M. Smith. 1973. Mercury, DDT, and PCB in harbor seals (*Phoca vitulina*) from the Bay of Fundy and Gulf of Maine. J. Fish. Res. Board Can. 30: 471-.

Gaskin, D. F., G. J. D. Smith, P. W. Arnold, M. V. Louisy, R. Frank, M. Holdrinet, and J. W. McWade. 1974. Mercury, DDT, dieldrin, and PCB in two species of *Odontoceti* (Cetacea) from St. Lucia, Lesser Antilles. J. Fish. Res. Board Can. 31: 1235-.

Gaskin, D. F., R. Frank and M. Holdrinet. 1983. Polychlorinated biphenyls in harbor porpoises *Phocoena phocoena (L.)* from the Bay of Fundy, Canada and adjacent waters, with some information on chlordane and hexachlorobenzene levels. 1983. Arch. Environ. Contam. Toxicol. 12: 211-219.

Gilbert, J. R., V. R. Schurman, and D. T. Richardson. 1977. Grey seals in New England: Present status and management alternatives. Marine Mammal Commn, Final Report MM7ACOO2, NTIS Publication PB-295 599. 40 pp.

Gilmartin, W. G., r. L. DeLong, A. W. Smith, J. C. Sweeney, B. W. deLappe, R. W. Risebrough, L. A. Griner, M. D. Dailey, and D. B. Peakall. 1976. Premature parturition in the California sea-lion. J. Wild. Dis. 12: 104-115.

Goode, G. B. 1884. The whales and porpoises. pp. 7-32 In Natural history of useful aquatic animals. Section 1. Edited by G. B. Goode. U. S. Comm. of Fish and Fisheries, Washington, D. C.

Grosslein, M. D., R. W. Langton, and M. P. Sissenwine. 1980. Recent fluctuations in pelagic fish stocks of the northwest Atlantic, Georges Bank region, in relation to species interactions. Rapp. P. v. Reun. Cons. Int. Explor. Mer., 177: 374-404.

Hain, J. H. W. R. K. Edel, H. E. Hays, S. K. Katona, and J. D. Roanowicz. 1981. General distribution of cetaceans in the continental shelf waters of the northeastern United States. Chap. II In a characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U. S. outer continental shelf. Ann. Rept. 1979, CeTAP Program, Univ. of Rhode Island, prepared for Bureau of Land Mgmt., U. S. Dept. of Interior, Washington, DC.

Hain, J. H. W, M. A. M. Hyman, R. D. Kenney, and H. E. Winn. 1985. The role of cetaceans in the shelf edge region of the western North Atlantic. Mar. Fish. Rev. 47(1): 13---17.

Hain, J. H., G. R. Carter, S. D. Kraus, C. A. Mayo, H. E. Winn. 1982. Feeding behavior of the Humpback Whale *Megaptera novaeangliae*, in the western North Atlantic. Fish. Bull. 80: 259-268.

Helle, F., M. Olsson, and S. Jensens. 1976a. DDT and PCB levels and reproduction in ringed seal from the Bothnian Bay. Ambio 5: 188-189.

Helle, E., M. Olsson, and S. Jensens. 1976b. PCB levels correlated with pathological changes in seal uteri. Ambio 5: 261-263.

Helle, F. 1980. Lowered reproductive capacity in female ringed seals (*Phoca hispida*) in the Bothnian Bay, northern Baltic Sea, with special reference to uterine occlusions. Ann. Zool. Fennici. 17: 147-158.

Heppleston, p. B., and M. C. French. 1973. Mercury and other metals in British seals. Nature 243: 302-304.

Holden, A. V. 1972. Monitoring organochlorine contamination of the marine environment and the analysis of residues in seals, Marine Pollution and Sea Life, London. Fishing News Ltd: 262.

Hui, C. A. 1979. Under sea topography and distribution of dolphins of the genus Delphinus in the southern California Bight. J. Mammal. 60: 521-527.

Hui, C. A. 1985. Undersea topography and the comparative distributions of two pelagic dolphins. Fish. Bull. 83: 472-475.

Katona, S. K., S. A. Testaverde, and B. Barr. 1978. Observations on a white-sided dolphin, *Lagenorhynchus acutus*, probably killed in gill nets in the Gulf of Maine. Fish. Bull. 76: 475-476.

Katona, S. K., V. Rough and D. T. Richardson. 1983. A Field Guide to the Whales, Porpoises and Seals of the Gulf of Maine and eastern Canada -Cape Cod to Newfoundland. Scribner's Sons, New York. 255 pp.

Kenney , R. D., and H. E. Winn. 1986. Cetacean high-use habitats of the northeast U. S. continental shelf/slope areas. Fish. Bull. 84: 345-357.

Kenney, R. D., and H. E. Winn. 1987. Cetacean biomass densities near submarine canyons compared to adjacent shelf/slope areas. Cont. Shelf Res. 7: 107-114.

Kenney, R. D., D. R. Goodale, G. P. Scott, and H. E. Winn. 1981. Spatial and temporal distribution of Humpback Whales in the CETAP study area. Chap. V in A characterization of marine mammals and turtles in the Mid-and North Atlantic areas of the U. S. outer continental shelf. Ann. Rept. 1979, Cetacean and Turtle Assessment Program, Bureau of Land Management. Contract No. AA5Sl-CT8-48, U. S. Dept. of Interior, Wash. D. C.

Kenney, R. D., M. A. M. Hyman, R. F. Owen, G. P. Scott and H. E. Winn. 1986. Estimation of prey densities required by western North Atlantic right whales. Mar. Mamm. Sci. 2: 1-13.

Knapp, C. L., and H. E. Winn. 1978. Harbor seals, New Hampshire to Long Island. Report to the Grad. School of Oceanography, Univ. of Rhode Island. 36 pp.

Kraus, S. D. 1985. A review of the status of right whales (*Eubalaena glacialis*) in the western North Atlantic with a summary of research and management needs. U. S. Marine Mammal Commission Contract No. MMC-84/08, Washington, D. C. Available National Technical Information Service, Report No. PB86-154143, U. S. Dept. of Commerce, Springfield VA 22161, 61 pp.

Kraus, S. D., J. H. Prescott, A. R. Knowlton and G. S. Stone. 1986. Migration and calving of right whales (*Eubalaena glacialis*) in the western North Atlantic. Rep. Int. Whale Comm. (Spec. Issue 10): 139-144.

Kraus, S. D., J. H. Prescott, P. V. Tumbull, and R. R. Reeves. 1982. Preliminary notes on the occurrence of the North Atlantic right whale, *Eubalaena glacialis*, in the Bay of Fundy. Rep. Int. Whal. Commn 32: 407-411.

Lazell, J. D. 1976. This Broken Archipelago. Quadrangle Press (Harper and Row), N. Y. 260 pp.

Lazell, J. D. 1980. New England waters: critical habitat for marine turtles. Copeia 1980: 290-295.

LeBoeuf, B. J., and M. L. Bonnell. 1971. DDT in California sea lions. Nature 234:108-110.

Little, F. A., and J. C. Andrews. 1982. Drift whales at Nantucket: The kindness of Moshup. In Man in the northeast 23: 17-32.

Mairs, d. F., and L. W. Scattergood. 1958. Recent Maine records of the bottlenose dolphin and the beluga. Maine Field Naturalist 14: 78-80.

Martin, J. H., P. D. Elliot, V. C. Anderlini, D. Girvin, S. A. Jacobs, R. W. Riseborough, L. R. Delong, and W. G. Gilmartin. 1976. Mercury-selenium-bromide imbalance in premature parturient California sea lions. Mar. Biol. 35: 91-104.

Mayo, C. A. 1982. Observations of cetaceans: Cape Cod Bay and Southern Stellwagen Bank, Massachusetts 1975-1979. NTIS Report No. PB82-186263, 68 pp.

Mayo, C. A., D. K. Mattila, S. Pittman and L. Baraff. 1988. Abundance, distribution and habitat use of large whales in Massachusetts Bay and the Great South Channel. Natl. Mar. Fish. Serv. /Northeast Fish. Center Contract No. 50-EANF-6-00059. 152 pp.

Mayo, C., C. Carlson, P. Clapham, and D. Mattila. 1985. Humpback whales of the southern Gulf of Maine. Center for Coastal Studies, Provincetown, MA. Shank Painter Printing Co., Provincetown, MA. 62 pp.

Meylan, A. 1986. The riddle of the ridley. Natural Hist. 95(11): 90-96.

Mitchell, F. D., V. M. Kozicki and R. R. Reeves. 1986. Sightings of right whales, *Eubalaena glacialis*, on the Scotian Shelf, 1966-1972. Rep. Int. Whal. Commn (Spec. Issue 10): 83-107.

Morreale, S. J., A. Meylan, and B. Baumann. 1989. Sea turtles in Long Island Sound, New York: An historical perspective. pp. 121-122 In Eckert, S. A., K. l. Eckert, and T. H. Richardson (Compilers). Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Tech. Memo. NMFS-SEFC-232. 306 pp.

Munson, L. D., and D. F. Gaskin. 1989. The distribution of right whales and zooplankton in the Bay of Fundy. Can. J. Zool. 67: 1411-1420.

National Fish and Wildlife Laboratory. 1980a. Selected vertebrate endangered species of the seacoast of the United States: Leatherback Sea Turtle. U. S. Fish Wildl. Serv., Biol. Services Program. 6 pp.

National Fish and Wildlife Laboratory. 1980b. Selected vertebrate endangered species of the seacoast of the United States: Kemp's (Atlantic) Ridley Sea Turtle. U. S. Fish Wildl. Serv., Biol. Services Program. 6 pp.

Neave, D. J., and B. S. Wright. 1968. Seasonal migrations of the Harbor Porpoise (*Phocoena phocoena*) and other Cetacea in the Bay of Fundy. J. Mammal. 49: 259-264.

Newby, T. C. 1973. Changes in the Washington State harbor seal population, 1942-1972. The Murrelet 54: 4-6.

O'Shea, T., R. L. Brownell, Jr., D. R. Clark, Jr. W. A. Walker, M. L. Gray, and T. G. Lamont. 1980. Organochlorine pollutants in small cetaceans from the Pacific and South Atlantic oceans. Pesticide Monit. J., 14: 35-46.

Overholtz, W. J., and J. R. Nicolas. 1979. Apparent feeding by the fin whale, *Balaenoptera physalus* and humpback whale, *Megaptera novaeangliae* on the American sandlance, *Ammodytes americanus*, in the Northwest Atlantic. Fish. Bull. 77: 285-287.

Paulbitski, P. 1975. The seals of Strawberry Spit. Pacific Discovery, California Academy of Sciences, San Francisco, California 28: 12-15.

Payne, P. M., and D. C. Schneider. 1984. Yearly changes in abundance of harbor seals, *Phoca vitulina*, at a winter haul-out site in Massachusetts. Fish. Bull. 82: 440-442.

Payne, P. M., and L. A. Selzer. 1989. The distribution, abundance and selected prey of the harbor seal, *Phoca vitulina concolor*, in southern New England. Mar. Mamm. Sci. 5: 173-192.

Payne, P. M., D. N. Wiley, S. B. Young, S. Pittman, P. J. Clapham and J. W. Jossi. 1990a. Recent fluctuations in the abundance of baleen whales in the southern Gulf of Maine in relation to changes in selected prey. Fish. Bull. 88: 687-696.

Payne, P. M., D. W. Heinemann and G. T. Waring. 1990b. The distributional biology and assessment of pilot whales *Globicephala* in the shelf waters of the northeastern United States, 1978-1988.

Payne, P. M., J. R. Nicolas, L. O'Brien, and K. D. Powers. 1986. Distribution of the humpback whale (Meoaptera novaeandliae) on Georges Bank and in the Gulf of Maine in relation to densities of the sand eel (*Ammodytes americanus*). Fish. Bull. 84: 271-277.

Payne, P. M., L. A. Selzer, and A. T. Knowlton. 1984. Distribution and density of cetaceans, marine turtles and seabirds in the shelf waters of the northeastern United States. June 1980 - Dec. 1983, from shipboard observations. NMFS/NFFC Contr. No. NA-81-FA-C-00023. 246 pp.

Plotkin, P. 1989. Feeding ecology of the loggerhead sea turtle in the northwestern Gulf of Mexico. pp. 139-141. *In* Eckert, S. A., K. l. Eckert, and T. H. Richardson (Compilers). Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Tech. Memo. NMFS-SEFC-232. 306 pp.

Prescott, J. H., and P. M. Fiorelli. 1980. Review of the harbor porpoise (*Phocoena phocoena*) in the U. S. Northwest Atlantic. Final Rept. to Marine Mamm. Commission Contract No. MM8ACO16, NTIS PB8O-176928. 55 pp.

Reeves, R. R., and F. Mitchell. 1986. The Long Island, New York, right whale fishery: 1650-1924. Rept. Int. Whal. Commn (Spec. Issue 10: 201-220.

Reeves, R. R., and S. K. Katona. 1980. Extralimital records of white whales (*Delphinapterus leucas*) in eastern North Amencan waters. Canadian Field-Naturalist 94: 239-247.

Reeves, R. R., J. G. Mead, and S. Katona. 1978. The right whale, *Eubalaena glacialis* in the western North Atlantic. Rep. Int. Whal. Commn 28: 303-312.

Reijnders, P. J. H. 1980. Organochlorine and heavy-metal residues in harbour seals from the Wadden Sea and their possible effects on reproduction. Neth. J. Sea Res. 14: 30-65.

Reijnders, P. J. H. 1982. On the ecology of the harbour seal *Phoca vitulina* in the Wadden Sea: population dynamics, residue levels, and management. The Vet. Quart. 4: 36-42.

Reijnders, P. J. H. 1984. Man-induced environmental factors in relation to fertility changes in pinnipeds. Env. Cons. 11: 61-65.

Risebrough, R. W., P. Reiche, S. G. Herman, D. B. Peakall, and M. N. Kirven. 1968. Polychlorinated biphenyls in the global ecosystem. Nature 220:

Schevill, W. F. 1956. *Ladenorhynchus acutus* off Cape Cod. J. Mammal. 27: 128-129.

Schevill, W. F., K. F. Moore, and W. F. Watkins. 1981. Right Whale, Eubalaena glacialis, sightings in Cape Cod waters. Woods Hole Ocean. Inst. Tech. Rept. WHOI-81-50, Woods Hole, MA. 16 pp.

Schevill, W. F., W. A. Watkins and K. F. Moore. 1986. Status of *Eubalaena glacialis* off Cape Cod. Rept. Int. Whal. Commn (Spec. Issue 10): 79-82.

Schneider, D. C., and P. M. Payne. 1983. Factors affecting haul-out of harbor seals at a site in Southeastern Massachusetts. J. Mammal. 64: 518-520.

Schurman, V. R. 1983b. Report on Muskeget area grey seals, winter and spring 1983. NMFS/NEFC Contract No. NA-83-FB-A-00075. 15 pp.

Scott, G. P., R. D. Kenney, J. P. Gilbert, and R. F. Edel. 1981. Estimates of cetacean and turtle abundance in the CeTAP study area with an analysis of factors affecting them. Chap. IX In A characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U. S. outer continental shelf. Ann. Rept. 1979, CETAP Program, Univ. of Rhode Island. Prepared for Bureau of Land Mgmt, U. S. Dept. of Interior, Washington, DC.

Selzer, L. A., and P. M. Payne. 1988. The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphins (Delphinus delphis) vs. environmental features of the continental shelf of the northeastern United States. Mar. Mamm. Sci. 4: 141-153.

Sergeant, D. E., A. W. Mansfield, and B. Beck. 1970. Inshore records of Cetacea for eastern Canada, 1949-1968. J. Fish. Res. Board Can. 27: 1903-1915.

Sergeant, D. F., and P. F. Brodie. 1969. Body size in white whales, *Delphinapterus leuca*s. J. Fish. Res. Board Can. 26: 2561-2580.

Sergeant, D. F., and P. F. Brodie. 1975. Identity, abundance and present status of populations of white whales, *Delphinapterus leucas*, in North America. J. Fish. Res. Board Can. 32: 1. 047-1054.

Sergeant, D. F., D. J. St. Aubin, and J. R. Geraci. 1980. Life History and northwest Atlantic status of the Atlantic white-sided dolphin, *Lagenorhynchus acutus*. Cetology 37: 1-12.

Sergeant,D. F., and H. D. Fisher. 1957. The Smaller Cetacea of Eastern Canadian Waters. J. Fish. Res. Board Can. 14: 83-115.

Sherman, K. C., C. Jones, L. Sullivan, W. Smith, P. Berrein, and L. Ejstment. 1981. Congruent shifts in sand eel abundance in western and eastern north Atlantic ecosystems. Nature 291: 486-489.

Shoop, C. R., T. L. Doty, and N. E. Bray. 1981. Sea turtles in the region between Cape Hatteras and Nova Scotia in 1979. Chap. IX In A characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U. S. outer continental shelf. Ann. Rept. 1979, CETAP Program, Univ. of Rhode Island. Prepared for Bureau of Land Mgmt, U. S. Dept. of Interior, Washington, DC.

Smith, G. J. D., and D. F. Gaskin. 1974. The diet of harbor porpoises (*Phocoena phocoena [L.]*) in coastal waters of eastern Canada, with special reference to the Bay of Fundy. Can. J. Zool. 52: 777-782.

Smith, T., P. M. Payne, D. W. Heinemann, G. T. Waring and A. Lange. 1988. Utility of cetacean and seabird sighting surveys conducted during fishery surveys. Int. Cons. Expl. Seas (ICES), C. M. 1988/N: L 5. 40 pp.

Standora, F. A., S. J. Morreale, R. Esters, R. Thompson and M. Holburger. 1989. Growth rates of juvenile Kemp's ridleys in Long Island Sound, New York: An historical perspective. pp. 121-122 In Eckert, S. A., K. l. Eckert, and T. H. Richardson (Compilers). Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Tech. Memo. NMFS-SEFC-232. 306 pp.

Stone, G. S., S. D. Kraus, J. H. Prescott and K. W. Hazard. 1988. Significant aggregations of the endangered right whale, *Eubalaena glacialis*, on the continental shelf off Nova Scotia. Can. Field Naturalist 102: 471-474.

Sullivan, R. M. 1980. Seasonal occurrence and haul-out use in pinnipeds along Humboldt County, California, 1980-1982. J. Mammal. 61: 754-760.

Summer, F. B. 1909. The Biological Laboratory of the Bureau of Fisheries at Woods Hole, Mass. Report of the past year's work, and announcement for the coming season. pp. 983-987 In Science, New Ser., Vol. 29.

Taruski, A. G., C. F. Olney, and H. F. Winn. 1975. Chlorinate hydrocarbons in cetaceans. J. Fish. Res. Board Can. 32: 2205-.

Testaverde, S. A., and J. G. Mead. 1980. Southern distribution of the Atlantic whitesided dolphin, *Lagenorhynchus acutus*, in the western North Atlantic. Fish. Bull. 78: 167-169.

Waring, G. T., Parry, B. L., Nicolas, J. R., Gerrior, P., and Payne, P. M. 1990. Incidental take of marine mammals in foreign fishery activities off the northeast USA, 1977-1988. Fish. Bull. 88: in press.

Waters, J. H., and C. J. Rivard. 1962. Terrestrial and marine mammals of Massachusetts and outer New England states. Standard Modern Printing Company, Brockton, Massachusetts. 151 pp.

Watkins, W. A., and W. E. Schevill. 1979. Aerial observation of feeding behavior in four baleen whales: *Eubalaena glacialis*, *Balaenoptera borealis*, *Megaptera novaeangliae*, *Balaenoptera physalus*. J. Mamm. 60: 155-163.

Watkins, W. A., and W. E. Schevill. 1982. Observations of right whales, *Eubalaena glacialis*, in Cape Cod waters. Fish. Bull. 80: 875-880.

Winn, H. E., C. A. Price and P. W. Sorensen. 1986. The distributional biology of the right whale (*Eubalaena glacialis*) in the western North Atlantic. Rep. Int. Whale Comm. (Spec. Issue 10): 129-138.

Winn, H. E., D. R. Goodale, M. A. M. Hyman, R. D. Kenney, C. A. Price, and G. P. Scott. 1981. Right whale sightings and the right whale minimum count. Chap. VI In A characterization of marine mammals and turtles in the Mid- and North-Atlantic areas of the U. S. outer continental shelf. Ann. Rept. 1979, CETAP Program, Univ. of Rhode Island, prepared for Bureau of Land Mgmt., U. S. Dept. of Interior, Washington, DC.

Wishner, K., E. Durbin, A. Durbin, M. Macaulay, H. Winn, and R. Kenney. 1988. Copepod patches and right whales in the Great South Channel off New England. Bull. Mar. Sci. 43: 825-44.