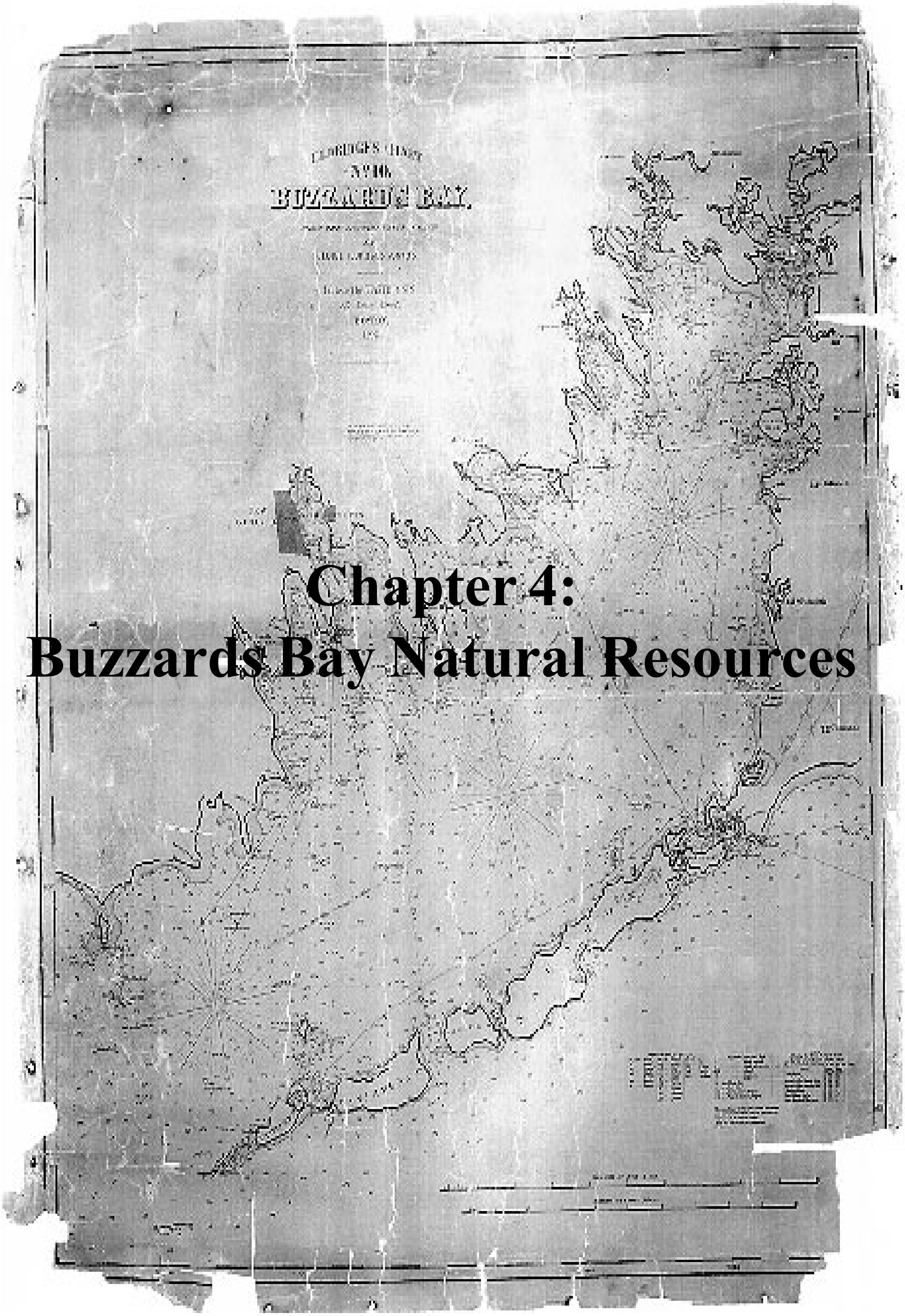
Chapter 4:
Buzzards Bay Natural Resources



Buzzards Bay maintains a wide variety of habitats within its environs, representative of most ecosystem types found along the mid-Atlantic coast of the United States. Barrier beaches, tidal wetlands, tidal flats, rocky intertidal zones, and hard and soft sediment systems are found all along the perimeter of the bay, as well as circulation-restricted coves and embayments providing protected habitat for many plant and animal species.

The somewhat unique positioning of Cape Cod along the Atlantic coast has made it a zoogeographic barrier making Buzzards Bay the northern limit for many marine species. North of Cape Cod to Labrador (the American Atlantic Boreal Region), the biota is more arctic in species composition compared with the more temperate species found from the south of Cape Cod to Texas (the American Atlantic Temperate Region). Cape Hatteras forms another boundary to the south, and the region between Cape Cod and Cape Hatteras is known as the Virginian Province. Because of the influence of different currents (the Labrador and Maine currents from the north and the Gulf Stream from the south), water temperatures vary greatly between Cape Cod Bay and Buzzards Bay, with many cold water species ranging only as far south as Cape Cod, and vice versa. The mixing of Cape Cod Bay water with that of Buzzards Bay since the construction of the Cape Cod Canal has stimulated interest regarding potential changes in distribution of various species as a result of this physical alteration.

The shallow water areas within Buzzards Bay are strongly influenced by meteorological conditions and watershed inputs. Because they are shallow and generally have limited tidal exchange, these areas tend to have greater ranges of environmental conditions than those in the central bay. For example, embayment waters frequently warm more rapidly than the bay with approaching summer months and cool more rapidly with the onset of winter. In addition, as these nearshore waters are the immediate recipient of freshwater inputs from terrestrial sources, their salinity structure is more typical of estuaries. Another ecological stress in these embayments is ice rafting, which results from tidal fluctuations during winter months. Ice rafting often leads to the scouring of many shallow water areas including tidal wetlands and flats. This scouring often results in the disturbance of bottom-dwelling communities or the dislocation and movement of large sections of wetland peat. As a result of their structure, circulation, and proximity to nutrient inputs from the adjacent watershed, these shallow embayments tend to have higher rates of productivity than the central bay region on an areal basis and are more susceptible to periodic hypoxic or anoxic conditions in their bottom waters. The net result is a relatively environmentally stable central bay region, fringed with embayments presenting not only a variety of physical habitats but also a greater range in environmental conditions. In this chapter we describe the major habitats within the Buzzards Bay estuarine system and the dominant plant and animal species that help to define them.

4.1. Open Water and Embayments

4.1.1. Fauna

Benthic. The composition and distribution of benthic communities within Buzzards Bay are determined primarily by the sediment characteristics of the bay bottom (Table 4.1). Composition and grain size affect the ability of many benthic animals, notably invertebrates and bivalves, to settle and burrow. The benthic community that evolves is secondarily affected by the sediment organic content, which represents a carbon source for benthic deposit feeders and heterotrophic microbial communities. For a benthic community under a vertically well-mixed water column a high sediment organic content is beneficial. In areas where periodic stratification occurs, however, the concomitant high microbial respiration rates create low oxygen conditions in bottom waters, which can result in lower populations through reduced recruitment and larval survival or even shifts in benthic community structure towards lower diversity and more opportunistic species. It is the interaction between grain size

Table 4.1. Dominant soft-bottom, hard-bottom, and rocky intertidal communities in Buzzards Bay. Soft-bottom species listed comprise 95% of the species present by number. Hard-bottom species are listed when found to comprise more than 1% of the population. Data on soft- and hard-bottom species from Sanders (1958, 1960); rocky intertidal data from unpublished field surveys (Boston University Marine Program).

Substrate	Species	Class or phylum[a]
Soft bottom		
	Nuncula proxima	Bivalvia
	Nephthys incisa	Polychaeta
	Ninoe nigripes	Polychaeta
	Cylichna orzya	Gastropoda
	Callocardia morrhuana	Bivalvia
	Hutchinsoniella macracantha	Crustacea
	Lumbrineris tenuis	Polychaeta
	Turbonilla sp.	Gastropoda
	Spio filicornis	Polychaeta
	Retusa canaliculata	Gastropoda
	Stauronereis caecus	Polychaeta
Hard bottom		
	Ampelisca spinipes	Crustacea
	Byblis serrata	Crustacea
	Cerastoderma nulatum[b]	Bivalvia
	Ampelisca macrocephala	Crustacea
	Glycera americana	Polychaeta
	Nephthys bucera	Polychaeta
	Tellina tenera	Bivalvia
	Ninoe nigripes	Polychaeata
Hard bottom (cont'd)		
	Lumbrineris tenuis	Polychaeta
	Nepthys incisa	Polychaeta
	Molgula complanata	Tunicata
	Unciola irrorata	Crustacea
Rocky intertidal		
	Semibalanus balanoides	Crustacea
	Balanus balanus	Crustacea
	Carcinus maenas	Crustacea
	Cancer irroratus	Crustacea
	Pagurus longicarpus	Crustacea
	Littorina littorea	Gastropoda
	Littorina obtusata	Gastropoda
	Littorina saxatilis	Gastropoda
	Mytilus edulis	Bivalvia
	Modiolus modiolus	Bivalvia
	Crepidula fornicata	Gastropoda
	Nereis virens	Polychaeta
	Ascophyllum nodosum	Phaeophyta
	Fucus vesiculosus	Phaeophyta
	Chondrus crispus	Rhodophyta

[a] Phyla are listed for seaweeds, classes for other species.

[b] Because *Cerastoderma* populations are highly seasonal, it is not considered to be a good characterizing species for this community (Sanders 1958).

and organic matter and oxygen that appears to be structuring Buzzards Bay benthic communities today.

Sanders (1958, 1960) characterized the benthic communities in Buzzards Bay into two faunal groups or assemblages. The first is typified by deposit feeders generally present in softer, muddier sediments and dominated by the polychaete *Nephthys incisa* and the lamellibranch *Nuncula proxima***.** The weak currents that allow organic matter to settle out in these areas provide a source of food for large numbers of these deposit feeders (average *Nuncula* density 30-40,000/m^2). Data from Sanders (1958, 1960) also indicate that the distribution of deposit feeders is strongly correlated to the percentage of clay, with the smaller clay particles having more surface area to bind organic matter. The second community is primarily found offshore in sandy bottoms and is made up mainly of filter feeders dominated by amphipods (*Ampelisca* spp.). The primary determinant for distribution of filter feeders is not fully known, but their communities generally predominate in areas of well-sorted fine sands indicative of moderate, relatively constant currents that provide sufficient food via suspension in the water column.

Driscoll and Brandon (1973) further divided subtidal habitats within Buzzards Bay into four functional groups: shallow protected, nearshore, open bay, and offshore. The shallow protected, nearshore, and offshore areas are generally characterized as having fine-grained sediments (mean grain diameter of less than 0.18 mm), analogous to the *Nuncula proxima - Nephthys incisa* communities identified by Sanders (1958, 1960). These three habitats have distinctly different sediment characteristics and faunal assemblages than the open bay areas (mean grain diameter greater than 0.18 mm), more comparable to the *Ampelisca* assemblage (Sanders 1958, 1960).

The similarities in sediment type between the shallow protected and offshore sites are identified as the result of two sets of physical conditions. In the shallow protected areas, eelgrass, which is often prevalent, exerts a dampening effect on currents, resulting in deposits of fine-grained, silt- and clay-rich sand. Near the mouths of harbors sediments are generally fine-grained but poorly sorted, due to stream inputs carrying little or no coarse detritus and to deposition in a dynamic flow field with variable wind and wave activity. The sediments in the deeper offshore areas also experience less wave energy and lower current velocities and are afforded some protection by the dendritic troughs of the Pleistocene drainage system (Driscoll and Brandon 1973), resulting in the accumulation of fine-grained but less organically rich sediments. Offshore areas are generally characterized by water deeper than 9 m. The offshore molluscan macrofauna of northwestern Buzzards Bay is predominately represented by two species (making up 90% of all collected), *Nassarius trivittatus* and *Yoldia limatula*. In contrast, the shallow, more protected areas are colonized by a variety of molluscan fauna, dominated by *Crepidula fornicata, Nuncula proxima, Crepidula plana, Bittium alternatum,* and *Laevicardium mortoni*. The most obvious difference in fauna is seen in the abundance of *Nuncula proxima* in shallow, protected areas and its near absence from other areas.

Nearshore sediments maintain greater relative abundance of *Macoma tenta* and *Eupleura caudata*, with few *Nuncula proxima* and relatively fewer *Nassarius trivittatus* than the offshore areas. Open-bay environments, on the other hand, are substantially different from the other three subsystem types. Benthic communities of the open bay are generally characterized by suspension feeders, carnivores, herbivores, or nonselective deposit feeders such as *Nassarius trivittatus*, *Chaetopleura apiculata,* and *Anachis avara*. Sanders (1958) suggested that the fauna of stable sand bottoms is probably inherently more diverse than that of mud bottoms, most likely because of the more stable (less stressful) environmental conditions at these sites.

Overall the deeper parts of Buzzards Bay have maintained a stable benthic community for several decades. Nearshore areas that have been organically enriched (possibly by sewage), such as those within New Bedford Harbor, are dominated by *Mediomastus ambiseta*; this species is an opportunistic colonizer of polluted sediments or those subject to disturbances that limit recruitment of most other benthic organisms. Monitoring of infaunal populations has been conducted at what is known as the 301(h) Site offshore from New Bedford Harbor (Howes and Taylor 1989), and populations have shown little change from what Sanders found in the late 1950's and early 1960's. It appears that benthic populations within the central bay remain relatively "pristine," even in the region of New Bedford, which contributes almost all of the sewage to Buzzards Bay waters and almost half of the total nitrogen load. Even in this region, the impact on benthic communities appears restricted to nearshore areas (Howes and Taylor 1989; Costa et al. 1992).

Although sediment characteristics are important to structuring the infaunal assemblages in Buzzards Bay, the reverse is also true. Bioturbation and sediment reworking by benthic infauna are significant in structuring the biogeochemistry of these sediments. In fact, Rhoads (1963) estimated that although one species, *Yoldia limatula*, a deposit-feeding pelecypod, represented less than 10% of the total bottom fauna, it was potentially capable of entirely reworking the sediments within its range of distribution in the bay (Fig. 4.1). More than half buried, this clam ingests sediment, extracting food and ejecting waste several centimeters into the water, which eventually settles into small mounds around the siphon. Typical of deposit feeders, this species acts to mix surface sedimentary layers, alters the characteristics of some of the particles through aggregation into fecal pellets, and potentially increases the oxidation state of the surface sediments through the presence of its burrow.

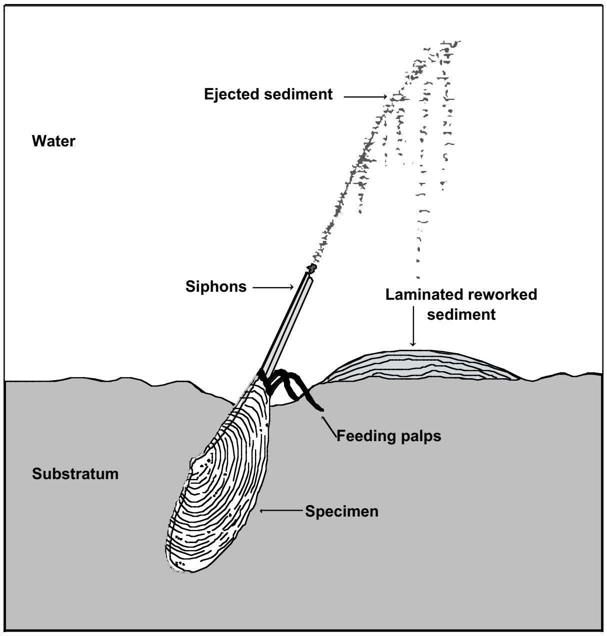


Fig. 4.1. Method of feeding and reworking of sediments by *Yoldia limatula*. From Rhoads (1963).

The state of oxidation or reduction of the benthic sediments at any one location is an integration of the type of benthic community, rate of bioturbation, and rate of delivery of organic-rich particles to the sediments. In areas with low organic matter delivery or deep burrowing, deposit-feeding communities the sediments are generally oxidized, and conversely more reducing (sulfitic) where high rates of organic deposition and shallow burrowing communities occur. In Buzzards Bay, physical disturbances can affect benthic communities and hence bioturbation by reducing the depth of bioturbation and increasing the sulfitic zone of the sediments; with sufficient time, the communities are reestablished. Over the past 100 years, however, nutrient and organic discharges to Buzzards Bay waters (e.g., New Bedford) have led to increased organic delivery to sediments in some areas, which appears to have resulted in the alteration of benthic communities. Whether the structuring factor is the rate of organic matter delivery directly or secondary effects of water column hypoxia or anoxia is unclear. The result is declining diversity and shallowing of the depth of bioturbation and therefore an increase in the sulfitic zone in those areas. This general scheme of alterations (Rhoads and Germano 1986) in benthic communities and sediment oxidation (Fig. 4.2) is occurring in Buzzards Bay today; the difficulty for ecologists and managers is to distinguish alterations driven by natural or physical forces from those driven by nutrients and organic matter.

Buzzards Bay sediments also play an important role in the life stages of many pelagic species. For instance, studies of the eggs of marine planktonic copepods in the bottom sediments of Buzzards Bay indicate that sediments may be part of an important pathway for recruitment of these organisms into the plankton community. The eggs, which have the ability to resist digestion when ingested by benthic predators, overwinter in the sediments and hatch in spring when water temperatures rise (Marcus 1984). In shallow coastal waters such as Buzzards Bay, storm events, current flow, and bioturbation also influence the transport and hatching of these eggs. Marcus (1984) and others (Dale 1976; Anderson et al. 1982) indicated this mechanism may also be important for dinoflagellate bloom formation, whereby large numbers of cysts and fine-grained sediment particles accumulate on the sea floor and are resuspended on a large scale by certain physical disturbances such as coastal storms. Marcus and Fuller (1989) later determined that physical mechanisms affecting sedimentation and transport can be used to predict the distribution and abundance of recently spawned eggs on the bay bottom.

Meiofauna. Meiofauna represent infauna from most marine phyla with the unifying trait that they are animals, mostly metazoans, that can pass through a 1.0-0.5 mm screen. Their role in organic matter cycling in coastal sediments is still an area of active research, but it is clear that they play a role in sediment microbial food chains and are consumed by deposit feeders. Meiofaunal populations in Buzzards Bay are overwhelmingly dominated by nematodes and kinorhynchs, composing between 89 and 99% of the total numbers (Wieser 1960). Certain species of nematodes appear to be restricted to particular sediment types; for instance *Odontophora* and *Leptonemella* species dominate sandy

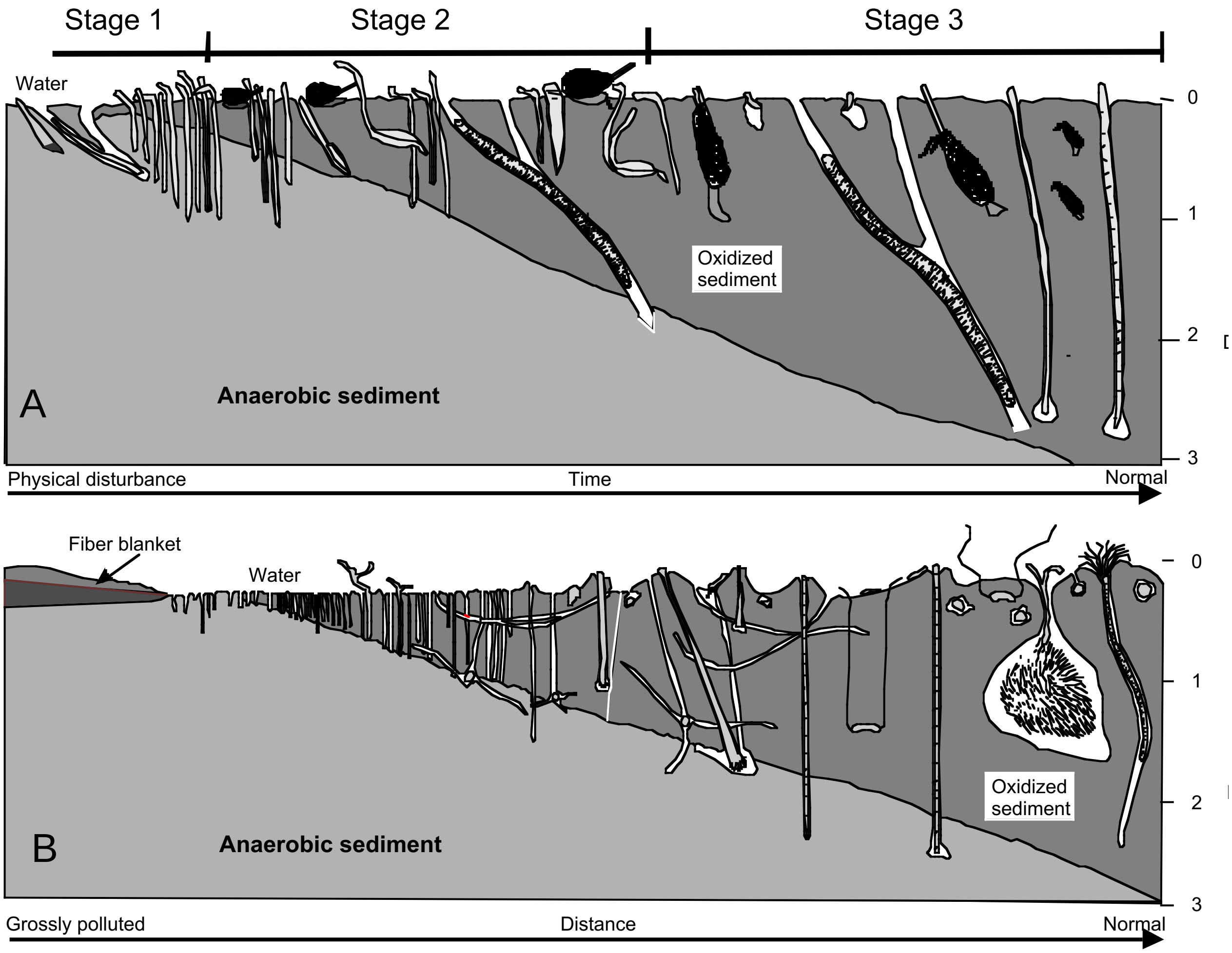


Fig. 4.2. Alterations in benthic communities and relation to sediment oxidation/reduction state under varying levels of (a) physical disturbance, or (b) nutrient and organic matter pollution. From Rhoads and Germano (1982).

sediments, whereas areas of finer grained, silty sediments are dominated by the nematode *Terschellingia* spp. and kinorhynchs such as *Trachydemus* spp. Observations of the distribution of these dominant metazoans are comparable to Sanders' (1958, 1960) sand and silt distinctions for macrofauna, with combinations of species determined by the relative amounts of sand versus fine deposits present.

Shellfish. Shellfish are benthic animals and in most cases infauna; however, because they support commercial and recreational fisheries, they have special conditions regulating their population densities. Shellfish are relatively fast growing and easy to harvest. Buzzards Bay, with its many protected harbors and embayments, provides numerous suitable habitats for hard-and soft-shelled clams, oysters, and scallops. Shellfish are also important in coastal food chains with large numbers of eggs and larvae entering the plankton during spring and summer months providing a food source for juvenile fish and crustaceans. Suitable habitat is important to the production of shellfish in that the young of various species require specific types of substrates or sediment grain sizes upon which to settle or burrow. Various shellfish species have specific salinity and temperature ranges for reproduction and growth. Water circulation also plays a role in maintaining temperature and oxygen conditions as well as in transporting planktonic food, since all of the harvested bivalve species are filter feeders. Hard-shell clams or quahogs, soft-shell clams, scallops, and oysters are the dominant shellfish species in the bay, followed to a lesser extent by the edible blue mussel, which although easily gathered and delicious has not reached the popularity it has in Europe.

The most widespread shellfishery in Buzzards Bay is the hard-shelled clam or quahog, *Mercenaria mercenaria* (Fig. 4.3). Cape Cod is as the northern boundary to large-scale distribution of the species (Belding 1916), which is a warm water mollusk. Quahogs grow in shallow and deep water; however, they were primarily harvested in shallower waters until the advent in 1982 of a deep water dredge fishery in the bay. *Mercenaria* populate sandy to muddy sand bottoms generally in areas where salinity is above 15 ppt and can be found virtually along the perimeter of the bay. They burrow into the sediments and extend their siphons into the water column to feed. These clams are quite tolerant to short-period stresses such as bottom water anoxia; they can also survive during harvest when they are out of water for long periods by "clamming up," remaining with their shells closed until conditions improve. Larger individuals are extremely hardy and can survive days of anoxia or emerge from deep burial (tens of centimeters) caused by shifting sands or overwash during storms. Although these clams grow quickly and achieve marketable size in 3-4 years, they may live up to 25 years.

Fig. 4.3. Quahogs (*Mercenaria mercenaria*), left, and shoft-shelled clams (*Mya arenaria*), right. Photo by D. Goehringer.

Soft-shelled clams, *Mya arenaria* (Fig. 4.3), generally occur in sandy or muddy sediments in protected harbors and inlets and in salt marsh creeks, burrowed in the sediment with siphons extending into the water column. Their fragile shells are less tolerant to disturbance and are more easily broken than those of most other species of clams in the Buzzards Bay region. Because their shells do not close tightly (a portion of the siphon protrudes from the shell), they have limited tolerance to anoxia and can suffer high mortalities from sulfide accumulation under low oxygen conditions resulting from either natural or anthropogenic causes. Because these shellfish are more prevalent in soft, organic-rich sediments, occasional low oxygen conditions are likely due to oxygen depletion in bottom waters that results from microbial decomposition of this organic matter. Intolerant of salinities less than 5 ppt, they frequently inhabit low-energy embayments where organic matter can accumulate yet with sufficient flushing or limited freshwater inputs to maintain high enough salinity for reproduction and growth. The combination of low-energy, high organic matter environments and sensitivity to hypoxia can result in mass mortalities of this species, as have occurred in Cape Cod Bay (G.R. Hampson, Woods Hole Oceanographic Institution, personal communication). Because of the somewhat fragile nature of their shells, there has been recent interest in hydraulic dredging to decrease losses during harvest and increase yields over traditional hand-tonging.

In addition to infaunal bivalves, Buzzards Bay is recognized for its high productivity of the epibenthic bay scallop, *Aequipecten irradians* (Fig. 4.4; Gutsell 1930). Cape Cod is considered the northern limit for the scallop, which is less common in the colder waters to the north (Goode 1887; Davis 1989). The commercial scallop fishery in Buzzards Bay began in New Bedford in 1870, principally in the lower Acushnet River and Clarks Cove, and rapidly expanded to the upper regions of the bay (Davis 1989). Today, there are many areas around the bay where scallops still sustain an important commercial fishery, primarily in the Westport River but also in the Acushnet River and Clarks Cove on the western shore, West Falmouth and Wings Neck

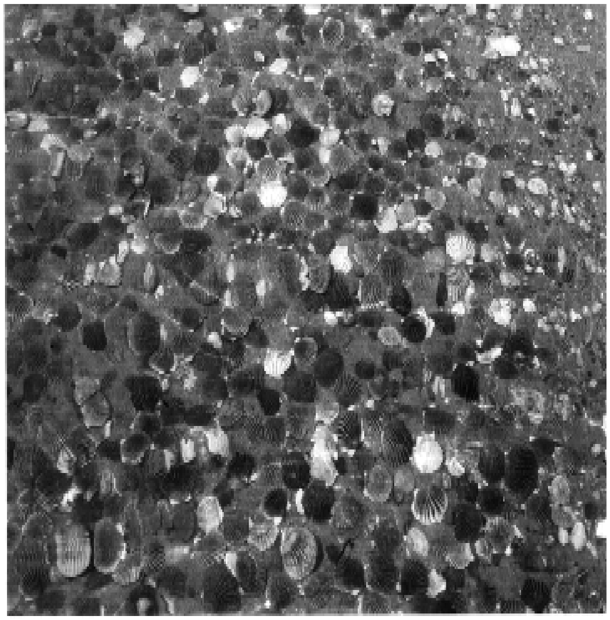


Fig. 4.4. Scallops *Aequipectin irradians*. Photo by D. Goehringer.

along the eastern shore, and the headwaters of the bay.

Adult bay scallops are highly mobile, propelling themselves through the water by expelling water through the rapid contraction of their shells by their adductor muscle. This muscle is highly prized for its delicate flavor and provides the main edible portion of the scallop. Bay scallops grow quickly and rarely live more than 2 years. Scallops have only one spawning season and environmental conditions can cause unpredictable sets (Lee 1980; Capuzzo et al. 1982). The combination of a short life span and limited spawning season is partially responsible for the large fluctuations in clean populations that drive the large annual variations in catch. Spawning generally occurs during early summer when water temperatures approach the annual maximum (20-24° C) and are coincident with phytoplankton blooms (Sastry 1966, 1968). Although bay scallops are generally most abundant in shallow embayments, they are also found, occasionally in large numbers, at depths of 4.5-12 m in Buzzards Bay (Capuzzo 1984). Studies of bay scallop gonads taken from offshore stations in Buzzards Bay (9 m depth) showed offshore populations spawned earlier and over longer periods than inshore populations (e.g., Wings Cove, 2-m depth). Although catches are less predictable in the offshore areas, the scallops appear to have 20-50% more muscle weight than specimens collected inshore (Capuzzo et al. 1982).

Scallops are filter feeders and as juveniles are sedentary, often attaching themselves by byssal threads to eelgrass (*Zostera marina*) blades above the sediment surface. The impacts of nutrient pollution—such as increasing epiphyte growth or turbidity in the water column, which decreases light availability—can have serious consequences for eelgrass beds, hence scallop populations, by eliminating an important substrate for the early growth of juveniles. Eelgrass blight or wasting disease, responsible for the loss of large expanses of eelgrass beds in various areas along the North Atlantic coast (1931-32), has indirectly been identified as the cause of subsequent declines in scallop populations in these regions. The presence of toxic pollutants such as heavy metals may also affect scallop populations. The scallop fishery in Acushnet River and Clarks Cove has declined in recent years, possibly as a result of exposure to the high levels of copper in New Bedford Inner Harbor and Outer Harbor sediments. Copper in the water column has been shown to reduce growth in these shellfish (Sindermann 1979; Davis 1989). Whatever the cause, scallop harvests have been low for the past decade.

Crassostrea virginica, the common oyster, is not as abundant in Buzzards Bay as other harvested bivalves. The entire eastern shore of the bay (Figs. 1.4, 3.1, and Table 3.1), the Agawam, Westport, and Weweantic rivers, Wings Cove, and parts of Sippican Harbor (in Marion) all support oyster beds. After going through initial juvenile stages, young oysters (known as "spat") require a hard substrate upon which to settle and grow and are often found on rocks, pilings, or frequently other oysters. As in the case of other bivalve mollusks, they are subject to a variety of natural predators (e.g., crabs, birds, sea stars, and oyster drills). Oyster harvesting is not presently a large commercial industry around Buzzards Bay, but evidence of past oyster harvests exists in shell middens, or shell piles, left by the Native Americans in areas around the bay shores. In these shell middens, as today, quahogs were the dominant species, with fewer oysters and soft-shelled clams (Kitteridge 1930; Emery 1979).

Other species of edible shellfish are also found in Buzzards Bay waters but provide little recreational or commercial harvest. Black clams, *Arctica islandica*, similar in appearance to quahogs, can be found throughout the bay. Although they generally inhabit deep waters, they are also found in shallow regions. *Pitar morrhuanus* or the "duck clam" is also fairly common in soft bottom areas but is generally not harvested because of its strong flavor and weak shell. The common razor or Atlantic jacknife clam (*Ensis directus*) is abundant in the lower intertidal to subtidal sandy and muddy regions. As the clam burrows deeply, the sharp edge of its long slender shell can inflict a significant cut to the unaware barefoot clammer. Although it supports a recreational shellfishery, this clam's rapid escape into deep burrows limits the catch per unit effort in comparison to other species.

The only major crustacean harvested is the lobster (*Homarus americanus*). Lobstering represents an important commercial resource for Buzzards Bay and supports a small recreational fishery. Buzzards Bay is a spawning ground for lobsters. Larval lobsters hatch in Buzzards Bay beginning in late May, and the earliest larval stage is no longer found by mid-July (Collings et al. 1983). Significantly greater numbers of gravid females as a proportion of the total catch are typically observed in Buzzards Bay compared to regions north of Cape Cod. In 1987 the catch percentage of gravid females for Buzzards Bay was 31%, in strong contrast to the state average of 9.2%, and about double the 19% reported for the lobster fishery of the Outer Cape (Estrella and McKiernan 1988, 1989). The higher larval densities in Buzzards Bay compared to other Massachusetts and New England waters north of Cape Cod are likely due to warmer temperatures, resulting in the more rapid maturation of females and enhanced spawning stock levels (Lux et al. 1983). The bay's water residence time and warm spring to fall temperatures help to make it one of the more favorable areas for growth and spawning of lobsters in New England. In fact, Buzzards Bay "exports" significant numbers of larvae (10-20 million per year) through the Cape Cod Canal (Collings et al. 1983). The Buzzards Bay larvae and spawn from lobsters residing in the rocky bottom of the canal presumably help to support the lobster fishery in Cape Cod Bay.

Primarily nocturnally active invertebrates, lobsters generally hide during the daylight hours in rock or grass shelters, emerging during twilight hours to feed. Small lobsters frequent shallow waters near shore, while larger individuals (occasionally up to 22.7 kg) are more prevalent in deeper offshore waters. Relatively slow moving in their four-legged walk, lobsters have the ability to rapidly propel themselves backward for short distances by the contraction of their tails. The characteristic claws of the lobster perform two functions: the larger of the two, or "crusher," is designed for cracking hard objects like the shells of snails or bivalves; the smaller, sharper claw, or "cutter" is used for tearing apart prey (generally fish) or plant material. Lobsters are also known for their cannibalistic behavior, frequently eating other lobsters in their soft-shell (just past molting) stage and even their own young (Meinkoth 1981; Davis 1989).

Fish. Only limited quantitative data are available on the fish populations in Buzzards Bay because prohibition of net fishing in bay waters nearly a century ago eliminated catch records available from this source. There is, however, sufficient information to identify the prevalent species that make the bay home for part or all of their life cycles. The fisheries of Buzzards Bay are discussed in Chapter 5.

Reviews of the available data on Buzzards Bay fisheries identify 10 dominant fish species (excluding salt marsh fish described in a following section) currently found in bay waters (Table 4.2), with numerous other species occasionally present. As in other embayments, these include residents and nonresidents (migratory species), some commercially and recreationally valuable and others not. With its

Table 4.2. Dominant commercially valuable fish species in Buzzards Bay in order of post-1960 abundance and their food preferences (adapted from Davis 1989).

Common name	Scientific name	Food preference
Scup (or porgy)	*Stenotomus chrysops*	Assorted benthos, occasionally small fish
Butterfish	*Peprilus triacanthus*	Copepods, small fish, jellyfish, worms
Winter flounder	*Pleuronectes americanus*	Worms, gastropods, bivalves
Alewife	*Alosa pseudoharengus*	Copepods, shrimp, eggs, and larvae
Blueback herring	*Alosa aestivalis*	Copepods, shrimp, eggs, and larvae
Atlantic menhaden	*Brevoortia tyrannus*	Phytoplankton
Black sea bass	*Centropristis striata*	Mysids and other benthic organisms
Tautog	*Tautoga onitis*	Mollusks, crabs, worms, lobsters
Bluefish	*Pomatomus saltatrix*	Fish, worms, shrimp, lobster, squid, crab
Striped bass	*Morone saxatilis*	Fish, worms, shrimp, lobster, squid, crab

many coves, smaller embayments, salt marshes, and tidal flats, Buzzards Bay represents a significant spawning ground for southern New England, perhaps the best area in all of New England (Davis 1989). In conjunction with a larger spawning area, including Vineyard and Long Island sounds, large numbers of American shad (*Alosa sapidissima*), striped bass, and alewives *(Alosa pseudoharengus)* migrate into the bay's tributaries during spawning season, attracted by the shallow, warm waters and high productivity of the numerous smaller estuaries and rivers. These migrations have provided a seasonally dependable source of fish for centuries (Table 4.3). The following is a brief natural history of the commercially and recreationally important species dominant in the bay, with species information summarized from Clayton et al. (1978), Meinkoth (1981), Davis (1989), and other sources as identified.

Scup (*Stenotomus chrysops*). Also known as "porgy," scup are the most abundant fish in Buzzards Bay. The variable populations of scup are generally attributed to varying abundances of successive year classes with recruitment influenced by environmental factors rather than stock size. Summer and early fall residents of Buzzards Bay waters, scup migrate to deeper warmer waters in winter. Spawning migrations to inshore regions occur in late spring, with June the month of peak reproduction (Bigelow and Schroeder 1953). Scup eggs are buoyant, and studies in the Weweantic River estuary indicate eggs are most abundant from May through June in water temperatures of 8.5^{o} to 23.7^{o} C (Lebida 1969). Sudden temperature decreases occurring in late fall have been identified as a major environmental cause of scup mortality in bays and estuaries such as Buzzards Bay (Clayton et al. 1978). Their main predators are other fish such as cod, bluefish (*Pomatomus saltatrix*), and weakfish (*Cynoscion regalis*). Scup are primarily bottom feeders, consuming small crustaceans, worms, mollusks, squid, and occasionally small fish. The healthy benthic and bottom-living communities of Buzzards Bay appear to provide highly suitable habitat for this species, as reflected by its continuous occurrence from the earliest records to present.

Winter flounder *(Pleuronectes americanus*). Winter flounder was a mainstay of the New England groundfish industry until the mid 1930's;

Table 4.3. Dates of "first catch" for various species of finfish in Buzzards Bay recorded by a weir fishery for 1880. Data from D.W. Dean, as quoted in Goode (1887).

Date	Common name	Scientific name	Date	Common name	Scientific name
3/24	Atlantic menhaden	*Brevoortia tyrannus*	4/26	Rock bass	*Centropristis striata*
	Alewife	*Alosa pseudoharengus*	4/27	Sea robin	*Prionotus carolinus*
	Smelt	*Osmerus mordax*	4/28	Squid	*Loligo opalescens*
	Tomcod	*Microgadus tomcod*	5/8	Butterfish	*Peprilus triacanthus*
4/1	Tautog	*Tautoga onitis*		Kingfish	*Menticirrhus saxatilis*
	Skate	*Raja erinaceae*	5/11	Squeteague	*Cynoscion regalis*
	Perch	*Morone americana*	5/12	Flounder	*Paralichthys deutatus*
4/6	Sea herring	*Clupea harengus*	5/13	Bluefish	*Pomatomus saltatrix*
	Eel	*Anguilla rostrata*	6/7	Sand shark	*Carcharhinus plumbeus*
4/14	Shad	*Alosa sapidissima*	6/8	Stinging ray	*Dasuatis centroura*
4/15	Striped bass	*Morone saxatilis*	6/10	Shark (unknown species)	
4/17	Scup	*Stenotomus chrysops*	6/25	Bonito	*Sarda sarda*
4/24	Dogfish	*Squalus acanthias*	8/30	Spanish mackerel	*Scomberomorus maculatus*
	Mackerel	*Scomber scombrus*	9/6	Goose fish	*Lophius americanus*

however, after this time the populations suffered serious declines, the causes of which are as yet unclear. Winter flounders still support an important fishery in the bay, utilizing the coves and embayments for critical early stages of their life cycle. The spawning season for winter flounder is February in Woods Hole (Breder 1922) and February and March for the Weweantic River (Lebida 1969). Winter flounders are believed to return to the estuaries of their origin for spawning (Perlmutter 1939; Saila 1961), after which the nonbuoyant egg clusters remain on the bottom until hatching. Larvae are abundant from March through June in the bay waters (Lebida 1969; Fairbanks et al. 1971; Peterson 1975). The young winter flounders tend to remain within embayments during their first year, moving out into more open bay waters during summer months and returning to spawning areas late in fall. It is during the fall migration when the young of the species are most vulnerable to predation and fishing.

Winter flounders feed only during the day on a diet consisting primarily of polychaetes, bivalves, gastropods, and crustaceans. The winter flounder's habit of burrowing into sediments increases its potential exposure to many pollutants compared with midwater species and results in a higher incidence of fin rot and hepatic carcinomas in impacted areas such as New Bedford (Ursin 1972). Pollution, overfishing, and loss of important nursery grounds, particularly loss of wetlands, are all anthropogenic activities attributed as factors leading to the decline in this resource.

Alewife *(Alosa pseudoharengus)*. The rivers and tributaries of Buzzards Bay have historically sustained significant populations of alewives. These fish were a staple in the diets of early settlers and their abundance was synonymous with the relative prosperity of coastal towns (Clayton et al. 1978). The abundance and regularity with which the alewives returned each year resulted in dependence on these fish, especially when other fisheries suffered decline. The value of the alewife fishery is evidenced by the substantial number of early laws and regulations in the statute books of the Commonwealth of Massachusetts protecting this resource. However, alewives and other anadromous fish around the bay have lost spawning habitat or access to historic spawning grounds because of obstruction of their inland migration. Alewife populations have declined sharply as a result. By 1913, the alewife fishery in Massachusetts had declined 75% from its original levels (Field 1913), and present levels are lower still.

In northern waters such as those of Buzzards Bay, alewives return to their spawning grounds as many as three to five times to spawn, whereas in southern regions they may spawn only once. Spawning migrations to freshwater ponds begin in late April to early May depending on water temperature. Alewife eggs are broadcast randomly at the spawning site, and larvae spend only their early stages in the freshwater pond, migrating out to the estuaries beginning as early as July and continuing through fall (Cooper 1961). Although they do not overwinter in the ponds, some do spend the rest of their first year in the estuary before migrating to the sea (Clayton et al. 1978). More recently, alewives have also been found to spawn in the brackish (up to 8 ppt) waters of coastal salt ponds, increasing their spawning habitat over that previously reported (Bourne 1983; Woods Hole Oceanographic Institution, personal communication).

Although historically caught by a variety of methods including gill nets, seines, and weirs, the largest numbers of alewives were caught in spring by nearshore weirs or by directly intercepting the fish on their way upriver to spawn. Capture was accomplished by stretching nets across rivers and simply scooping the fish into barrels. The most frequently identified rivers in Buzzards Bay for alewife migrations are the Acushnet, Wareham, Mattapoisett, Weweantic, and Agawam, referred to often in the historic literature for their seasonally prolific alewife catch. Alewives are still actively fished today, primarily by nets as they enter the spillways or streams to freshwater and coastal salt ponds.

Blueback herring (*Alosa aestivalis*). Often found with alewives (and commercially classified together with alewives as "river herring"), blueback herrings are anadromous fish and suffer similar declining populations resulting from obstructions to herring runs and the effects of pollutants on spawning stocks. These fish enter brackish waters to spawn in spring, usually by mid-May. Being more salinity tolerant, they have a reproductive advantage over alewives in that the population is not so dependent on the nursery potential of freshwater areas (Chittenden 1972; Clayton et al. 1978). Juvenile blueback herrings are common throughout Buzzards Bay in late summer and fall. This species feeds primarily on copepods, pelagic shrimp, fish eggs, and larvae. Herrings and alewives provide an important prey resource for many other species of fish, notably bluefish and striped bass.

Atlantic menhaden *(Brevoortia tyrannus*). Accounting for the largest portion of the United States catch, menhaden are primarily used for fish meal and oils rather than direct human consumption. Menhaden populations are often variable; no commercial landings were recorded from 1963 to 1968 in New England (Moss and Hoff 1989). The variable populations observed in Buzzards Bay may be due in part to their speed and schooling behavior, which make quantitative assessment difficult, especially since catches are generally from seines. They spawn at sea and in inshore waters, usually between April and October, and are typically most abundant in Buzzards Bay in late summer, when juveniles are prevalent. Juveniles and adults feed primarily in the upper water column on phytoplankton through filtration. Smaller crustaceans and various larvae are also consumed as the harvest of plankton is mainly size selective, similar to collection by towing a plankton net. The inshore distribution of menhaden is likely the result of the concentration of plankton in nutrient-rich coastal waters (Bigelow and Welsh 1924). Menhaden is considered an important prey species for most carnivorous marine fish, with a large population biomass seasonally concentrated in shallow waters.

Black sea bass (*Centropristis striata*). This fish is a summer visitor to Buzzards Bay, migrating inshore in spring and offshore to deeper waters in late fall. The diet of adults consists of crustaceans, fish, and mollusks. Juvenile black sea bass utilize Buzzards Bay as a nursery ground and, as bottom feeders, eat primarily mysids in the shallow areas. Sea bass are born as females, transforming into males after their first spawning. As a result females tend to predominate due to their high percentage in young age classes. In contrast, recreational catch consists primarily of males, their larger size making them sought after by sport fishermen. The selective recreational catch may impact populations by altering sex ratios and decreasing the number of males available for reproduction (Davis 1989).

Tautog (*Tautoga onitis*). Tautog is an important sport fish; moving in from offshore waters in spring, this species is abundant in bay waters from May through September. As it does for most of the major species, the bay provides critical spawning and nursery habitat for tautog. Tautog spawning in Buzzards Bay is noted in historical records (Davis 1989) and the continued abundance of tautog is noted on species lists from 1620 to present. This species spawns in weedy, inshore areas, thus the many sub-embayments and coves, especially those with extensive eelgrass beds, are highly suitable for reproduction. The Weweantic River estuary is a frequent spawning ground for this species (Clayton et al. 1978). The buoyant eggs and juveniles remain inshore, with juveniles overwintering within the estuary, particularly in vegetated areas. The primary diet of tautogs consists of mollusks, blue and ribbed mussels, crabs, worms, and lobsters. The tautog population in Buzzards Bay may be slowly increasing based on the catch since 1980, which is primarily from recreational fishing and lobstering; however, no quantitative assessment exists at present.

Butterfish *(Peprilus triacanthus*). Butterfish spawn during summer months in shallow waters throughout the mid-Atlantic Bight, and Buzzards Bay provides a nursery area for the species. Juvenile butterfish grow quickly and migrate offshore to deeper waters in late fall, returning again in April. The diet of the butterfish consists primarily of copepods, small fish, jellyfish, and polychaetes; in turn, butterfish are a prey source for bluefish, silver hake *(Merluccius bilinearis),* red hake *(Urophycis chuss),* and striped bass. It is an important commercial species all along the mid-Atlantic shelf and is frequently identified in the historic literature as being an abundant and important species for Buzzards Bay (Davis 1989). The schooling behavior and therefore patchy distribution of this fish results in variable year-to-year catch statistics. These variations are thought to be due primarily to limitations in catch rather than significant changes in the population (Davis 1989).

Bluefish *(Pomatomus saltatrix).* Seasonal migrations of bluefish represent an important recreational and commercial fishery during summer months in Buzzards Bay. Although spawning offshore, juveniles (known as "snapper blues") move in large numbers into the warmer inshore waters of the bay. These fish are voracious feeders, consuming a wide variety of fish and invertebrates in the water column. Mackerels, menhadens, alewives, herrings, and weakfish, as well as shrimp, lobsters, squid *(Loligo opalescens),* crabs, mysids, and annelid worms, are all part of the bluefish's diet. So efficient are they as predators, bluefish were frequently blamed for decreases in other fish species within Buzzards Bay waters (Baird 1873; Belding 1916). The abundance of juveniles in shallow nearshore waters also provides an important source of prey for other predaceous species. Large fluctuations in bluefish populations occur from year to year, but these fluctuations are attributed more to environmental factors than to human disturbances. The value of the recreational fishery, primarily surfcasting, party boat, and individual hook and line fishing, is estimated to exceed that for the commercial fishery for bluefish along the mid-Atlantic (Saila and Pratt 1973). Bluefish has been a consistently important food fishery for at least the past 100 years in Buzzards Bay. This species is also important in estuarine food chains; juveniles exploit prey in wetlands and embayments, and adults feed on the abundant larger prey species.

Striped bass *(Morone saxatilis).* Except when migrating, striped bass, another anadromous fish, is primarily a nearshore and brackish water species. The young remain in their natal estuary until about 2 years old, with Chesapeake Bay being the primary spawning ground for most of the striped bass along the east coast. Striped bass are not known to spawn in Buzzards Bay waters; however, small fish (averaging 3-5 years old out of a potentially 20 year life span) are frequently found in the Weweantic River estuary, New Bedford Harbor/Acushnet River, and throughout the bay itself (Clayton et al. 1978). Although primarily a summer resident, some overwintering bass have been reported in southern Massachusetts rivers. Like bluefish they are voracious feeders, consuming fish and invertebrates such as herring, smelt, hake, squid, crabs, lobsters, and polychaetes. Striped bass represents one of the most important recreational species in the bay. Overfishing and natural annual fluctuations in populations have resulted in a recent 91-cm size limit for this species in Massachusetts.

Many species prevalent in Buzzards Bay depend on the brackish waters found in the many tidal wetlands bordering the bay for spawning areas and more often as nursery habitat and feeding areas. Many of the species discussed above are predatory, exploiting fish and animal populations in wetlands during early stages of growth. Shrimp and menhaden, although spawned at sea, often seek out these brackish waters for nursery grounds during their developmental stages, growing on the abundance of organic material provided in these systems. Tidal wetlands are temporary or permanent homes to many other species of fish as well. Mummichog *(Fundulus heteroclitus)*, striped killifish (*Fundulus majalis*), silversides (*Menidia menidia*), and four-spined sticklebacks (*Apeltes quadracus*) abound in Buzzards Bay salt marshes; other species, such as alewives, Atlantic menhaden, tautog, sea bass, winter flounder, and three-spined sticklebacks (*Gasterostrus aculeatus*), are only seasonal visitors, but their residence period in these marshes represents a very important stage in their life cycles. More information on these tidal marsh species is presented in the section on salt marshes.

Avian Fauna. The diversity of marine habitats within the Buzzards Bay system is reflected in the avian fauna. Marine and estuarine birds harvest the aquatic resources of the open bay waters as well as the bay's intertidal marshes and mudflats. More than 50 resident and migrant species rely upon bay waters for food and nesting habitat (Table 4.4), not including the various terrestrial species that opportunistically feed within intertidal areas.

Islands located around the bay (Ram, Bird, Gosnold, Nashauwena, Penekise, Pasque, and Cuttyhunk) are important nesting habitats for seabirds. For instance, as of 1984, Gosnold had over 1,000 nesting pairs of double-crested cormorants (*Phalacrocorax auritus*) in addition to a significant number of herring (*Larus argentatus*; 658 pair) and great black-backed (*Larus marinus*; 130 pair) gulls; Nashauwena supported nesting pairs of snowy egrets (*Egretta thula*; 30 pair), black-crowned night herons (*Nycticorax nycticorax*; 20 pair), common terns (*Sterna hirundo*; 140 pair), least terns (*Sterna antillarum*; 68 pair), roseate terns (*Sterna dougallii*; 2 pair), herring gulls (930 pair), and great black-backed gulls (200 pair) (B. Blodgett, Massachusetts Natural Heritage and Endangered Species Program, personal communication). Long-term studies of avian population dynamics are being conducted in this area by the Massachusetts Natural Heritage and Endangered Species Program and the Massachusetts Division of Fish and Wildlife. Of particular interest are Ram and Bird islands (owned by the Massachusetts Natural Heritage and Endangered Species Program), both of which are the subject of intensive bird recovery programs where attempts are being made to reestablish nesting colonies for roseate, least, and common terns. Increasing populations of nesting herring gulls and great black-backed gulls have diminished the availability of nesting sites for these terns. In addition, the gulls prey on tern eggs and young, increasing mortality. Attempts are being undertaken to increase tern nesting populations by discouraging or removing nesting gulls in formerly established tern sites, encouraging recolonization by the terns in these as well as new areas. Bird Island, a primary nesting site for the endangered roseate tern, is a prime example.

Table 4.4. Birds of Buzzards Bay.

Common name	Scientific name	Status[a]
Open Water		
Common loon	*Gavia immer*	C/W
Red-throated loon	*Gavia stellata*	U/W
Double-crested cormorant	*Phalacrocorax auritus*	N/C
Great cormorant	*Phalacrocorax carbo*	U/W
American black duck	*Anas rubripes*	N/C/W
Mallard	*Anas platyrhynchos*	N/C/W
Brant	*Branta bernicla*	C/W
Black scoter	*Melanitta nigra*	C/W
Surf scoter	*Melanitta perspicillata*	C/W
White-winged scoter	*Melanitta fusca*	C/W
Canada goose	*Branta canadensis*	N/C/W
Mute swan	*Cygnus olor*	N/C/W
Canvasback	*Aythya valisineria*	C/W
Greater scaup	*Aythya marila*	C/W
Common goldeneye	*Bucephala clangula*	C/W
Common eider	*Somateria mollissima*	C/W
King eider	*Somateria spectabilis*	U/W
Bufflehead	*Bucephala albeola*	C/W
American wigeon	*Anas americana*	C/W
Red-breasted merganser	*Mergus serrator*	C/W
Common black-headed gull	*Larus ridibundus*	C
Herring gull	*Larus argentatus*	N/C/W
Great black-backed gull	*Larus marinus*	N/C/W
Common tern	*Sterna hirundo*	N/C
Least tern	*Sterna antillarum*	N/U
Roseate tern	*Sterna dougallii*	N/U
Oldsquaw	*Clangula hyemalis*	C/W
Intertidal		
American oystercatcher	*Haematopus palliatus*	N/U
American (Great) egret	*Casmerodius albus*	N/C
Snowy egret	*Egretta thula*	N/C
Great blue heron	*Ardea herodias*	N/C/W
Striated heron	*Butorides striatus*	N/C
Black-crowned night heron	*Nycticorax nycticorax*	N/U
American bittern	*Botarus lentiginosus*	U
Northern harrier	*Circus cyaneus*	N/C/W
Osprey	*Pandion haliaetus*	N/C
American kestrel	*Falco sparverius*	C/W
Killdeer	*Charadrius vociferus*	U
Black-bellied plover	*Pluvialis squatarola*	N/C
Semipalmated plover	*Charadrius semipalmatus*	N/C
Piping plover	*Charadrius melodus*	N/U
Belted kingfisher	*Ceryle alcyon*	C
Willet	*Catoptrophorus semipalmatus*	N/C
Sanderling	*Calidris alba*	C
Spotted sandpiper	*Actitis macularia*	N/C
Semipalmated sandpiper	*Calidris pusilla*	C
Least sandpiper	*Calidris minutilla*	C
Dunlin	*Calidris alpina*	U
Sharp-tailed sparrow	*Ammodramus caudacutus*	N/U
Clapper rail	*Rallus longirostris*	N/U/W
Black rail	*Laterallus jamaicensis*	U
King rail	*Rallus elegans*	U

[a] N=nestor in Buzzards Bay; C=common, U=uncommon, W=winters in Buzzards Bay.

Sources: B. Blodgett, H. Hausmann, Massachusetts Division of Fisheries and Wildlife; Massachusetts Natural Heritage Program; Camp, Dresser and McKee (1990); Peterson (1980); Trull (1991); Massachusetts Audubon Society (1989); unpublished species lists. Many wintering birds are found year round.

A complete synthesis of the voluminous information on avian resources in the Buzzards Bay system is well beyond the scope of this text. In fact, entire texts could be, and indeed have been, devoted to the subject of birds on Cape Cod. Several worthy of note include Bailey (1968), Massachusetts Audubon Society (1989), and Trull (1991).

4.1.2. Flora and Aquatic Primary Productivity

The aquatic flora of Buzzards Bay reflects the diversity of physical environments discussed previously (Table 1.1). The water column supports phytoplankton communities having a range of productivity from the nutrient-enriched embayments with chlorophyll-*a* concentrations over 10 mg/m^3 to the open waters near the mouth of the bay at 1-2 mg/m^3 (Roman and Tenore 1978; Howes and Taylor 1991). Areas of the bay bottom above the photosynthetic compensation depth and intertidal flats support a variety of benthic floral types with diverse species assemblages. These floral types include macroalgae, particularly in the areas of hard substrate (e.g., rocky shores of the Elizabeth Islands) and in the shallow waters and intertidal areas; periphyton, which colonize the surface layers of sandy and muddy bottoms and intertidal flats; and subtidal (eelgrass) and intertidal (salt marsh) rooted macrophyte communities with associated periphytic and epiphytic associations (e.g., on eelgrass).

Because secondary production and habitat quality within Buzzards Bay depend directly on the amount and distribution of organic matter produced by phototrophs, it is useful to compare the relative amounts of organic matter produced by the different floral types. Although Buzzards Bay has been studied for more than a century, a quantitative bay-wide assessment of each of the floral assemblages is not available. However, enough data exist to make relative comparisons (Table 4.5).

Phytoplankton production has been determined in moderately detailed annual studies on the western (Symada 1990) and eastern (Roman and Tenore 1978) shores. It is likely that at least some of the three-fold higher carbon fixation along the western shore (360 g C m^{-2} year $^{-1}$) versus eastern shore (106 g C m^{-2} year $^{-1}$) results from the greater nutrient enrichment from loading in the New Bedford-Fairhaven area. Estimates of eelgrass and salt marsh production should be fairly accurate because of the availability of mapping studies (Hankin et al. 1985; Costa 1988a) and site-specific productivity estimates (Valiela and Teal 1979; Costa 1988b). Tidal export from salt marshes is also included in studies

Table 4.5. Annual primary production of the aquatic resources of Buzzards Bay (adapted from Costa 1988b).

		Total		
Ecosystem component	**Production (g C m^{-2} year $^{-1}$)**	**Area (ha)**	**Production (t C/year)[a]**	**% of subtidal carbon cycle**
Phytoplankton[b]	230	55,000	126,500	89.1
Benthic periphyton	45	2,076	930	0.7
Eelgrass - aboveground[c]	295	2,920	8,600	
Total	334		9,800	6.9
Eelgrass epiphytes	--	--	1,960	1.4
Macroalgae	500	400	2,000	1.4
Salt marshes - aboveground	160	1,993	3,200	
(Potential export)[d]			640	0.5
Subtidal Carbon cycle			141,830	100.0

[a] t = metric ton = 10^6 g.

[b] Area from Signell 1987. Production from: Camp, Dresser and McKee, Inc. 1990 (360 g C m^{-2} year^{-1}, Western Shore) and Roman and Tenore 1978 (106 g C m^{-2} year^{-1}, Eastern Shore).

[c] Area currently colonized as mapped by Costa 1988a.

[d] Area from Hankin et al. 1985. Production and export extrapolated from Great Sippewissett Marsh (Valiela and Teal 1979).

since the effects of salt marsh organic matter production on the open waters of the bay are based on detrital food chains. Periphyton, eelgrass epiphytes, and macroalgae are estimated from other systems and adjusted to approximate distribution within Buzzards Bay (Costa 1988a).

Although macrophytes have higher rates of production, Buzzards Bay supports essentially a phytoplankton-based (89%) carbon cycle. Although macrophyte production is more concentrated, phytoplankton photosynthesize throughout most of the water column of the bay and its embayments (Table 4.5). In addition, the areal extent of phytoplankton habitat is more than seven times that for all benthic floral types. Historically this distribution has not changed significantly given the relatively small contributions from wetlands and eelgrass beds. These latter plant communities, however, contribute more than organic matter. Eelgrass beds and tidal wetlands provide habitats with ecological processes and niches very different from those of the open bay. The concentration of organic matter production in these systems and the physical environment they create give them a disproportionate role in the secondary production of Buzzards Bay.

Phytoplankton and Zooplankton. Buzzards Bay phytoplankton populations are generally reported as being dominated by *Skeletonema costatum, Leptocylindrus minimus*, and species of *Rhizosolenia.* Zooplankton are dominated by the copepods *Acartia* spp. and *Paracalanus crassirostris.* Most of the phytoplankton productivity in Buzzards Bay is attributed to diatoms, with dominant species consisting of a mix of estuarine and coastal species commonly found in New England. Red tide blooms have not been significant in Buzzards Bay to date. Brown tides (Casper et al. 1987), so detrimental to filter-feeding communities and certain fish populations, have not been observed, although these phytoplankton have been reported in nearby Narragansett Bay.

Macroalgae. The distribution of macroalgae in Buzzards Bay appears to be controlled by temperature (lower bay waters are colder than those in the shallow embayments and upper bay), substrate, light, and nutrient availability. The temperature effect is particularly noticeable in the shallow regions, which exhibit distinct seasonal floras of winter and early spring versus midsummer and fall (Davis 1913).

Within the Buzzards Bay system there is a wide range of macroalgal habitats, each habitat containing a diversity of algal species. The shallow, high-light, nutrient-rich regions support the most luxurious growth. Brackish pools and intertidal areas within salt marshes have algal mats dominated by *Lyngbya* and *Microcoleus,* floating or loosely attached growths of *Enteromorpha* species, and patches of *Ascophyllum* along creek banks. The shallow embayments and nearshore zone of the open bay support green algae, *Cladophora,* with *C. flexuosa* and *C. arcta* abundant on hard substrates (rocks, piers) in spring and summer and *C. gracilis* forming dense accumulations in embayments in summer.

Those areas of rock or cobble shores (southeastern shore) support the most impressive macroalgal growth. The rockweeds, *Ascophyllum nodosum* and *Fucus vesiculosus,* abound on rocks in the littoral zone. Other hard-bottom (sand, shells, or rock) species of note are *Laminaria* spp., *Condrus crispus* and *Polysiphonia* (8 spp.) in deeper water and *Sargassum* and *Codium* in the shallower areas of the bay. *Phyllophora* is notable as being found at the lower depths on substrate ranging from rock to sand to mud and is distributed throughout the bay (Davis 1913).

Macroalgae are of concern to resource managers because dense accumulations can result from excessive nutrient loading to shallow coastal water bodies (Valiela et al. 1990; Costa et al. 1992). When they occur, these accumulations may have detrimental impacts on benthic communities, both infauna and fish. At the more modest levels of production generally found in Buzzards Bay, attached macroalgae can have the opposite effect, providing habitat for animals and increasing secondary productivity.

Eelgrass. Eelgrass, or *Zostera marina*, is a rooted subtidal macrophyte that forms extensive beds in areas where light penetration is sufficient to support growth. Eelgrass is a perennial angiosperm (Fig. 4.5) that is able to flower and undergo pollination, seed dispersal, and growth completely underwater. Propagation of this species is primarily by rhizome within existing beds and by seedlings in new growth areas.

Eelgrass beds are important to the bay ecosystem as sources of organic matter production (Table 4.5), as habitat for invertebrate and fish species (Adams 1976; Thayer et al. 1984), and as a food source for geese (Buchsbaum and Valiela 1987). Eelgrass beds alter hydrodynamics and generate low-velocity zones, causing sediment and organic matter deposition that secondarily affect benthic animal communities. The roots and rhizomes serve both for nutrient uptake and binding the substrate. The plants themselves become a substrate for attachment of epiphytic organisms and the eggs and larvae of various species.

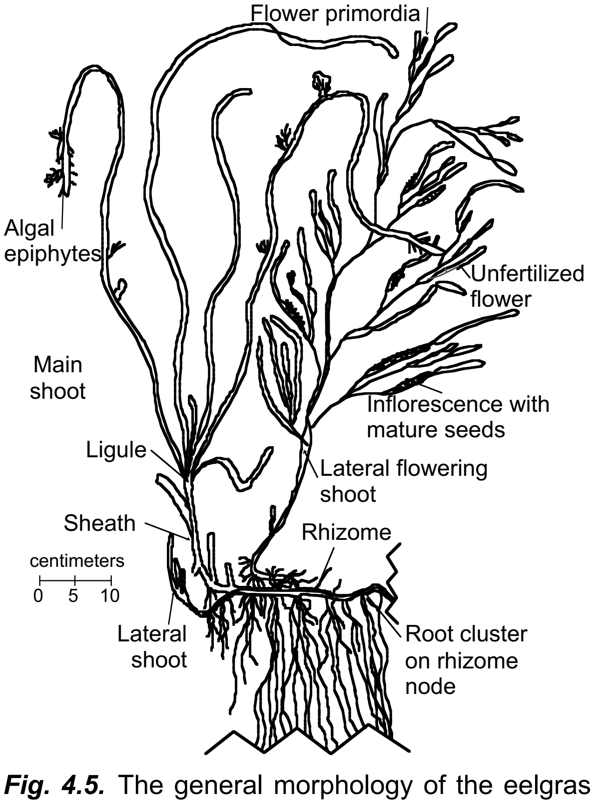


Fig. 4.5. The general morphology of the eelgrass *Zostera marina.* From Costa (1988a).

Buzzards Bay populations of *Zostera* appear to have generally recovered (Costa 1988b) from the catastrophic decline because of a “wasting” disease (Labarynthula), which decimated eelgrass beds throughout New England from 1931 to 1933 (Cottam 1933). Costa (1988b), using aerial photographs, determined that several years after the decline, eelgrass beds in Buzzards Bay covered less than 10% of the present area. Although epidemics of “wasting” disease have not reoccurred since the 1930’s in Buzzards Bay, smaller outbreaks have been found in New England (Short et al. 1986).

Zostera appears to colonize sandy and mud bottoms of the open bay and its embayments. The major factor determining the upper limits of this subtidal species appears related to desiccation in summer and ice scour in winter (Davis 1913; Costa 1988b). While the lower limit is set by light penetration (Dennison and Alberte 1985, 1986), the level of light intensity is less important in determining depth than the daily duration of intensity above a physiologically set level.

Light penetration in simplest terms is a function of depth and the concentration of particles within the water column. The particles can be living (phytoplankton) or inert (sediments). Because Buzzards Bay has no large river discharging into it and relatively coarse-grained sediments resulting from its formation, the major source of particles attenuating light is generally phytoplankton within the water column (and epiphytes on the eelgrass leaves). As a result, light attenuation relative to eelgrass growth in Buzzards Bay may be more directly related to factors controlling phytoplankton and epiphyte density (e.g., nutrients) than in other systems with a higher inorganic load. Shallow protected embayments support less than one-third of the eelgrass of Buzzards Bay. The nearshore zone of the open bay, with its greater circulation and water transparency, contains beds as deep as 6 m, although 3-m beds are much more common. Compared to the open water areas, eelgrass growth in the more turbid embayments is restricted, generally growing in depths of 0.6 to 1.8 m (Costa 1988b).

Examination of the maximum depth of *Zostera* growth at sites throughout the bay (Fig. 4.6)

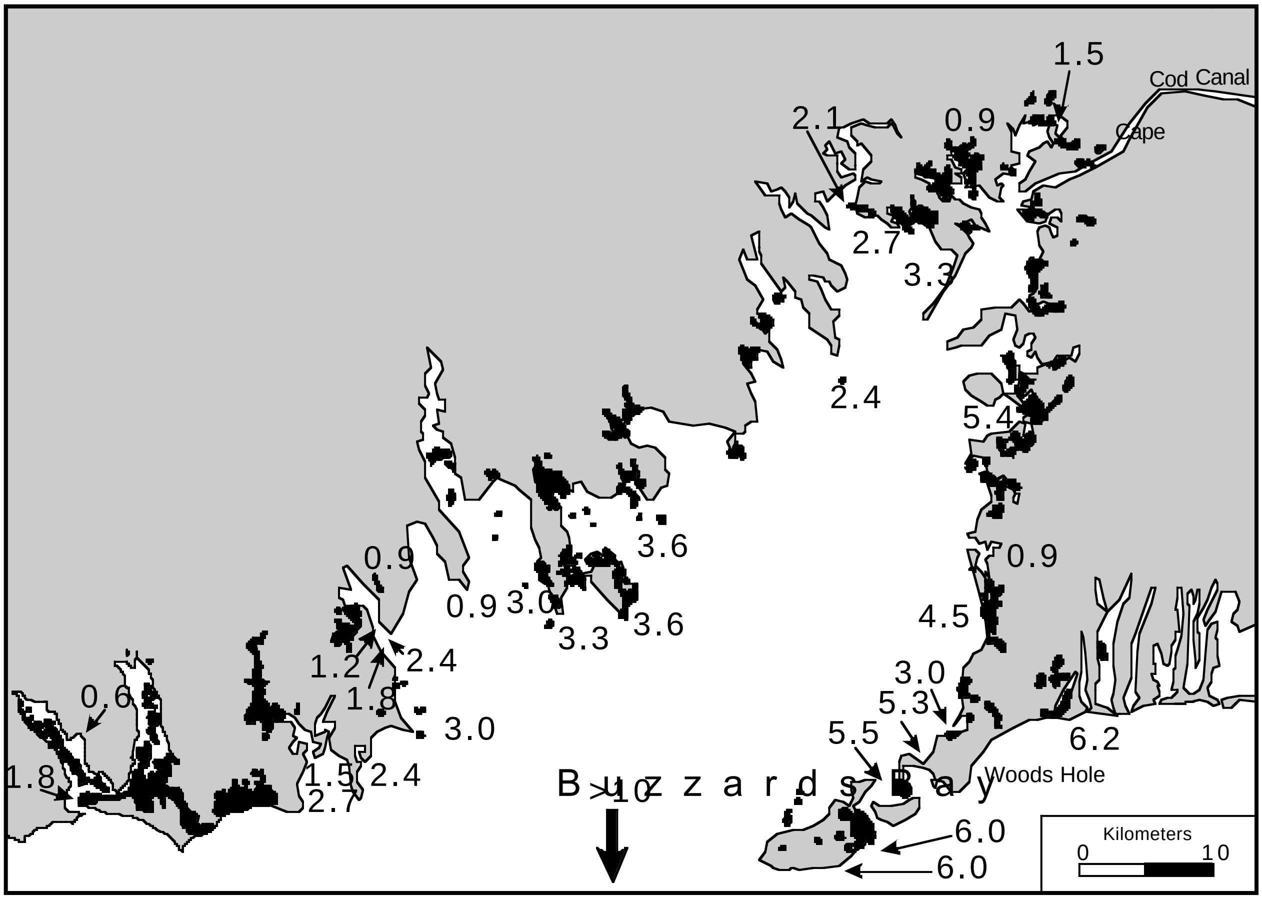


Fig. 4.6. Maximum depth (meters mean low water) of eelgrass (*Zostera marina*) in different parts of Buzzards Bay. From Costa (1988a)

Table 4.6. Eelgrass (*Zostera marina)* potential habitat area versus present area colonized in Buzzards Bay (adapted from Costa 1988a).

Town	**Habitat area[a] 0-3.6 m depth (ha)**	**Area of *Zostera* beds (ha)**	**Area of *Zostera* cover[b] (ha)**	**Habitat colonized by beds (%)**
Bourne	1,130	700	477	62
Dartmouth	823	151	104	18
Fairhaven	1,190	450	346	38
Falmouth	1,397	559	397	40
Marion	870	331	189	38
Mattapoisett	630	446	317	71
New Bedford	240	1	0.2	0.3
Wareham	1,480	914	564	62
Westport	1,420	389	265	27
Elizabeth Is.[c]	n.d.	540	270	–
Totals	>9,180	4,481	2,929.2	

[a] Almost all of current eelgrass beds are at or above 3.6 m depth (Costa 1988).

[b] Area of beds corrected for percent area colonized (% coverage).

[c] All values estimated, not directly measured.

n.d. = not determined.

suggests that the eastern shore, with its lower levels of nutrient loading and river flow, may have higher transparency and possibly better water quality than the western shore. This finding is consistent with the significantly lower levels of nutrients and phytoplankton productivity (Table 4.5) near Woods Hole where *Zostera* grows to 5.5 m versus the maximum depth in the New Bedford-Fairhaven area of 0.9 to 3.0 m. In general, however, the 3.6-m contour encloses almost all of the potential intensive growth area for *Zostera* in Buzzards Bay (Costa 1988 a,b).

Zostera covers extensive areas of the nearshore of Buzzards Bay and forms a nearly continuous band from Westport to Woods Hole. The area of existing beds is about 4,500 ha or about 8% of the subtidal area of the bay. Correcting the area of the beds for bare areas within the beds, the actual vegetated area is about 3000 ha (Table 4.6).

As in the case for the maximum depth of growth, the extent of theoretically habitable bottom actually colonized appears to be related to anthropogenic impacts. This is particularly clear in the case of New Bedford Outer Harbor, Dartmouth, and to a lesser extent Fairhaven, where only 0.3%, 18%, and 38%, respectively, of the available area has beds (Table 4.6), and much of the total terrestrially derived nutrient load enters the bay. The potential sensitivity of *Zostera* beds to nutrient loading (operating through phytoplankton and epiphyte effects) has served to make eelgrass a sentinel species for monitoring nutrient-related water quality of Buzzards Bay (Buzzards Bay Project 1990; Costa et al. 1992).

4.2. Intertidal

4.2.1. Salt Marshes

Salt marshes (Fig. 4.7) represent an important component in the ecology of Buzzards Bay (Tables 1.1 and 4.5). Salt marshes occur in pockets all around the border of the bay, including Little and Great Sippewissett in West Falmouth, Allen's Pond and Little River in Dartmouth, Weweantic in Wareham, along the Westport River, and Priest's Cove and West Island in Fairhaven. Westport has the largest area of salt marsh in the Buzzards Bay system, primarily due to the presence of the Westport River. In contrast, New Bedford has the smallest area, caused both by the physical structure of the harbor as well as by large-scale development that has occurred over the years. These tidal wetlands within the bay system are typical of New England marshes, generally forming behind protective barriers such as barrier beaches, or as narrow fringing marshes in low-energy environments such as circulation-restricted coves and embayments. The diminished velocities of tidal water as it enters these coves and embayments results in the deposition of suspended particles, ultimately resulting in the establishment of sediments at an elevation within the tidal range suitable for the colonization of marsh plants. The absence of high-energy waves is

Fig. 4.7. Aerial view of the Great Sippewissett Salt Marsh, West Falmouth, Massachusetts. Photo by B. Howes.

important to the establishment of these species, as waves prevent the formation of a stable substrate (Redfield 1972). In the initial formation of a wetland, a gradation in sediment type exists, from sandy toward the mouth of the wetland to silty toward the head. This gradation reflects the characteristics of the suspended matter, as tidal waters have a lower ability to keep heavier materials like sand in suspension, resulting in sand deposition near the mouth and subsequent deposition of finer particles nearer the headwaters. Once the substrate is available at suitable elevation and the plants begin to colonize, the extensive root and rhizome systems of marsh species stabilize the sediments, and the marsh becomes established. About half of the production of the dominant low marsh species *Spartina alterniflora* is in belowground production.

The value of these highly productive intertidal wetlands has long been recognized—as habitat for waterfowl and shellfish, as storm buffers for adjacent upland, as nursery grounds for various species of fish, and as potential buffers for terrestrial nutrient inputs to coastal waters. Tidal flushing of salt marshes is also postulated as a mechanism for export of plant detritus to estuarine food webs in embayments like Buzzards Bay. Wilson et al. (1985) estimated between 5% and 7% of the organic matter in Buzzards Bay sediments was made up of vascular plant remains, with the bulk of the balance of organic matter derived from phytoplankton. They also estimated an export of 3-4 x10^5 kg particulate organic carbon annually from marshes into the bay, amounting to 25-30% of the total amount of vascular plant debris in the top 1 cm of surface sediment.

Saltwater marshes in New England, including those in Buzzards Bay, are generally divided into two rather distinctive zones: the low marsh, dominated by the salt marsh cordgrass, *Spartina alterniflora;* and the high marsh, dominated by the salt marsh hay, *Spartina patens*, and the spike grass, *Distichlis spicata.* Flooding frequency and duration are the primary determinants to the distribution of low and high marsh zones. The low marsh zone is located between mean low water and mean high water, while the high marsh is the region lying between mean high water and spring high water. Both the low and high marshes are sufficiently flooded by seawater to inhibit the growth of more freshwater marsh plants such as *Typha* (cattail) and *Phragmites* (reed).

Low marsh is typically flooded on every high tide and is almost exclusively colonized by *Spartina alterniflora*, occasionally with *Limonium nashii* (sea lavender) or *Salicornia* (glassworts) present. *Spartina alterniflora* exhibits two growth forms, the tall form (up to 1-2 m in height), which grows 1-3 m inland from creeks, and the short form (less than 50 cm), which grows inland from the tall zone. The differences in these morphologies is generally attributed to a combination of nutrient availability, sediment oxidation, and plant-sediment interactions, with the more productive tall form growing in better drained, more oxidized sediments (therefore, plants possess increased ability to uptake nitrogen) with low concentrations of plant growth inhibitors (such as sulfides; Howes et al. 1986). In response to the anoxic sediments resulting from the high organic matter inputs and frequent inundation, these plants have adapted an aerenchyma system of gas-filled lacunae to transport oxygen to their roots and rhizomes, which support aerobic respiration and nutrient uptake (Teal and Kanwisher 1966; Howes and Teal 1994). The physiological difficulties of plant water uptake and evapotranspiration in saline sediments has been diminished by the evolution of salt glands, which secrete a concentrated salt solution to maintain osmotic balance while water is being lost during evapotranspiration. The naturally high levels of primary productivity found in salt marshes are generally attributed to the abundance of *Spartina alterniflora.*

The high marsh supports greater plant diversity than the low marsh and is dominated primarily by salt marsh hay and spike grass. Along the upland border where the duration of tidal flooding is least, salt-tolerant plants such as saltmeadow rush (*Juncus gerardii*), switch grass (*Panicum virgatum*), chairmaker's rush (*Scirpus americanus*), salt marsh bulrush (*Scirpus robustus*), and marsh elder (*Iva frutescens*) are commonly found. In most of the marshes around Buzzards Bay where the headwaters are fresh or brackish, stands of reeds and cattails predominate at the landward edges of the wetlands. Although few animals live or burrow in the sediments of the high marsh zone, the historic utilization of salt hay as feed and fodder for animals and more recently its use as a weed-free garden mulch have focused attention on the value of these wetlands as a usable resource for almost four centuries.

Marine life is abundant in the salt marshes of Buzzards Bay, such as snails, crabs, mussels, amphipods, and large numbers of small fish. Many species of birds (wrens, rails, and wading birds; Fig. 4.8) feed on the fish and invertebrates, while others (Canada goose (*Branta canadensis*) and snow goose (*Chen caerulescens*); Teal 1986) feed on marsh plants. Mammals such as voles, field mice, raccoons (*Procyon lotor*), and skunks (*Mephitis mephitis*) forage in the marsh during low tides. Marshes are well known for their abundance of mosquitoes and biting flies, and great efforts are undertaken through management practices, such as ditching, to limit the habitat (primarily stagnant pools) required for breeding. Although considered a nuisance to humans and potentially carriers of diseases such as encephalitis, these insects provide substantial food for birds and surface-feeding fish in the wetland ecosystem. Other insects such as plant hoppers, grasshoppers, and aphids, as well as many species of amphipods and spiders, also are an important part of the fauna of Buzzards Bay salt marshes.

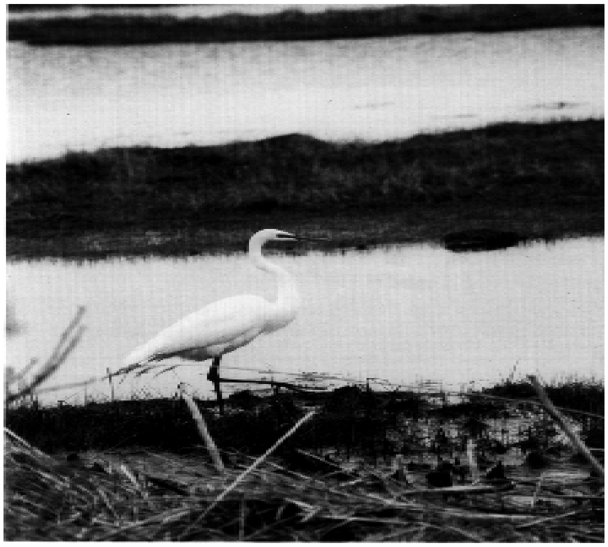


Fig. 4.8. The great egret (*Casmerodius albus*). Photo by B. Howes.

Molts of the horseshoe crab (*Limulus polyphemus*) and frequently the crab itself, are common sights around Buzzards Bay. Known as a "living fossil," horseshoe crabs have remained basically unchanged over the past 200 million years, with ancestors estimated to have roamed shorelines roughly 350 million years ago. Not actually a crab at all, *Limulus* is an arthropod, related to spiders and scorpions. The larger females move from deeper water in early summer to lay eggs along the high tide line. Horseshoe crabs are particularly interesting in that they possess a blue, copper-based blood with only one type of cell, which can be extracted for use in various medical assays such as identification of infections caused by spinal meningitis and *E. coli,* as well as certain types of cancers and blood clots.

Fish are an important part of the ecology of Buzzards Bay salt marshes, and as both predator and prey they represent an important component of the estuarine food web in the marsh-bay system. The tidal marshes of Buzzards Bay support resident species, which spend most of their life within the tidal creeks and pools of the marsh system, and nonresident or invading species, which enter into marsh waters and spend only a portion of their life there. Of the nonresident species, some are adults that enter into salt marshes to spawn, and others are juveniles of coastal species that use the marshes as nursery grounds.

The resident species of fish found in Buzzards Bay salt marshes are typified by the Atlantic silverside, the four-spined stickleback, and three species of killifish, mummichog, striped killifish, and sheepshead minnow (*Cyprinodon variegatus*). Spawning in the marsh, most of these fish are active from April through October and then move out of the marsh into deeper water or burrow into the bottom of tidal creeks or pools during winter. The resident species are associated with the marsh throughout their life cycles. The most abundant of these, the Atlantic silverside (Fig. 4.9), lives only 1 year, and the relatively few that survive the winter by migrating into deeper waters return to spawn in spring. Mummichogs (Fig. 4.10) live several years, surviving the winter by residing in the bottom of creeks or marsh pools, often in the more brackish upper reaches of the marsh. The striped killifish on the other hand winters in the lower sandier reaches of the marsh during the winter months. These latter species utilize plants and animals in their diets, feeding on algae that lives on the surface of the marsh, but obtaining higher quality food through the consumption of eggs of other species like the horseshoe crab, small bivalves like *Gemma gemma,* and other invertebrates.

Fig. 4.9. The silversides (*Menidia menidia*). Photo by J. Teal.

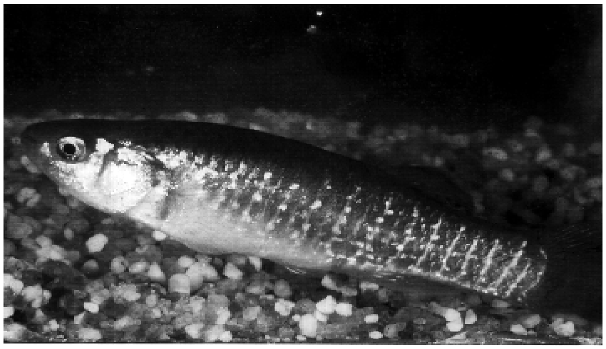


Fig. 4.10. The mummichog (*Fundulus heteroclitus*). Photo by J. Teal.

Nonresident species differ in their use of the marsh. Some use the marsh as spawning grounds, others for protective nursery grounds with abundant food for the growth of juveniles. The three-spined stickleback enters the marsh from Buzzards Bay in spring to spawn and then returns with its young back into the bay. Other invading fishes, such as the alewife, the Atlantic menhaden, the tautog, the sea bass, and the winter flounder use the marsh as a nursery ground and are only present as juveniles during mid and late summer. Bluefish and striped bass enter the marshes as moderate to large adults for brief periods during high tide and leave during ebbing tide, feeding on many of the smaller resident species in late summer.

In a study of the fish populations of Great Sippewissett salt marsh in West Falmouth, Werme (1981) found that resident fish were far more abundant than nonresidents (Table 4.7), as is often the case for other fish and bird assemblages. Two resident species, Atlantic silverside and mummichog, accounted for more than 90% of the fish in the marsh. Large differences were found in the growth rates between the resident and nonresident species, with nonresidents growing an average of 10 times as quickly as the resident fish (Table 4.8). Investigation of gut contents and fullness of the dominant resident and nonresident species were consistent with their different growth rates, with invading fish maintaining higher feeding rates than the resident fishes and generally consuming a higher percentage of animal foods (Table 4.9). Resident species tended to be more omnivorous, frequently with high levels of algae and detritus in their guts. While their diet was generally lower in quality than that of the nonresidents, resident species increased the percentage of animals in their diet during spawning and overall maintained much larger populations (Table 4.7).

Other nondominant species found in the marshes of Buzzards Bay include bay anchovy (*Anchoa mitchilli*), sheepshead minnow, American eel (*Anguilla rostrata*), striped mullet (*Mugil cephalus*), northern pipefish (*Syngnathus fuscus*), butterfish, black sea bass, cunner (*Tautogolabrus*

Table 4.7. Occurrence and abundance of resident and nonresident salt marsh fishes. Percent occurrence (corrected for distance) for each of three areas, the main channel (M.C.) which connects to Buzzards Bay, sandy creeks and muddy creeks (the furthest landward). Averages are shown ± SE. Asterisk (*) indicates significance of t-test at 0.05 level of significance. (From Werme 1981).

Species	Seasonal occurrence	Abundance/ 100 m	Percent occurrence M.C.	Percent occurrence Sand	Percent occurrence Mud
Residents					
Menidia menidia	Apr. - Oct	151.7 ± 84.4	32	56	12
Apeltes quadracus	Apr. - Oct.	0.2 ± 0.0	67	33	0
Fundulus heteroclitus	Apr. - Oct.	110.8 ± 12.8	11	42	47
Fundulus majalis	Apr. - Oct.	11.5 ± 5.0	16	82	2
Cyprinodon variegatus	Apr. - Oct.	9.9[a]	0	61	39
Average		56.8 ± 31.1	25 ± 14	55 ± 12	20 ± 7
Nonresidents					
Alosa pseudoharengus	July - Sept.	1.8 ± 0.0	58	32	9
Brevoortia tyrannus	Aug. - Sept.	1.3 ± 0.1	0	64	36
Gasterosteus aculeatus	Apr. - June	0.4	22	48	30
Tautoga onitis	June - Sept.	0.4 ± 0.2	77	23	0
Centropristes striata	Aug. - Sept.	0.5 ± 0.2	0	100	0
Pseudopleuronectes americanus	May - Sept.	0.5 ± 0.2	19	53	28
Average		0.8 ± 0.3	29 ± 12	53 ± 11	17 ± 7
t-test		*	NS	NS	NS

[a] Standard error not available.

NS - not significant.

Table 4.8. Mean total length and average percent increase in length/month of resident and nonresident salt marsh fishes. Averages are shown ± SE. Asterisks (**) indicate significance of t-test at 0.01 level of significance. (From Werme 1981.)

Species	Mean length	% length/ month	Species	Mean length	% length/ month
Residents			**Nonresidents**		
Menidia menidia	51 ± 0	30	*Alosa pseudoharengus*	62 ± 2	100
Apeltes quadracus	28 ± 0	10	*Brevoortia tyrannus*	78 ± 5	--
Fundulus heteroclitus	42 ± 2	20	*Gasterosteus aculeatus*	27 ± 1	400
Fundulus majalis	50 ± 0	20	*Tautoga onitis*	50 ± 0	180
Cyprinodon variegatus	35 ± 0	10	*Centropristes striata*	40 ± 5	100
			Pseudopleuronectes americanus	88 ± 24	--
Average	41.2 ± 4.4	18.0 ± 3.7	Average	57.5 ± 9.4	195.0 ± 70.9
t-test	NS	**	t-test	NS	**

NS - not significant.

Table 4.9. Average gut fullness, percent fish with empty guts, and percent carnivory, herbivory, and detritivory in the diets of resident and nonresident salt marsh fishes. Averages are shown ± SE. Asterisks (**) indicate significance of t-test at 0.01 level of significance. (From Werme 1981.)

Species	Average gut fullness	Percent empty guts	Carnivory	Percent Herbivory	Detritivory
Residents					
Menidia menidia	36.3 ± 1.0	34	70	20	10
Apeltes quadricus	32.8 ± 4.4	49	80	5	15
Fundulus heteroclitus	24.8 ± 0.9	51	23	52	25
Fundulus majalis	18.0 ± 0.9	53	55	15	25
Cyprinodon variegatus	18.0 ± 1.4	57	13	61	26
Average	26.0 ± 3.7	49 ± 4	48 ± 13	31 ± 11	20 ± 3
Nonresidents					
Alosa pseudoharengus	62.3 ± 4.7	18	97	0	3
Brevoortis tyrannus	52.5 ± 12.1	0	0	67	33
Gasterosteus aculeatus	56.8 ± 4.7	26	90	0	10
Tautoga onitis	78.5 ± 1.0	0	100	0	0
Centropristes striatus	40.0 ± 8.4	6	90	0	10
Pseudopleuronectes americanus	65.0 ± 6.9	0	90	0	10
Average	59.2 ± 5.3	8 ± 5	78 ± 16	11 ± 11	11 ± 4
t-test	**	**	NS	NS	NS

NS - not significant.

adspersus), and sand lance (*Ammodytes americanus*). These species are commonly found in Buzzards Bay and are all nonresidents. Adult eels and young bluefish, terns, egrets, and herons enter the marsh sporadically to feed on the fish in these marshes.

The migration of young fish hatched or reared in the marsh to estuarine waters as well as the transient feeding of deeper water fish such as bluefish and striped bass on marsh residents provide mechanisms whereby the abundant productivity found in these intertidal wetlands is exported to estuarine food webs. These processes represent important components of the role and function of these wetlands in coastal ecology and provide a strong argument in defense of wetland protection and preservation in the coastal landscape.

Ribbed mussels *(Geukensia demissa*, formerly *Modiolus demissus*) are frequently found in the intertidal wetland areas around the bay, generally growing abundantly in the peat around marsh grasses, and are most prevalent in the lower elevation areas of creekbanks where tidal inundation is greatest. This mussel is important in the ecology of coastal wetlands. Mussels are active filter feeders, straining all types of particulates out of the water column, ingesting the edible and processing the inedible into pseudofeces that accumulate around the mussel in areas where tidal currents are not sufficient to sweep them away. Average rates of biodeposition in the form of pseudofeces for the ribbed mussel is 549 g/year (Davis 1985). These mussels can actually bury themselves in these pseudofeces and in some areas must continuously migrate upward over time. This phenomenon results in the marsh acquiring a hummocky appearance with the height of the hummocks being limited to the level at which the mussels can still extract enough food from flooding tidal waters to survive (Teal and Teal 1969). In addition, the network of

Table 4.10. Average biomass and release of ammonia into marsh waters during summer by major marsh organisms. Biomass of mollusks excludes the shell weight; plant biomass aboveground only. Excretion proceeds for 12 h/day for *Geukensia,* 24 h/day for other species. Data from Jordan and Valiela (1982).

Species	Biomass (kg)	Release (μg NH_3-N/h/kg)	Release (kg NH_3-N/day/kg)
Bivalves			
Geukensia demissa	8,900	42	4.5
Mercenaria mercenaria	1,800	42[a]	1.8
Mya arenaria	1,000	30	0.73
Gemma gemma	460	42[a]	0.46
Grasses			
Spartina alterniflora	130,000	0.90	2.8
Spartina patens	3,600	0.42	0.4
Fish			
Menidia menidia	240	180	1.1
Fundulus heteroclitus	490	65	0.76
Fundulus majalis	120	160	0.47
Arthropods			
Uca pugnax	3,600	11[b]	1.0
Carcinus maenas	410	11	0.11
Orchestia spp.	140	11[b]	0.04
Snails			
Melampus bidentatus	460	19[c]	0.21
Ilyanassa obsoleta	55	19	0.02

[a] Excretion assumed equal to that of *G. demissa.*

[b] Excretion assumed equal to that of *C. maenas.*

[c] Excretion assumed equal to that of *I. obsoleta.*

byssal threads produced by these mussels increases the coherence of their substrate (Davis 1985) and may, along with belowground roots and rhizomes, stabilize marsh peat, especially areas along creekbanks. In areas with high levels of contaminants like polychlorinated biphenyls (PCB's) and metals in the water column (such as found in the Acushnet River estuary), the deposition of pseudofeces from filtration of organically bound contaminants increases the levels of these contaminants in the surface sediments of the marsh.

Studies by Jordan and Valiela (1982) indicate that ribbed mussels play an important role in the nitrogen cycle of coastal salt marshes. Nitrogen filtered but not deposited by ribbed mussels is excreted as ammonia or dissolved organic nitrogen, or used for production of flesh, shell, byssal threads, or gametes. The resident ribbed mussel population in Great Sippewissett Salt Marsh (West Falmouth) was found to maintain the highest biomass of any animal population, releasing more ammonia into the water than any population of plants or animals (Table 4.10), and accounting for 31% of the ammonia released into tidal waters during summer. Most of this ammonia is presumed to be taken up by phytoplankton or edaphic diatoms, bacteria, and fungi growing on *Spartina* detritus, as the overall ammonia concentration in tidal waters remains relatively unchanged. The population of ribbed mussels in Great Sippewissett was calculated to theoretically filter all of the water in each tidal cycle, although they presumably refilter water in their adjacent vicinity. Their biggest role in the nitrogen cycle of salt marshes is the retention of nitrogen within the system through biodeposition of suspended particulate nitrogen. This is also true for other marsh species, *Mercenaria mercenaria, Mya arenaria,* and *Gemma gemma*; however, given the dominance of the ribbed mussel in this marsh, it is responsible for most of the total bivalve filtration and biodeposition. If the amount of particulate nitrogen filtered by these mussels was instead exported from the system, a significant loss of nitrogen to coastal waters would result. Because nitrogen limits phytoplankton productivity in Buzzards Bay, the increased nitrogen retention by ribbed mussel filtration may actually serve to reduce fertilization of adjacent bay waters.

In addition to their aesthetic value, the importance of marshes as storm buffers, habitats, and nursery grounds for numerous species, and historically as a valuable source of salt marsh hay, has long been a basis for defense in their protection. More recently, the role of salt marshes as nutrient buffers for coastal waters is becoming increasingly evident as our understanding of these complex environments continues to grow. This is especially true for areas such as Buzzards Bay where residential development is continually increasing.

Because marshes exist at the land and sea interface, questions arose in the late 1960's and early 1970's as to whether salt marshes were nitrogen limited, as are many coastal marine systems, or phosphorus limited, as are many terrestrial systems. Experiments undertaken to answer this fundamental question, most notably long-term fertilization experiments initiated in 1970 in the Great Sippewissett Salt Marsh, identified nitrogen as the nutrient limiting production in the salt marsh environment (Valiela et al. 1975; Teal 1986). Much attention has been paid in recent years to the role of nitrogen-limited salt marshes in intercepting or buffering nitrogen inputs from terrestrial sources as they move toward coastal waters. The increased understanding of marsh processes in this regard has contributed to the development of artificial wetland ecosystems (such as Solar Aquatics; Teal and Peterson 1991) for the tertiary treatment of nutrient-rich wastewater and septage. These new technologies hold promise for dealing with the often competing objectives of utilization and protection in valuable yet ecologically fragile coastal environments like Buzzards Bay. More information is available on salt marsh ecology in Teal (1986) and Nixon (1982).

4.2.2. Tidal Flats

Tidal flats are gently sloping unvegetated areas extending seaward of coastal landforms to mean low water (MLW). These flats are typically exposed at low tide, revealing sediments ranging from sands to muds and silts. Tidal flats are generally depositional environments, with the area and duration of exposure dependent on tidal amplitude. They are often associated with other types of coastal environments such as embayments, salt marshes, spits, and barrier beaches that provide a source of sediment for development of the flat.

Tidal currents in Buzzards Bay are primarily responsible for the sediment makeup of these flats. Along shorelines exposed to higher currents and wind-driven wave energies, such as along the edge of the bay proper, these flats tend to be made up of coarser, sandier sediments, while those flats in more protected areas, such as in estuaries, behind barrier beaches, or within wetlands or salt ponds, generally have finer, siltier sediments. Their association with other types of marine systems is important for providing both a source of strata and a source of allocthanous organic matter to the organisms that inhabit them.

Because the overlying water column retreats at high tide, only infaunal and epibenthic animals colonize tidal flats. At high tide, however, numerous species of fish "commute" to graze on the benthos and epibenthic algae. The infaunal communities inhabiting the tidal flats along Buzzards Bay provide a valuable resource to the aquatic food web and to the many species of waterfowl that feed on these organisms during low tide. Shorebirds, feeding primarily on invertebrates such as polychaetes, mollusks, and crustaceans, often follow the water's edge as it advances and retreats over the flats, with maximum foraging during low tide when most of the tidal flat is exposed. Many other species utilize the tidal flats, including crabs such as rock crab

(*Cancer irroratus*), green crab (*Carcinus maenas*), and blue crab (*Callinectes sapidus*); these species migrate on and off the flats with the tide, feeding on submerged bivalves and annelids. The lady or calico crab (*Ovalipes ocellatus*) frequently buries itself in the sandy sediments of these flats. Hermit crabs (*Pagurus longicarpus* and *P. pollicaris*) and snails (*Ilyanassa* and *Nassarius*) also coexist on the tidal flats; the hermit crabs utilize the empty shells of the snails for semipermanent homes. The horseshoe crab frequently uses the tidal flats as feeding and spawning grounds and deposits its eggs at the high water line. As with marshland, Westport has the largest areas of tidal flat and barrier beach within Buzzards Bay. Additional information on New England tidal flat communities can be found in Whitlatch (1982).

4.3. Terrestrial

The physical processes that formed Buzzards Bay not only led to a wide variety of marine environments but also resulted in a diversity of land forms, habitats, and natural resources within its upland regions. Human activities within the watershed area over the past several centuries, however, have significantly altered the structure and composition of many of these terrestrial systems.

Numerous kettle ponds, common to pitted outwash plains such as Buzzards Bay, are a dominant feature of the landscape. These deep ponds were formed when large blocks of ice left by the retreating glaciers were buried by glacial debris and outwash sands that collapsed as the ice melted, leaving the depressions. When the base of the depression was below the water table, a pond was formed. Many of these ponds support freshwater marshes, typically dominated by *Typha* and *Phragmites,* and provide important habitat for many species of animals.

Other freshwater environments within the Buzzards Bay watershed, like the freshwater marshes, are structured by the amount and duration of freshwater saturation. Critical habitats such as sphagnum bogs, cedar swamps, and vernal pools dot the landscape around the bay. Sphagnum bogs are similar to marshes in that they become established in areas of persistently saturated soils. These bogs are dominated by *Sphagnum* spp. or “peat” mosses and low-growing shrubs like cranberry (*Vaccinium macrocarpon*). The live sphagnum or peat mosses grow in thick mats overlying deep layers of accumulated peat. A very fragile system, these bogs often support a variety of rare and unusual plants such as wild orchids and carnivorous plants such as sundews (*Drosera* sp.). Sphagnum bogs can be found around the bay, notably in Falmouth (Chappaquoit) and Bourne (near the railroad bridge).

Like sphagnum bogs, cedar swamps, which are dominated by the Atlantic white cedar (*Chamaecyparis thyoides*), highbush blueberry (*Vaccinium corymbosum*), and swamp azalea (*Rhododendron viscosum*), occur in areas of saturated soils and acidic waters that affect decomposition and nutrient availability. The white cedar swamp is commonly found along with red maples (*Acer rubrum*), which often restrict the extent of white cedar growth. These cedar swamps can be found in pockets or associated with cranberry bogs around Buzzards Bay, in Bourne (east of the Bourne Bridge) and Falmouth (east of Woods Hole and east of Little Sippewissett Marsh in West Falmouth), but most notably in the Acushnet Cedar Swamp in New Bedford and Dartmouth, considered to be one of the last truly wilderness areas in southeastern Massachusetts. Cedar swamps, like huckleberry and maple swamps, were historically much more abundant but were cleared and diked to form many of the existing cranberry bogs, which is the dominant agriculture of the region (White 1870; Thomas 1990). Cranberry bogs require damp but not saturated soils for best production, conditions found in many of the swamp forests. Some attempts were made by the early settlers to conserve the white cedar swamps because their wood was used in the construction of moisture-proof foundations and for the cedar shingles prevalent on many houses in the region. The diminished availability of firewood with progressive deforestation, however, increased the mining of peat from cedar swamps and, with the expansion of the cranberry industry in the 1800's, led to the near loss of this ecosystem from the watershed.

In the elevated areas around Buzzards Bay, the highly permeable soils of the region provide an ideal site for the growth of hardy species of oak (*Quercus* spp.), pitch pine (*Pinus rigida*), and white pine (*Pinus strobus*), the dominant trees of the region's forested land. Although somewhat small and "scrubby" (i.e., the name "scrub oak") by inland standards, these hardy trees reflect the low nutrient environment under which these forests have developed. Even with the encroachment of human development over time, these forests still support large numbers of wildlife, including deer (*Odocoileus virginianus*) and even coyote (*Canas latrans*). These woodlands have played an important role in the history of the region, yet the species we see today are not necessarily those viewed and utilized by the early settlers.

Significant changes have occurred in the bay's surrounding upland over the past several hundred years. In what is now primarily pitch pine-dominated forest, the landscape once supported significant stands of old growth forests of white pine, oak, walnut (*Juglans* spp.), beech (*Fagus grandifolia*), and holly (*Ilex opaca*). The extensive acreage of these original forests was frequently identified in the logs of early explorers and settlers (White 1870; O'Brien 1990). Although living near the sea, the early European settlers were predominantly farmers. Early on, they attempted to clear the forests for agricultural land with little understanding, and therefore regard, for the long-term impact on these virgin forests. These settlers were not the first, however, to impact the woodlands. Evidence in archeological records indicates that Native Americans typically practiced "slash and burn" techniques to clear the forests for the production of corn. Large-scale deforestation, however, occurred primarily from the late 1600's through the 1800's. Although many of the settlers shifted from farming to fishing, the cutting of the forests did not diminish. With fishing and whaling came shipbuilding, an important mainstay of the economy that increased the demand for wood for construction. There was also an associated demand for firewood to fuel the evaporation of seawater for preparation of salt and to boil whale blubber. About 1.5 cords of wood were required for producing only one bushel of salt (O'Brien 1990); at its peak, production of salt from Cape Cod was estimated at more than 1/2 million bushels per year (Fawsett 1990). In fact, the Sandwich Glassworks was established in the town of Sandwich not for its abundant sand (which was supposedly too impure) but for the extensive pitch pine and red oak (*Quercus rubra*) forests, which were cleared starting around 1825 and provided fuel for the glass furnaces for over 60 years, leaving the formerly well forested Sandwich hills basically bare.

The combined result of these various demands for wood was a general deforestation of the old growth forests all around Buzzards Bay, with only a few virgin areas now remaining; a notable example is a grove of white pine forest located in Beebe Woods, a forest preserve located just west of Falmouth center. After cutting, much of the woodland was left to natural succession. The relatively poor soil conditions that evolved after the destruction of the forests have led to reforestation by hardier species, notably the pitch pine, which grows widely in the region in those areas buffeted by wind and sea as well as on nutrient poor, sandy, barren soils. The survivability of this species also encouraged its widespread planting in the late 1800's so that with species of oak (scrub (*Quercus ilicifolia*), red, post (*Quercus stellata*), etc.), eastern red cedar (*Juniperus virginiana*, also known as juniper), and red maple, significant reforestation has occurred.

4.4. Unique and Threatened Environments

4.4.1. Anadromous Fish Runs

These fish runs are an important component of the fisheries of Buzzards Bay. Streams linking marine and freshwater bodies provide runs for several species of fish that grow to maturity in the ocean and migrate to fresh water to spawn. Living primarily in salt water, anadromous fish such as alewives, blueback herrings, white perches (*Morone americana*), and rainbow smelts (*Osmerus mordax*) migrate up tidal streams to brackish and freshwater systems where, after spawning, the fry hatch and eventually return to the sea. Except for rainbow smelt, which migrate from February through April, migration begins in early March or April (when the water temperatures of inland rivers and streams begin to warm up relative to colder waters offshore) and generally continues into June. Anadromous fish typically return to the place where they were hatched, although it is not entirely clear how they identify any particular stream except perhaps by the unique water chemistry that may be associated with one area versus another. Anadromous fish runs within the Buzzards Bay watershed are shown in Table 4.11.

Successful fish runs have common characteristics: an unimpeded connection between creeks, ponds, lakes, rivers, or streams and the sea; sufficient volume and depth of flow to enable fish to overcome periodic obstructions within the run such as fish ladders, natural falls, or log jams; good water quality in the spawning area; and, of course, an availability of fish. Because fish in their early life stages are very vulnerable to fluctuations in their spawning or nursery environment, relatively constant environmental conditions such as temperature and salinity can be important to successful recruitment. Industrial pollution also has local impacts on anadromous fish, such as in New Bedford Inner Harbor where several historically productive

Table 4.11. Anadromous fish runs of Buzzards Bay. (From Massachusetts Department of Environmental Quality Engineering 1978.)

Town	River	Species	Spawning area
Falmouth	Herring Brook	Alewife, blueback herring	Wings Pond
	Wild Harbor River	Alewife	Dam Pond
Bourne	Herring River	Alewife	Little Herring Pond
Wareham	Sippican River	Alewife	Sippican River
	Agawam River	Alewife, rainbow smelt	Mill Pond
	Wankinco River	Alewife	Parker Mills Pond
	Red Brook	Alewife, blueback herring	White Island Pond
	Gibbs Brook	Alewife	Dicks Pond
Marion	Weweantic River	Alewife, rainbow smelt	Horseshoe Pond
Mattapoisett	Mattapoisett River	Alewife	Mattapoisett River
Acushnet	Acushnet River	Alewife	Sawmill Pond
Dartmouth	Slocums River	Alewife, rainbow smelt	Destruction Brook/ Russell's Mill Dam
Westport	Richmond Pond	Alewife	Richmond Pond
	Cockeast Pond	Alewife	Cockeast Pond
	Westport River	Alewife, brook trout	Westport River

fish runs have been all but eliminated. However, around Buzzards Bay it appears that simple impediments to migration by construction of dams without fish ladders or alteration associated with development, farming, or cranberry growing and even failure to maintain existing runs are the prime causes of declines of anadromous fish populations. Renewed interest in this fishery around Buzzards Bay in recent years, however, has resulted in increased attention to maintaining or improving the existing fish runs, and in reestablishing some of those lost through neglect or alteration.

4.4.2. Endangered Species

Some endangered and threatened species have been identified in the region of Cape Cod and the Buzzards Bay watershed (Table 4.12). To successfully preserve these species, it is necessary to preserve their habitats since the decline of many animal species is due to loss of nesting or ecological habitat. Species at the limits of their ranges are particularly sensitive as additional suitable habitat may not be readily available in response to alteration or destruction of existing areas. In addition to the obvious concerns over diminishing wildlife populations and decreasing habitat for many coastal species, indirect effects of activities in the coastal zone may also impact populations. The use of fertilizers and pesticides, for example, may affect areas far from the source of application. Beyond the direct impact of development, the mere presence of people may adversely affect the territorial behavior of many animals. Pets roaming free on the beach may act as predators and cause birds to abandon their nests. Stabilization of eroding dune systems near endangered nesting sites by "planting" used Christmas trees has been identified as problematic as they provide hiding places for many predatory animals. Even kite flying near ground-nesting birds can affect behavior because the kites are perceived as large avian predators.

Because the list of rare and endangered species (Table 4.12) is substantial and new species are being added, a species by species discussion is beyond the scope of this text. Several species, however, most notably avian fauna, are the focus of intensive, integrated, and highly visible protection programs and are briefly discussed.

Sandy beaches surrounding Buzzards Bay, notably Little Beach and Horseneck Beach on the bay's western shore, provide habitat for the federally listed piping plover (*Charadrius melodus*; Fig. 4.11). Piping plovers are indigenous to sandy beaches and have evolved a sand-colored body that is difficult to spot. Migrating from areas of the south Atlantic coast to northern Mexico, they arrive in late March and April and nest on the open beaches through August (O'Brien 1990). In the 1800's, piping plovers were extremely abundant but were hunted to near extinction by the early 1900's for the millinery trade. The Migratory Bird Treaty Act of 1918 provided the piping plover with some protection, and populations increased into the 1940's; thereafter, human disturbance and predation of nesting sites, primarily from development and increased recreational use of beaches, once again resulted in population decline. Recent surveys indicate less than a thousand pairs occur along the Atlantic Coast (D. Mignogno, U.S. Fish and Wildlife Service, Hadley, Mass., personal communication). Each nesting season, beach areas of active and potential nesting are cordoned off or fenced to exclude people and predators, and nesting success is followed and recorded to gauge population dynamics. Considered of "special concern" by the Massachusetts Natural Heritage Program and Endangered Species Program are least terns, whose nesting habitats—sparsely vegetated regions of the barrier beach above the high tide line—are similar to those of the piping plover. In the Buzzards Bay area, efforts undertaken to protect plovers are frequently expanded to include nesting habitats for least terns.

Buzzards Bay, specifically Bird Island located in Marion, also provides habitat for another federally listed endangered species, the roseate tern. These birds breed primarily on small islands and occasionally at the end of barrier beaches and build nests under or next to vegetation or some other object affording protection. Two distinct breeding populations are found in North America: one occurs along

Table 4.12. Rare plants and wildlife identified by the Massachusetts Natural Heritage Program and Endangered Species Program for the Cape Cod region including the Buzzards Bay watershed. From VanLuven (1991) and O'Brien (1990).

Species	Status
Plants	
Isoetaceae (quillworts)	
Isoetes acadiensis (Acadian quillwort)	Endangered
Ophioglossaceae (adder's-tongue ferns)	
Ophioglossum vulgatum (adder's-tongue fern)	Threatened
Schizaeaceae (climbing and curly grass ferns)	
Lygodium palmatum (American climbing fern)	Special concern
Alismataceae (arrowheads, water-plantains)	
Sagittaria teres (terete arrowhead)	Special concern
Poaceae (grasses)	
Aristida purpurascens (purple needlegrass)	Threatened
Dichanthelium wrightianum (Wright's panic-grass)	Special concern
Dichanthelium commonsianum (common's panic-grass)	Special concern
Dichanthelium mattamuskeetense (Mattamuskeet panic-grass)	Endangered
Diplachne maritima (saltpond grass)	Threatened
Elymus mollis (sea lyme-grass)	Endangered
Panicum philadelphicum (Philadelphia panic-grass)	Special concern
Setaria geniculata (bristly foxtail)	Special concern
Spartina cynosuroides (salt reed-grass)	Special concern
Spenopholis pennsylvanica (swamp oats)	Threatened
Cyperaceae (sedges)	
Carex oligosperma (few-fruited sedge)	Threatened
Carex striata (Walter's sedge)	Endangered
Eleocharis obtusa (ovate spikerush)	Endangered
Psilocarya nitens (short-beaked baldrush)	Threatened
Psilocarya scirpoides (long-beaked baldrush)	Special concern
Rhynchospora inundata (horned beakrush)	Threatened
Rhynchospora torreyana (Torey's beakrush)	Endangered
Scleria pauciflora (papillose nutrush)	Endangered
Araceae (arums)	
Orontium aquaticum (golden club)	Threatened
Juncaceae (rushes)	
Juncus biflorus (two-flowered rush)	Endangered
Juncus debilis (weak rush)	Endangered
Haemodoraceae (bloodworts, redroots)	
Lachnanthes carolina (redroot)	Special concern
Iridaceae (irises)	
Sisyrinchium arenicola (sandplain blue-eyed grass)	Special concern
Orchidaceae (orchids)	
Arethusa bulbosa (dragon's mouth orchid)	Threatened
Listera cordata (heartleaf twayblade)	Endangered
Platanthera dilatata (leafy white orchid)	Threatened
Spiranthes vernalis (grass-leaved ladies' tresses)	Special concern
Tipularia discolor (cranefly orchid)	Endangered
Polygonaceae (docks, knotweeds)	
Polygonum puritanorum (pondshore knotweed)	Special concern
Polygonum setaceum (strigose knotweed)	Special concern

Table 4.12. (continued)

Species	**Status**
Chenopodiaceae (saltworts, sea-blights)	
Suaeda americana (American seepweed)	Special concern
Portulacaceae (purslanes, spring beauties)	
Claytonia virginica (narrow-leaved spring beauty)	Threatened
Rosaceae (roses, shadbushes)	
Crataegus bicknellii (Bicknell's hawthorn)	Endangered
Linaceae (flaxes)	
Linum intercursum (sandplain flax)	Special concern
Linum medium (rigid flax)	Threatened
Empetraceae (crowberries)	
Corema conradii (broom crowberry)	Special concern
Hypericaceae (St. John's-worts)	
Hypericum adpressum (creeping St. John's-wort)	Threatened
Cistaceae (rockroses, frostweeds)	
Helianthemum dumosum (bushy rockrose)	Special concern
Cactaceae (cacti)	
Opuntia humifusa (prickly pear)	Special concern
Melastomataceae (meadow beauties)	
Rhexia mariana (Maryland meadow beauty)	Threatened
Haloragaceae (water-milfoils)	
Myriophyllum pinnatum (pinnate water-milfoil)	Special concern
Apiaceae (parsleys, angelicas)	
Hydrocotyle verticillata (saltpond pennywort)	Special concern
Gentianaceae (gentians)	
Sabatia campanulata (slender marsh pink)	Endangered
Sabatia kennedyana (Plymouth gentian)	Special concern
Asclepiadaceae (milkweeds)	
Asclepias verticillata (linear-leaved milkweed)	Threatened
Asclepias purpurascens (purple milkweed)	Threatened
Boraginaceae (borages)	
Mertensia maritima (oysterleaf)	Endangered
Scrophulariaceae (figworts)	
Agalinis acuta (sandplain gerardia)[a]	Endangered
Lentibulariaceae (bladderworts)	
Utricularia biflora (two-flowered bladderwort)	Threatened
Utricularia fibrosa (fiberous bladderwort)	Threatened
Utricularia subulata (subulate bladderwort)	Special concern
Caprifoliaceae (honeysuckles)	
Triosteum perfoliatum (broad tinker's-weed)	Endangered
Asteraceae (asters, composites)	
Achillea millefolium (seaside yarrow)	Threatened
Eupatorium aromaticum (lesser snakeroot)	Endangered
Eupatorium leucolepis (New England boneset)	Endangered
Gnaphalium purpureum (purple cudweed)	Endangered
Lactuca hirsuta (hairy wild lettuce)	Endangered
Prenanthes serpentaria (lion's foot)	Endangered

Table 4.12. (continued)

Species	Status
Wildlife (vertebrates)	
Fish	
Lampetra appendix (American brook lamprey)	Threatened
Acipenser brevirostrum (shortnose sturgeon)[a]	Endangered
Amphibians	
Hemidactylium scutatum (four-toed salamander)	Special concern
Scaphiopus holbrookii (eastern spadefoot toad)	Threatened
Reptiles	
Clemmys guttata (spotted turtle)	Special concern
Malaclemys terrapin (diamondback terrapin)	Threatened
Terrapene carolina (common box turtle)	Special concern
Pseudemys rubiventris bangsi (Plymouth red-bellied turtle)[a]	Endangered
Caretta caretta (loggerhead sea turtle)[a]	Threatened
Lepidochelys kempii (Kemp's ridley sea turtle)[a]	Endangered
Dermochelys coriacea (leatherback sea turtle)[a]	Endangered
Birds	
Podilymbus podiceps (pied-billed grebe)	Threatened
Botaurus lentiginosus (American bittern)	Special concern
Ixobrychus exilis (least bittern)	Threatened
Accipiter striatus (sharp-shinned hawk)	Special concern
Circus cyaneus (northern harrier)	Threatened
Haliaeetus leucocephalus (bald eagle)[a]	Endangered
Gallinula chloropus (common moorhen)	Special concern
Rallus elegans (king rail)	Threatened
Charadrius melodus (piping plover)[a]	Threatened
Bartramia longicauda (upland sandpiper)	Endangered
Sterna antillarum (least tern)	Special concern
Sterna dougallii (roseate tern)[a]	Endangered
Sterna hirundo (common tern)	Special concern
Sterna paradisaea (Arctic tern)	Special concern
Tyto alba (common barn-owl)	Special concern
Asio flammeus (short-eared owl)	Endangered
Ammodramus savannarum (grasshopper sparrow)	Special concern
Parula americana (northern parula warbler)	Threatened
Pandion haliaetus (osprey)	Special concern
Mammals	
Halichoerus grypus (gray seal)	Special concern
Wildlife (invertebrates)	
Bivalvia (mussels and clams)	
Leptodea ochracea (tidewater mucket)	Special concern
Ligumia nasuta (eastern pond mussel)	Special concern
Hirudinea (leeches)	
Macrobdella sestertia (New England medicinal leech)	Special concern
Odonata (dragonflies and damselflies)	
Aeshna mutata (spring blue darner dragonfly)	Endangered
Anax longipes (long-legged green darner dragonfly)	Special concern
Enallagma carunculatum (bluet damselfly)	Special concern
Enallagma laterale (lateral bluet damselfly)	Special concern
Enallagma recurvatum (barrens bluet damselfly)	Threatened

Table 4.12. (continued)

Species	Status
Lepidoptera (butterflys and moths)	
Fixsenia ontario (northern haristreak butterfly)	Special concern
Speyeria idalia (regal fritillary butterfly)	Endangered
Abagrotis crumbi banjamini (coastal heathland cutworm)	Special concern
Apharetra purpurea (blueberry sallow moth)	Threatened
Bagisara rectifascia (straight lined mallow moth)	Special concern
Catocala herodias gerhardi (Gerhard's underwind moth)	Threatened
Cicinnus melscheimeri (Melscheimer's sack bearer moth)	Threatened
Cingilia catenaria (chain dot geometer moth)	Special concern
Hemileuca maia (barrens buckmoth)	Threatened
Lithophane viridipallens (pale green pinion moth)	Special concern
Metarranthis apiciaria (coastal swamp metarranthis moth)	Special concern
Oligia hausta (northern brocade moth)	Special concern
Papaipema stenocelis (chain fern borer moth)	Special concern
Papaipema sulphurata (decodon stem borer moth)	Threatened

[a] Indicates species is federally listed as same status (U.S. Fish and Wildlife Service 1994).

a series of islands off the northeastern coast of the United States, from New York to Maine, and has smaller numbers of individuals extending as far as the Canadian Maritime Provinces; the second breeds on islands in the Caribbean Sea region extending from the Florida Keys and the Bahamas to the Lesser Antilles. Buzzards Bay represents an important locale for this species; approximately 60% of the northeast population nests on Bird Island in Buzzards Bay (1,650 nesting pairs in 1984; U.S. Fish and Wildlife Service 1989; B. Blodgett, Massachusetts Natural Heritage and Endangered Species Program, personal communication). As is true for the piping plover, the roseate tern population was significantly decreased in the late 1800's because of hunting associated with the millinery trade. The Migratory Bird Treaty Act of 1918 facilitated recovery of this species in the northeast to about 8,500 nesting pairs by the 1930's; however, the population decreased to roughly 2,500 pairs by 1977 because of increased numbers of nesting herring gulls and great black-backed gulls and increased human activities (U.S. Fish and Wildlife Service 1989). Extensive efforts have been undertaken to increase the species' nesting population and to expand the breeding range through a recovery program for the northeastern population. The goals of this program are to increase the species' nesting population to 5,000 pairs within at least six colonies in its current northeast range and hopefully effect an ultimate return to 1930's levels (U.S. Fish and Wildlife Service 1989).

Fig. 4.11. The piping plover (*Charadrius melodus*). Photo by D. Goehringer.

The osprey *(Pandion haliaetus*) is considered a rare bird whose numbers diminished throughout the United States during the 1950's and 1960's as a result of the widespread use of the pesticide DDT. The pesticide primarily affected ospreys by causing a thinning of the eggshell, rendering the eggs fragile and susceptible to disturbance or predation. Ospreys nest high above the ground, building large nests up to 2.4 m in diameter usually in large dead trees near the water, which provide them with easy access to their primary diet of fish. Human activities and development along the coast have resulted in the disappearance of many of these potential nesting platforms. Efforts all around Buzzards Bay to erect poles with nesting platforms have resulted in the return of many ospreys to the bay shores (Poole 1989).

A nonavian endangered species under federal protection is the Plymouth red-bellied turtle (*Pseudemys rubiventris bangsi*), a subspecies of the red-bellied turtle of mid-Atlantic coastal plains. Only about 200 adults making up 12 populations are currently known, all within Plymouth County, which extends into the northeastern portion of the bay's watershed. Primarily a herbivorous freshwater reptile inhabiting freshwater ponds, the Plymouth red-bellied turtle requires a sandy substrate in the surrounding upland for nesting in late June and early July. Hatchlings emerge from late August through October, and survivors reach maturity at 8 to 15 years, females possibly later than males. While many factors have led to the decline of the Plymouth red-bellied turtle, possibly the most significant has been habitat losses both by direct destruction or indirect alteration resulting from land-use practices that prevent upland burning and decrease the availability of suitable nesting sites (Massachusetts Natural Heritage Program 1987).

There are a few strictly marine threatened or endangered species that use the bay; all are sea turtles. Federally listed species that frequent Buzzards Bay waters are the loggerhead (*Caretta caretta*, threatened), Kemp's ridley (*Lepidochelys kempii*, endangered), and leatherback (*Dermochelys coriacea*, endangered). These sea turtles visit the bay in summer after migrating from overwintering regions in warmer southern waters. Water temperature partially dictates their appearance because they lack the ability to regulate body temperature. Ridley and loggerhead turtles cannot withstand temperatures below 23.2° C and 19.5° C, respectively (O'Brien 1990), while the leatherback, which may have some thermoregulatory mechanism, has been found in colder northern waters (D. Mignogno, personal communication). The numbers of sea turtles frequenting Buzzards Bay are difficult to ascertain since their subtidal distribution makes sightings rare; however, 14 leatherback sea turtles were stranded around the bay from 1984 to 1987. Kemp's ridley sea turtle reports include three strandings in the early 1900's and a large number of sitings and strandings during a single event in the 1930's. Since the 1930's there have been no reports of further Kemp's ridley strandings (cf. Payne et al. 1994), although they have been occasionally sighted (Prescott in Camp, Dresser, and McKee, Inc. 1990). Only a single loggerhead has been found stranded in recent years (1985) within Buzzards Bay.

Use of Buzzards Bay by sea turtles is likely greater than suggested by the available sighting and stranding reports given the difficulty in seeing turtles at sea and the restriction against net fishing within the bay, which is a major source of sightings in other regions (cf. Payne et al. 1994).

Buzzards Bay does not present a habitat for significant utilization by either whales or dolphins. It appears that the absence of topographic and oceanographic features that concentrate prey species (and possibly the bay's shallow waters) are the underlying causes. A few individual sightings of cetaceans have been reported this century, though they tend to be near the entrance to Buzzards Bay, typically off Cuttyhunk, rather than within the bay itself (Payne et al. 1994).