PECONIC ESTUARY PROGRAM

NATURAL RESOURCES SUBCOMMITTEE

CHARACTERIZATION REPORT OF THE LIVING RESOURCES OF THE PECONIC ESTUARY

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BY

MARCI L. BORTMAN AND NANCY NIEDOWSKI

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INTRODUCTION

The U. S. Congress recognized both the importance of estuaries and human threats to these systems and in 1987 established the National Estuary Program (NEP). The NEP is currently made up of 28 estuaries, each of which consists of representatives of government, education, research, industry, nongovernmental organizations, and citizens from the local community. Each national estuary program consists of a group of people working together and through consensus building, is currently in the process of developing or implementing a Comprehensive Conservation and Management Plan (CCMP). The CCMP is a framework for managing an estuary based on recommendations to reduce pollution and protect estuarine resources.

In 1993, the Peconic Estuary was designated as an estuary of national significance and included in the NEP (Figure 1). The Peconic Estuary Program has identified the Peconic Estuary as embracing diverse resources and habitats, which, in turn, provide values and uses important to all the citizens of New York as well as to residents of the region. The members of the Peconic Estuary Program aim to develop and implement a CCMP that will protect, restore, and enhance the Estuary so that its many values and uses exist for current and future generations, as well as for the well-being of the ecosystem.

The broad objectives of this program are to identify the living resources at risk, and to determine how human activities have or could alter the health of these resources. An understanding of the current stresses and potential threats to the living resources of the Peconics must be obtained. As this understanding develops, actions will be taken to correct impairments, or to prevent further degradation of the habitats in which organisms live. This report provides background information necessary to understand the biological functioning of the Peconic Estuary through an examination of species and habitats in the system and their relationships with one another, to water quality, and to land use.

BACKGROUND

Estuaries are bays, sounds, harbors, and other semi-enclosed coastal waters that are connected to the sea and where fresh water from rivers, streams, creeks, or ground water mixes with salt water (Pritchard 1967). Estuaries provide: (1) critical habitat for numerous birds, mammals, fish, shellfish, and other wildlife; (2) nursery and spawning areas for many marine organisms including commercially and recreationally important fish and shellfish; and, (3) natural buffers that filter sediment and nutrients out of water draining from land, absorb flood waters, and dissipate waves during storms; protecting human property. Marshes, mudflats, beaches and dunes, inlets, submerged aquatic vegetation, and other marine and terrestrial habitats are linked to comprise critical transition zones between land and sea. Estuaries are recognized as some of the most fertile waters in the world and contain a variety of specialized plants and animals (Odum 1989 from Newell *et al.* 1994). The community of organisms living in estuaries includes mammals, birds, reptiles, insects, bacteria, fish, shellfish, and plants, which all interact within a complex food web.

The Peconic Estuary and its watershed have been identified as one of the "Last Great Places" in the western hemisphere by The Nature Conservancy due to its rich mosaic of underwater and coastal habitats that support a variety of marine life, birds and other wildlife, some of which are rare and endangered, or commercially and recreationally important. Approximately 124,800 acres drain to the Estuary, 30,000 of which are protected by public and private agencies and organizations. The watershed supports 140 globally and state rare species and exemplary examples of natural, diverse communities including over 90 separate areas that have been designated as significant coastal fish and wildlife habitats by the New York Department of State (Suffolk County Department of Health Services 1991; Pleuthner 1995).

The Peconic Estuary provides important habitat as well as spawning and nursery grounds to a wide variety of marine organisms--most notably shellfish such as bay scallops (*Argopecten irradians*), hard clams (*Mercenaria mercenaria*), and fish such as bay anchovy (*Anchoa mitchelli*), Atlantic silverside (*Menidia menidia*), scup (*Stenotomus chrysops* [also called porgy]), summer flounder (*Paralichthys dentatus* [also called fluke]), winter flounder (*Pleuronectes americanus*), windowpane flounder (*Scopthalmus aquosus*), weakfish (*Cynoscion regalis* [also called grey sea trout]), and tautog (*Tautog onitis* [also called blackfish]). One of the most important underwater habitats of the Estuary are the meadows of eelgrass (*Zostera marina*) found along the edges of the eastern end of the Peconic Estuary. These eelgrass beds provide food, shelter and nursery grounds to many marine animals including worms, shrimp, scallops and other bivalves, crabs, and fish. Eelgrass beds stabilize the bay bottom and are also an important component of the nutrient cycle in the Estuary.

Estuaries are in a constant state of change, responding to a continuum of short to long-term forces. For example, estuaries respond to short term fluctuations from tides and stormwater runoff, seasonal changes in light, temperature and diversity and abundance of marine resources, and other long-term changes such as the rise in sea level (Newell *et al.* 1994). Overlain on these natural changes are human influences on estuaries, which can consist of modifying the natural pattern of estuarine inputs or disrupting habitats (Newell *et al.* 1994). Changes in inputs include discharging pollutants (i.e., toxics, excess nitrogen and phosphorus from sewage, fertilizers and other sources) into estuaries from point and nonpoint sources. Filling in of wetlands, hardening shorelines, and dredging areas near eelgrass beds are examples of how human activities can alter some of the estuaries' most critical habitats (National Estuarine Research Reserve undated). As development continues in the watershed and demand on the Peconic Estuary increase, so too does the importance of protecting this ecosystem.

PHYSICAL DESCRIPTION OF THE SYSTEM

The Peconic Estuary is a series of connected bays between the north and south forks of eastern Long Island. At the head of the Estuary is Flanders Bay into which the Peconic River flows (Hardy 1976). However, the largest source of freshwater input to the Estuary is from nonpoint sources such as groundwater seepage and runoff (Hardy 1976). From Flanders Bay, the Peconic Estuary stretches eastward to Great Peconic Bay, Little Peconic Bay, and Gardiners Bay. Between Little Peconic Bay and Gardiners Bay is Shelter Island, around which water flows by means of two tidal channels (Hardy 1976).

The Peconic Estuary watershed encompasses approximately 505 km^2 (124,800 ac). The shoreline consists of numerous necks, islands, bluffs, tidal creeks, and marshes (Hardy 1976). The Peconic Estuary was formed by both stream erosion and the retreat of the Wisconsin glacier in response to a warming global climate. The glacier left two prominent end moraines that separate to form the Peconic Estuary. The southernmost and older of the two moraines, the Ronkonkoma Moraine, makes up the central and south fork sections of Long Island. The Harbor Hills Moraine makes up the north shore and north fork of Long Island, including Orient Point, Plum Island, and Fishers Island. It is the younger of the two moraines, marking where the glacier retreated from the Ronkonkoma Moraine and remained in place for an extended period of time (U. S. Fish and Wildlife Service 1997).

The bays which make up the Peconic Estuary are fairly shallow. The deepest areas of the Estuary are at the races (ranging from approximately 5.5 m to 29 m [18 to 95 ft]) north and south of Shelter Island. Flanders Bay is the most shallow of the bays having deepest water depths of about 4.3 m (14 ft). The other bays that make up the Peconic Estuary range between 6 and 12 m (20 to 40 ft) deep at their centers with deeper pockets located east of Robins Island and southeast of Cedar Beach Point. Water depths increase to > 9 m (30 ft) east of Gardiners Island.

The Peconic bays experience semidiurnal tidal currents with highest velocities through constricted passes (approximately 100 cm s^{-1}) such as north and south of Shelter Island (Wilson and Beltrami 1998). Weak gyres caused by tidally induced residual currents are found to occur in the middle of the bays with smaller gyres occurring near promontories (Wilson and Beltrami 1998). Tides dominate circulation and mixing in the Estuary. Wind is the second most important force in mixing and dispersal (Hardy 1976).

The tidal range varies from 0.7 m (2.3 ft) in Shelter Island Sound, to 0.76 m (2.5 ft) in Gardiners Bay, and 0.82 m (2.7 ft) in Flanders Bay (Hardy 1976). The Shinnecock Canal connects Great Peconic Bay to Shinnecock Bay. A tidal gate on the canal only allows flow from Great Peconic Bay to Shinnecock Bay thereby limiting tidal exchange into the Estuary.

Average salinity of Gardiners Bay is 29.4 practical salinity units (psu). Further westward in Flanders Bay, the average salinity is lower at approximately 27.7 psu (Hardy 1976). Nuzzi and Waters (1998) found similar salinity ranges for the different bays. Temperatures range in the Estuary from approximately -0.1 to 26.3 °C from January to August (Bruno *et al.* 1983). During their research in Little Peconic Bay, Bruno *et al.* (1983) found temperature differences of 1.8 °C between surface and bottom waters, indicating a well-mixed water column. However, they also found occasional temporary stratification between 0.5 and 2.5 m during periods of relative water column stability. These periods of stratifications lasted only on the order of a few hours.

The residence time of the water, or how long a particle of water remains in a particular bay, decreases eastward: 55 days in Flanders Bay; 48 days in Great Peconic Bay; 32 days in Little Peconic Bay; and, 22 days in Shelter Island Sound (Hardy 1976). Gardiners Bay has higher flushing rates and presumably residence time is much less than 22 days.

ECOLOGY OF THE PECONIC ESTUARY

Ecosystems consist of communities of organisms and their physical settings or habitats. There is a complex flow of energy through an ecosystem (Parsons *et al.* 1988). The pathway through which energy is transferred from one assemblage of organisms to another is based upon feeding relationships (trophic levels) called a food web (Strieb 1993). Food webs are complex, involving numerous energy sources, interactions, and sinks. Sunlight is the primary energy source for plants (primary producers). Marine plants, which range from microscopic phytoplankton to meadows of seagrass beds in the Peconic Estuary, form the base of the food web. They are the energy source for a whole host of animals (primary consumers), which are in turn prey for numerous predators (secondary and tertiary consumers). Some organisms feed on both plants and animals, usually depending on food availability. The estuarine sediment is a sink for inorganic and organic matter such as fecal material and organisms when they die. Some of the organic matter raining down from the water column is consumed by benthic or bottom species. Some is lost by burial or sedimentation with time, while other energy and nutrients from organic matter are recycled back into the food web through consumption by decomposers such as bacteria and fungi. Energy also leaves the estuarine food web as organisms migrate out of the estuary. Organisms are constantly entering and leaving the Peconic Estuary; however, the basic functions may remain constant for long periods of time (Odum 1989 from Newell *et al.* 1994).

The living resources of the Peconic Estuary can be categorized by the part of the estuary which they inhabit. Pelagic communities consist of planktonic (drifting) and nektonic (swimming) organisms that live in the water column. Benthic communities are organisms found on the bottom of the estuary. These organisms live on the surface (epifauna) of the sediment or live within (infauna) the sediment. Shoreline communities include tidal wetlands, rocky intertidal habitats, beaches and dunes, and bluffs. Plants and animals found in each of these locations, their trophic interactions, and the direct and indirect threats to them or their habitats are described below.

Pelagic Communities

Plankton

The plankton community consists of drifting organisms that are moved by tides and currents. Plankton (derived from the greek, *planktos,* to wander) are made up of bacterioplankton, phytoplankton, and zooplankton. Phytoplankton are single-celled microscopic marine plants that form the base of the food web in the Peconic Estuary. Zooplankton are the primary consumers in the food web and consist of small organisms from almost every animal phylum (Lerman 1986). The two main groups of zooplankton are meroplankton and holoplankton. Meroplankton spend only a portion of their life as plankton, usually when they are larvae such as some species of finfish, molluscs, echinoderms, and crustaceans. Holoplankton spend their whole life as plankton. The most common forms of zooplankton are protozoa and copepods, which are small, unicellular organisms and shrimp-like crustaceans, respectively. Some planktonic organisms have limited mobility, which allows them to perform diurnal (daily) migrations vertically in the water column to avoid predators and obtain nutrients and food.

In 1979 and 1983, several studies performed on the Peconic Estuary plankton by scientists from the former New York Ocean Science Laboratory in Montauk found that dinoflagellates and diatoms are the most common types of phytoplankton found in the Estuary (Bruno *et al.* 1980; 1983). Dinoflagellates have two flagella, or tails that help them control, to a limited extent, their position in the water column. Unlike dinoflagellates, diatoms do not have flagella. They have tests, or shells, made of silica and frequently form long chains of cells. They are the dominant type of large plankton called net plankton (> 20 μm) that blooms (i.e., rapid growth that outcompetes other phytoplankton to make up the majority of the phytoplankton biomass) as part of the natural, estuarine cycle in late winter-early spring in response to increased light availability. The phytoplankton bloom continues until they suffer nutrient depletion and/or the biomass is grazed down by zooplankton (D. Lonsdale, MSRC, SUNY Stony Brook, pers., comm. 1998). In other estuaries, phytoplankton abundance during a bloom becomes limited by essential nutrients (nitrogen and silica). Until recently, nutrients were not found to limit phytoplankton growth even during algal blooms in the Peconic Estuary (Bruno *et al.* 1983; Kim 1993); however, there is now strong evidence that nutrient limitation is occurring particularly in the summer in areas such as West Neck Bay (D. Lonsdale, MSRC, SUNY Stony Brook, pers., comm. 1998). Therefore, grazing of phytoplankton by zooplankton and fish and nutrient depletion play an important role in limiting bloom duration.

Bruno *et al.* (1980) estimated phytoplankton biomass (by measuring chlorophyll *a*) and productivity and found that peaks in chlorophyll *a* corresponded with peaks in primary productivity from July to August and in January. Lowest chlorophyll *a* levels for the year were recorded in October (Bruno *et al.* 1983; Turner *et al.* 1983). Phytoplankton cell densities were higher in Flanders Bay (averaging 5.11×10^5 cells l^{-1}) than Little Peconic Bay (9.51×10^4 cells l^{-1}), which was similar to the rest of the Estuary. A study performed by Kim (1993) found similar results with highest chlorophyll *a* levels occurring in Reeves Bay (1.8 to 239 mg chl à m^{-3}) compared to New Suffolk (1.6 to 10.2 mg chl à m^{-3}) and West Neck Bay (1.1 to 10.3 mg chl à m^{-3}) with maximum concentrations occurring in late summer.

Annual primary productivity in the Peconic Estuary ranges from 5 to 1234 g carbon (C) m^{-2} y^{-1} with the highest productivity occurring in Reeves Bay (Bruno *et al.* 1980; Bruno *et al.* 1983; Turner *et al.* 1983; Kim 1993). The nanoplankton (< 20 μm) dominates phytoplankton abundance from spring through early fall and accounts for 68% of the total primary productivity and 69% of the standing crop (measured as chlorophyll *a*). Nanoplankton productivity usually peaks in late summer/early fall. Net plankton (> 20 μm) accounts for approximately 32% of the total primary productivity. Lonsdale *et al.* (1996) and Kim (1993) found small nanoplankton (< 10 μm) to be a major contributor to primary production, contributing to between 80 and 95.7% of total phytoplankton production in the summer months and from 50 to 60% of total phytoplankton production during the winter and spring in the Peconic Estuary. Total primary productivity rates and phytoplankton biomass (as measured by chlorophyll *a*) during brown tide blooms remain at levels comparable to non-brown tide bloom years (Bricelj and Lonsdale 1997).

Bruno *et al.* (1980) characterized the phytoplankton communities and found them to be very similar to those in other northeastern U. S. estuaries. They discovered an increase in phytoplankton diversity from west to east in the Estuary; however, their finding was mostly due to phytoplankton blooms consisting predominantly of two dinoflagellate species, *Prorocentrum minimum* and *Peridinium trochoideum*, and an unidentified euglenoid (historically called "small forms") occurring in Flanders Bay near Meetinghouse Creek and the mouth of the Peconic River in the spring. The most common diatom species identified in Peconic waters were *Skeletonema costatatum* and *Thalassiosira nordenskjoldii*, both of which dominate the winter-spring bloom (Bruno *et al.* 1983).

Kim (1993) found in Reeves Bay a rapid succession of dominant phytoplankton species that included short-chained diatoms (*Leptocylindrus danicus* and *Skeletonema costatum*) and a cryptonomad (*Chroomonas amphioxieia*) in spring, followed by the dinoflagellate, *Gyrodinium aureolum*, and an euglenoid (*Euglena pumila*) in summer. The dinoflagellates *Gyrodinium aureolum* and *Prorocentrum redfieldii,* and the euglenoid *Euglena proxima* are usually dominant throughout the fall and winter (Kim 1993). Due to a paucity of information, it is unknown whether this succession of species occurs every year.

Kim (1993) found the waters of New Suffolk and West Neck Bay to have phytoplankton species composition similar to Reeves Bay. The diatom, *Leptocylindrus danicus*, was dominant during the spring, followed by *Gyrodinium aureoleum* in late spring. Phytoplankton species composition was found to differ in New Suffolk from Reeves Bay and West Neck Bay in June with the dominance of a large solitary diatom *Rhizosolenia setigera.* The euglenoid, *Euglenia pumila* was the most common phytoplankton species in July in New Suffolk and West Neck Bay. The heterotrophic dinoflagellate *Polykrikos kofoidii* appears in mid-August and can comprise greater than 60.3% of the > 5 μm cell numbers (Kim 1993). During the fall, the noncolonial diatom *Asterionella glacialis* is typically the dominant species at New Suffolk. Studies performed in West Neck Bay did not find a distinct dominant species during the fall season. During the winter season, the diatoms *Skeletonema costatum* and *Leptocylindrus danicus* have been found to be in largest numbers at New Suffolk and West Neck Bay (Kim 1993).

The predominant zooplankton that graze on phytoplankton in the spring are large copepods (~ 1 mm) such as adult *Acartia hudsonica, Centropages hamatus, Pseudocalanus* sp., late-stage copepodites (juvenile copepods), and American sand lance (*Ammodytes americanus*) larvae (Turner *et al.* 1983). From spring to summer, zooplankton are eaten by juvenile fish, ctenophores (comb jellies), and other organisms in the Estuary. The reduction in zooplankton grazing pressure and increasing water temperature result in a second phytoplankton bloom during the summer. The summer bloom is comprised mostly of small nanoplankton (< 5 μm) which includes mostly dinoflagellates and short-chained diatoms (Bruno *et al.* 1980; Turner *et al.* 1983; Lonsdale 1995). The dominant zooplankton in the summer are smaller than in the spring and include nauplii and copepodites of *Acartia tonsa, Oithona* sp., and *Parvocalanus* sp. (Lonsdale 1995). Both short-chained diatoms and dinoflagellates bloom again for a brief period in early fall (September). Bruno *et al.* (1980) hypothesizes that the diatoms blooming in September have shorter chains than in the winter due to zooplankton grazing.

Turner *et al.* (1983) concluded that the phytoplankton-zooplankton seasonal cycle in the Peconics follows two generalized trophic pathways based on the warmer (summer) season and colder (late fall, winter, and early spring) season:

1) net plankton ➔ larger zooplankton ➔ larval fish (Cold season)

2) nanoplankton ➔ small zooplankton ➔ gelatinous zooplankton (Warm season)

Larval fish are the dominant consumers of zooplankton in early spring, ctenophores during the summer, and juveniles of bay anchovy, during late summer-early fall (Turner *et al.* 1983). However the results of work performed on a finer scale by Kim (1993) in the Peconic Estuary disagree with some of Turner *et al.*'s (1983) findings. Kim (1993) agrees that gelatinous zooplankton are the dominant grazer in the summer; however, he found that gelatinous zooplankton prey on larger zooplankton.

Phytoplankton-zooplankton grazing studies performed by Caron *et al.* (1989), Kim (1993), and Lonsdale *et al.* (1996) in Reeves Bay and West Neck Bay found five main groups of heterotrophic planktonic organisms, categorized by size, that play a key role in energy transfer through the planktonic food web. The first group are heterotrophic nanoflagellates (< 20 μm), which are the smallest in size. The second group (20 to 64 μm) consist of protozoa that are heterotrophic dinoflagellates and microflagellates (e.g. aloricate ciliates and small loricate ciliates). These two size groups of protists are major grazers of small phytoplankton and bacteria and, in turn, are an important food source for larger zooplankton. This central role of protozoa is most pronounced during the warmer months (Lonsdale *et al.* 1996). The third group are the microzooplankton (64 to 202 μm) which are made up of large loricate ciliates, copepod nauplii, and various other holoplanktonic and meroplanktonic larvae. Microzooplankton were found to be important grazers when small phytoplankton were in abundance. The fourth group are the mesozooplankton (> 202 μm) which include copepod adults and copepodites (juvenile copepods) of various copepods species. The mesozooplankton graze on large phytoplankton; however, microzooplankton and heterotrophic protozoa in the first group were also found to be an important food source especially during summer when nanoplankton (< 5 μm) are the most abundant phytoplankton. A larger percentage of the mesozooplankton diet was made up of ciliates as compared to phytoplankton. Lonsdale *et al.* (1996) suggest that ciliate populations are controlled by intense grazing by copepods and are crucial to copepod nutrition during the summer months. Lonsdale *et al.* (1996) found that microzooplankton such as ciliates and copepod larvae preyed mostly on phytoplankton to obtain the majority of their carbon ration. The fifth and largest group are the gelatinous macrozooplankton consisting of hydromedusae (*Sarsia* sp.), scyphomedusae (*Aurelia aurita*), and ctenophores (*Mnemiopsis leidyi*). Gelatinous macrozooplankton prey on the mesozooplankton and larger microzooplankton. As a result of microzooplankton and mesozooplankton grazing by the gelatinous predators, phytoplankton blooms of dinoflagellates and euglenoids have been observed following increased gelatinous macrozooplankton abundance (Kim 1993).

There are not many organisms known to consume gelatinous macrozooplankton. The ctenophore, *Beroe* sp., preys on other ctenophores such as *Mnemiopsis* sp. Butterfish (*Peprilus triacanthus*) have been observed feeding on the tentacles of gelatinous zooplankton (T. Rotunno, personal communication, 1998). Some organisms that eat gelatinous zooplankton are not limited to feeding on these prey. In fact, numerous organisms will vary the prey on which they feed depending on food availability. For example, most estuarine and coastal copepods are omnivorous (adapted to eat plant and animal matter); they may switch their feeding behavior between herbivory (plant-eating) and carnivory (animal-eating) depending on whether plant food or animal food items are available (Kim 1993; Lonsdale *et al.* 1996). Therefore, energy and matter are not transferred in a simple linear manner and it becomes difficult to fully interpret the trophic interactions in an estuary (Kim 1993).

An important conclusion made by Kim (1993) is that gelatinous macrozooplankton such as ctenophores play a significant role in "top-down" control of the plankton food web in the Peconics. Top-down control means that the abundance, distribution, and diversity of the lower trophic levels depend directly or indirectly on trophic activities of higher trophic levels (Menge 1992). Therefore, gelatinous macrozooplankton may be a keystone predator of the Peconic Estuary plankton (Kim 1993). Similar conclusions were reached by Deason and Smayda (1982) who investigated plankton dynamics in Narragansett Bay, Rhode Island during the 1970s.

Brown Tide and Other Novel Phytoplankton Blooms

Since 1985, the Peconic Estuary periodically has experienced a pelagophyte bloom ($> 10^9$ cells l^{-1}) called brown tide, which consists of small (~ 2 μm), unicellular golden-brown algae (*Aureococcus anophagefferens*) that can persist for months. Brown tide has occurred as far north as Narragansett Bay, Rhode Island and as far south as Barnegat Bay, New Jersey. A similar species (*Aureoumbra lagunensis*) is responsible for brown tides in Texas bays and lagoons. Blooms of brown tide have been limited to shallow, relatively unstratified estuaries. To date, it has been unpredictable in onset, duration, and cessation (PEP Draft Brown Tide Module 1997). However, there has been a general trend for the onset of brown tide in the Peconics to occur during periods of reduced rates of estuarine flushing and elevated salinities (Bricelj and Lonsdale 1997). Research of historical meteorological data has found that onset of brown tide is also associated with anomalously high and persistent irradiance along with low wind stirring of the water column during spring (Wilson and Beltrami 1998).

The brown tide bloom usually begins in late May and peaks in June and July, turning the waters brown as a result of millions of algal cells in the water. Although there can be patchy distributions of brown tide, *Aureococcus anophagefferens* cell densities tend to be highest in the western bays and decrease eastward. Wilson and Beltrami (1998) suggest that the physical environment of the constricted western end of the Estuary is conducive to bloom onset. Bloom conditions have been most severe in Flanders Bay and West Neck Bay at Shelter Island. During the summer of 1995, brown tide was widespread in the Peconics in high concentrations (maxima reaching 1.7 x 10^6 cells ml^{-1}; Bricelj and Lonsdale 1997).

The cause of the bloom is still unknown. However, there are theories that brown tide may be related to an input of certain chemicals such as citric acid or trace metals such as iron or selenium, or the bloom may be related to groundwater inputs of dissolved inorganic nitrogen, which converts to dissolved organic nitrogen in the Estuary (Cosper *et al.* 1989; Cosper *et al.* 1993; LaRoche *et al.* 1997). Brown tide does not appear to occur in response to inorganic macronutrient loading (e.g. eutrophication; Bricelj and Lonsdale 1997). In fact, persistence of brown tide may be related to its ability to grow at very low dissolved inorganic nitrogen levels (Bricelj and Lonsdale 1997). Persistence of brown tide blooms may also be related to the ability of *Aurecococcus anophagefferens* cells to use both autotrophic and heterotrophic pathways to survive (Bricelj and Lonsdale 1997).

The major documented effects are drastic declines in bay scallops as a result of starvation. *Aureococcus anophagefferens* has been found to have toxic properties that cause growth and feeding reduction in suspension feeding organisms (Gainey and Shumway 1991). Brown tide has also been implicated in causing eelgrass loss due to light attenuation (Cosper *et al.* 1987); however, there is no direct evidence of this. Loss of eelgrass may have also contributed indirectly to poor recruitment of juvenile bay scallops (Bricelj and Lonsdale 1997). Lonsdale *et al.* (1996) found that the brown tide did not contribute to or hinder growth and survival of copepods at lower bloom concentrations (i.e., < 5 x 10^5 cells m^{-1}) if there were alternate food sources present. However, microzooplankton are selective and generally avoid ingesting *Aurecococcus anophagefferens* cells (Bricelj and Lonsdale 1997).

There is no evidence currently linking brown tide and direct impacts on finfish; however, there may be effects on feeding, migration, behavior, etc. Presumably, if the food source and habitat of finfish is affected, then possible predator-prey imbalances can be expected to occur during brown tide events. Turbidity may be an indirect effect of brown tide on larval fish by reducing their ability to capture prey (Bricelj and Lonsdale 1997). Shima and Cowen (1989) did not find significant effects of brown tide on larval bay anchovy growth and abundance during moderate blooms in Great South Bay. However, marked declines in egg hatching rates and fish larvae survival were associated with the brown tide occurring in Texas waters (Bricelj and Lonsdale 1997). There have been no studies focusing effects of brown tide on gastropods, deposit feeders, crabs, whelks, or other benthic macrofauna.

Recent findings presented at the 1998 Sea Grant Brown Tide Symposium raised some new and important questions regarding the importance of sediment with the initiation and duration of brown tide (i.e., benthic-pelagic coupling including nutrient flux from the sediment, possibly a resting stage of the brown tide, or effects from turbidity). There have been numerous reports and textbooks devoted specifically to novel phytoplankton blooms such as brown tide and should be referred to for further information.

Other algal blooms identified to periodically occur in the Peconic Estuary include dinoflagellates (*Prorocentrum minimum, Peridinium trochoideum, Gyrodinium aureolum*) and euglenoid blooms (*Euglena proxima* and *Eutreptia marina*; Kim 1993). The dinoflagellate, *Prorocentrum minimum*, was found to bloom under high loadings of nitrogen from poorly treated sewage, agricultural loading, and atmospheric deposition in Japan and the southeastern waters of the U. S. (Burkholder 1998).

Nuzzi and Waters (1993) performed studies in Peconic Estuary embayments to determine the presence of red tide blooms caused by a dinoflagellate, *Alexandrium tamarense* (=*Gonyaulax, Protogonyaulax tamarensis*). In New England during periods of red tide, toxins from this dinoflagellate accumulate in suspension feeding organisms such as bivalve molluscs and can be harmful to humans (i.e. paralytic shellfish poisoning) if the shellfish is eaten. From 1986 to 1989, Nuzzi and Waters (1993) found a spring bloom of *A. tamarense* occurred periodically in Reeves Bay. In 1989, they collected samples in Terrys and East Creeks during a bloom of *A. tamarense*. Nuzzi and Waters (1993) did not detect toxin in mussels collected during the bloom in the creeks but they did detect toxin, presumably from *A. tamarense*, in mussels in Reeves Bay. Nuzzi and Walters (1993) concluded that toxin production and concentrations in mussels do not appear to be related to *A. tamarense* population size but rather an environmental trigger or a set of environmental factors. They also suggest that selective feeding and/or detoxification by the shellfish may also play a role in making toxin concentrations below dangerous levels. Another type of red tide bloom (*Gyrodinium aureolum*) was found to occur in Reeves Bay during zooplankton research performed by Kim (1993).

Finfish

Unlike plankton, nekton are organisms that are able to maintain their position and move against local currents. This group includes bony (true) fish, cartilaginous fish (e.g. sharks and rays), squid, sea turtles, and marine mammals. These species are generally higher in the food web than plankton, although many of the fish species are plankton during larval and juvenile stages (Strieb 1993).

Some finfish consume phytoplankton and zooplankton including the eggs and larvae of finfish and crustaceans in the Peconic Estuary. Many of these fish such as bay anchovy, Atlantic silverside (*Menidia menidia*), American sand lance (*Ammodytes americanus*), Atlantic menhaden (*Brevoortia tyrannus*; also known as mossbunker), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), Atlantic herring (*Clupea harengus*), and killifish (*Fundulus* spp.), make up the majority of the "forage" base or food for finfish in higher trophic levels such as bluefish (*Pomatomus saltatrix*), weakfish, and striped bass (*Morone saxatilis*). Juveniles of some finfish in higher trophic levels are also part of the forage base for finfish in the Peconic Estuary. Early ecological studies of juvenile fish and fish eggs by the State of New York undertaken in the 1930s identified the waters of Great Peconic Bay eastward to Montauk Point as the most important spawning and nursery area of New York for "summer fishes" (Perlmutter 1939). The most common summer fishes caught were scup, winter flounder, Atlantic mackerel (*Scomber scombrus*), butterfish, tautog, weakfish, and pollock (*Pollachius virens*). A total of 40 species of eggs and juvenile fish were identified. While it is known there are different habitats within the Estuary that are important to finfish (e.g. eelgrass, macroalgae, small tidal creeks), it is unclear at this time what the relative importance of these different habitats is to the forage fish in the Estuary.

Forage fish also support numerous birds (e.g. terns, herons) and jellyfish. In deep water (> 3 m), terns feed primarily on schools of forage fish driven to the water surface by feeding bluefish. Bluefish may be better competitors than birds for these forage fish (Safina 1990).

The bay anchovy has been identified by numerous researchers as the single most important prey fish species of weakfish and is also an important forage fish for bluefish and striped bass (Morton 1997). Bay anchovies were found to be the most abundant finfish species in the Peconics (Weber *et al.* 1998). They are typically found in schools inhabiting all types of estuarine habitats (Morton 1989). Bay anchovies typically spawn from May to August over a wide area in Peconic waters (Weber *et al.* 1998). Although adult bay anchovies are sometimes found in seagrass beds, Olney and Boehlert (1988) determined that in the Chesapeake Bay, seagrass beds are not important spawning or nursery areas for bay anchovy or any other finfish that produced pelagic eggs (i.e., eggs that stayed in the water column). Water quality criteria may be more important than habitat quality in determining the bay anchovy's well-being; however, little is known about its vulnerability to toxic contaminants (Houde *et al.* 1991). In referring to the Chesapeake Bay stock, Houde *et al.* (1991) suggested that the bay anchovy has a "top down" influence on plankton dynamics in estuaries. Early studies by Hildebrand and Schroeder (1928; from Morton 1989) of gut contents of bay anchovies found shrimp to be the principal food of adults and copepods the principal food of juveniles. Other studies found that large bay anchovy also prey on larval fish, rotifers, copepods, detritus, and benthic organisms such as molluscs, small crustaceans, and polychaetes (Morton 1989; Houde *et al.* 1991).

A second important forage fish species is the Atlantic silverside. Approximately 22% of New York State's landings of this species were harvested from the Peconic Estuary (Weber and Grahn 1995). Atlantic silversides spawn in the Peconics from late spring to early summer with young of the year present in the Estuary from June to August. Spawning generally occurs in eelgrass beds and upper intertidal areas (e.g. saltmarsh) where vegetation is abundant (Middaugh 1981). Atlantic silverside eggs are an important food source for sea birds, waterfowl, and blue claw crabs (Houde *et al.* 1991; Middaugh 1981). Adult species remain resident in the Estuary until October when they move offshore (Weber *et al.* 1998).

River herring such as alewife and to a lesser extent blueback herring are anadromous species that spawn in the tidal creeks of the Peconics. They remain in the Estuary until the fall when they leave to mature in the Atlantic Ocean. These fishes eventually return to the Peconics for spawning. Their eggs are semi-demersal (float on the bottom) to pelagic and are adhesive until they eventually harden (Klauda *et al.* 1991). Dams have been built on some of the streams and creeks emptying into the Peconics, which has led to disruptions in herring spawnings by preventing their movement to fresh water (Young and Woltmann 1994).

Alewife Creek is one of the few alewife habitats that is free of barriers to migratory passage from the marine environment to the Big Fresh Pond (a freshwater pond). The creek becomes brackish and tidal below Noyack Road. Big Fresh Pond and Alewife Creek are both located in medium-density residential areas, but continue to remain bordered by mostly undeveloped woodlands (NYSDOS 1987). Other alewife runs include the tidal creek connected to Little Reed Pond, which itself is connected to Lake Montauk.

Atlantic herring (*Clupea harengus*), another forage fish species, spawn in the open waters of the Peconics. During spawning events, pound net fishermen in the Peconics have reported bringing up thousands of Atlantic herring eggs attached to their nets (A. Weber, NYS Department of Environmental Conservation, pers. comm., 1997).

Forage fish are harvested as bait for commercial and recreational fishing or are caught as bycatch in the pound net, gill net, and to a lesser extent, trawl fishery, and sold locally as bait. For example, most of the Atlantic menhaden taken in the Peconic Estuary are used as bait for the lobster fishery (A. Weber, NYS Department of Environmental Conservation, pers. comm., 1997). Although the bay anchovy is a major food source for top predators in the Peconics, it is not a preferred baitfish harvested by fishermen possibly because these fish are soft-bodied. Atlantic silverside and American sand lance are more significant fish species harvested for bait in the Peconics (Weber and Grahn 1995).

Historically, there has been a paucity of accurate data on the annual catch of most forage fish harvested in the Peconics, primarily because fisheries for these species are small scale and highly seasonal and often go unreported. Therefore, it is unknown whether size of the total catch varies from year to year and what the size and bycatch is of forage fish harvesting. There is also a lack of documentation on specific areas in the Peconic Estuary where harvesting of forage fish occurs.

Since 1987, the NYSDEC has collected data on young of the year, juvenile, and small fish populations such as forage fish and macroinvertebrates in the Peconic Estuary. From May to October organisms are collected by a small-mesh otter trawl in the open waters west of Shelter Island. From 1987 to 1989, 85% of the total catch per tow consisted of bay anchovy and Atlantic silverside (Weber *et al.* 1998). Bay anchovy were the most abundant finfish species collected, representing over 57% of the total catch of finfish over the nine year study period (Weber *et al.* 1998). Bay anchovy have the largest biomass of any estuarine fish found along the Atlantic and Gulf coasts (Houde *et al.* 1991). Since 1990, crustaceans, particularly lady crabs (*Ovalipes ocellatus*), dominated the total catch each year in the NYSDEC trawl survey (Weber *et al.* 1998). Because killifish mostly inhabit tidal creeks and sand lance abundance is greatest in late winter to early spring, these fish species are not usually caught during the NYSDEC trawl survey in the Peconics and little is known about them in the Peconic bays. In general, sand lance are an important food source for mackerel, striped bass, and shorebirds.

Aside from bay anchovy, finfish that made up most of the catch of juveniles caught by the NYSDEC during its annual small mesh trawl survey were winter flounder (14%), windowpane flounder (5%), weakfish (5%), Atlantic silverside (4%), scup (3.4%), and northern puffer (*Sphoeroides maculatus* [1.2%]). Bluefish, butterfish, tautog, oyster toadfish (*Opsanus tau*), smooth dogfish (*mustelus canis*), and sea robins (*Peristedion* spp.) were also caught but each accounted for less than 1% of the total catch of finfish.

Winter flounder are recreationally and commercially important small-mouthed flat fish that feed on a variety of plankton, small invertebrates, and plants (Azarovitz 1982). They are most abundant in the Peconic Estuary from late spring to early summer with their numbers declining thereafter as they migrate offshore to cooler waters (Lobell 1939; Azarovitz 1982). These fish spawn in the shallow waters of the Peconics from late winter to early spring depending on temperature (Weber *et al.* 1998). Temperature and salinity are also the controlling factors of the survival and viability of eggs (Howell and Smith 1991). Winter flounder have demersal eggs, which means they are found on or near the bottom. Tagging experiments have found that adults, which are mature by ages 2 or 3 and can live up to 20 years, return annually to the same spawning grounds (Howell and Smith 1991). Winter flounder found in the Peconic Estuary are very fast growing relative to those found in Shinnecock and Moriches Bays and western Long Island Sound (Poole 1966).

Windowpane flounder became popular as a food fish in the 1970s (Dery and Livingstone 1982). Shrimps and to a lesser extent other crustaceans are the predominant prey of these species (Dery and Livingstone 1982). Windowpane flounder can be found at all life stages in the Peconic Estuary throughout the year. Windowpane flounder spawn in nearshore waters over an extended period of time ranging from May to August (Weber *et al.* 1998). Like winter flounder, spawning is tied to temperature with spawning ceasing during summer months when temperatures are above 20 °C (Smith *et al.* 1975). Summer flounder, also called fluke, are commonly found in the summer in the Peconics in areas of sandy and muddy bay bottoms. They lay buried in the bottom sediment waiting for prey such as small fish, squid, crabs, and shrimp. They also have been known to feed on molluscs, worms, and sand dollars (Ethan C. Eldon Associates, Inc. 1995).

Weakfish have been historically and continue to be one of the most popular commercially and recreationally harvested fish in the Peconic Estuary. Young weakfish feed on invertebrates such as shrimp, squid, crab, worms, and clams while larger, older weakfish prey on small forage fish (Wilk 1982). Weakfish spawn throughout the Peconics in spring and early summer. Studies performed in the 1930s found weakfish that spawned in New York spend their first summer in the Estuary and then migrate south in the fall to winter offshore of Virginia and North Carolina (Nesbit 1939). Instead of returning the following spring, they remain in waters south of New York. Young weakfish (< 4 years) can migrate as far south as Florida in the fall and winter. Older fish that were spawned in the Peconic Estuary move offshore in fall and return to the Estuary by spring (Wilk 1982).

Like weakfish, scup are also a popular fish that is harvested commercially and recreationally in Peconic waters. Scup are bottom feeders consuming small crustaceans, worms, molluscs, and vegetation (Morse 1982). Scup spawn in the Peconic Estuary from spring to summer. Scup younger than 4 years tend to inhabit estuaries while older fish tend to stay in nearshore ocean waters and at the mouths of bays (Morse 1982). Scup migrate seasonally, moving offshore in the winter.

Like scup, tautog spawn in the Peconic Estuary from spring to summer and migrate seasonally, moving offshore in the winter (Sogard *et al.* 1992). Tagging studies by Cooper (1966 from Sogard *et al.* 1992) found tautog return to the same spawning locations. Recently settled juveniles feed mostly on copepods and amphipods (Sogard *et al.* 1992). Both small tautog (< 25 mm) and the oyster toadfish concentrate in shallow, vegetated habitats such as eelgrass. Large juveniles and adults prefer hard substrates and feed primarily on mussels.

Bluefish are migratory fish that reside in Peconic waters from spring through fall. Bluefish are voracious feeders preying on a variety of fish and squid. Juveniles, called snappers, congregate in shallow areas and tidal creeks feeding primarily on copepods, crustaceans, and smaller fish. Striped bass are also a migratory fish found in the Peconic Estuary. They are a top predator in the Estuary and are considered and important game fish throughout the East coast of the U. S. Like bluefish, striped bass are voracious feeders, consuming a wide variety of forage fish and invertebrates including crustaceans, annelids, molluscs, and squid (Thomson *et al.* 1978).

Otter trawl and pound nets were landing the bulk of the commercial fishery in the 1930s in the Peconic Estuary, catching mostly butterfish, scup, weakfish, bluefish, mackerel, and squid (Dickinson 1939). Scup and Atlantic menhaden are the top species (by weight) landed since the 1950s (Table 1; Weber and Grahn 1995). Swellfishes or northern puffer, winter flounder, and butterfish were also taken in large amounts during the 1950s and 1960s; however, they were replaced as the largest catch in the 1970s and 1980s by weakfish, bluefish, striped bass, and longfin squid (*Loligo pealii*). From 1990 to 1992, lobster (*Homarus americanus*) became one of the top five species taken, edging out weakfish in total landings by weight (Weber and Grahn 1995). The majority of the lobster landings occur in the easternmost part of the Peconic Estuary. Tautog are primarily caught by recreational anglers in the Estuary (Weber *et al.* 1998).

The New York State Environmental Conservation Law bans trawls and gill nets in the Peconic Estuary west of Shelter Island, and limits the use of haul seines based on a maximum length and minimum mesh size and during certain days of the week. Haul seines have been historically used in the Peconics to catch weakfish and kingfish (*Menticirrhus* spp.). Since 1994, trawling west of Shelter Island in the Peconic Estuary was also banned by the New York State Legislature and special NYSDEC permits are required to use pound nets or trap nets. Many of these laws were historically enacted in response to conflicts between competing user groups (i.e., commercial and recreational fishermen). In recent years, numerous regulations addressing overfishing have been implemented by NYSDEC on a statewide basis.

The results of an analysis by the NYSDEC of landings data collected by the National Marine Fisheries Service for the Peconic Estuary indicate a steady decline in the amount of fish caught from the Peconic Estuary from the 1980s (1.3 million kg [2.9 million lbs]) through the early 1990s (less than 154,000 kg [340,000 lbs]). A slight increase during the mid-1990s may be signaling the start of a recovery (Weber and Grahn 1995). Prior to 1986, the average annual landings in the Peconics were 1.1 million kg [2.4 million lbs] per year equaling 9.4% of total landings for New York. Since 1989, average annual landings decreased to 298,000 kg [658,000 lbs] per year, a decline of almost 73%. From 1989 to 1992, fish harvested in the Peconic Estuary accounted for only 2.2% of total New York landings. Because landings data from 1986 to 1988 were not available, it is unclear whether the reported decrease in landings was a sudden drop or a gradual decline (Weber and Grahn 1995).

Possible factors contributing to the decline in landings include: 1) brown tide (first reported in 1985); however, its effect on finfish or crustacean resources is less well known); 2) decrease in water quality; 3) loss of suitable fish habitat; 4) shifts in fishing effort; 5) changes in fish distribution or migratory patterns; 6) implementation of fisheries laws and regulations that restrict catch and effort; or 7) the collapse of overfished stocks (i.e., striped bass and longfin squid are fully exploited and scup, bluefish, winter flounder, weakfish, summer flounder, Atlantic sturgeon (*Acipenser oxyrhynchus*), black sea bass (*Centropristis striata*), and American lobster are overexploited species; Weber and Grahn 1995; NMFS 1995). Fishery declines may also be due to low recruitment, which may result from less egg development, less adults producing eggs, and/or less habitat.

Other possible threats to fishery resources in the Peconic Estuary include impacts from loss of habitat and contamination. Habitat loss, and in some cases toxicity of fish, can result from navigational and shellfish dredging, shoreline hardening (i.e., removal of salt marsh) or from water quality impacts due to sewage treatment plants (nitrogen, phosphorus, organics), failing septic systems (nitrogen, phosphorus, organics), agriculture (nitrogen, phosphorus, organics, pesticides, herbicides, fungicides, erosion/sedimentation), stormwater runoff (nitrogen, phosphorus, organics, toxics [oil, agriculture], industry (toxics), boating (nitrogen, phosphorus, organics, oil/gas [toxics]), aquaculture (disease, nitrogen, phosphorus, organics) resulting in eutrophication, excess turbidity, and toxicity. Chemical-specific toxicity studies on marine organisms in the Chesapeake Bay found that different species had varying sensitivities to different contaminants. For example, mercury threatens hard clams, blue crabs, striped bass, and oysters (*Crassostrea virginica*), copper affects soft shell clams (*Mya arenaria*), hard clams, and oysters, tributyltin (used in boat paints) threatens hard clams, menhaden, oysters, and striped bass, aldrin and dieldrin (pesticides) threaten oysters, and cadmium threatens striped bass (Chesapeake Bay Program Toxics Subcommittee 1993). Most of these impacts have not been quantified in the Peconic Estuary and further study is needed. It is also unknown what effect and on what species (due to timing) navigational dredging may have on fish spawning and recruitment in the Peconic Estuary.

Aquaculture

Aquaculture is a term that generally describes the culture of fish and shellfish resources for potential availability as food. The level of intervention can range from reseeding waters with bay scallops to the multiple acre operation of fish pens. Both examples of these aquaculture activities occur in the Peconic Estuary. The majority of aquaculture activities in the Peconics involves the small-scale culture of hard clams and oysters on less than 2 ha (5 ac) parcels (D. Barnes, NYS Department of Environmental Conservation, pers. comm., 1998).

Since June 1997, Mariculture Technologies, Inc. has operated a fish pen aquaculture operation in the northeastern area of Gardiners Bay off the coast of Plum Island. The fish pen project covers an area of approximately 5 ha (12.5 ac). The off-bottom culture permit issued to Mariculture Technologies, Inc. by the NYSDEC allows stocking up to 56,000 summer flounder averaging up to 500 g (1.1 lb) each within four net pens.

The company recently requested a permit revision to increase the maximum allowable fish to 100,000 averaging 225 g (0.5 lb) each. It is expected that stocking of a 225 g summer flounder in May would result in a 1,322 g (2.9 lbs) fish by early October. The area of the fish pens would remain the same. Mariculture Technologies Inc.'s request of higher stocking of smaller fish is due largely to determining that production of 500 g fish was not cost effective or even feasible in a hatchery system. This amendment request to stock a larger number of smaller fish was denied by the NYS Department of Environmental Conservation.

An assumption of the Mariculture Technologies, Inc. State Permit Discharge Elimination System (SPDES) permit is that 7.6 kg (16.8 lbs) per day of suspended solids, 6.7 kg (14.9 lbs) per day of biological oxygen demand, 2.0 kg (4.5 lbs) per day of total nitrogen, and 0.3 kg (0.68 lbs) per day of total phosphorus per 1,000 kg of fish would be released to marine waters. These values were calculated based on an initial assumption that 50% of the feed introduced to the net pens would become waste. However, Mariculture Technologies, Inc. (1998) contends the food to waste conversion rate is actually lower. After installing underwater cameras to observe the fish while feeding, company staff determined less food was necessary to satiate the fish. The amount of food was also decreased when the summer flounder were found to be feeding on "wild" shrimp and small butterfish that periodically entered the pens.

Stocking of fingerling sized fish (not totaling more than 22,000) in three different pens resulted in high mortality in 1997 due to stress from excessive handling, transport, and temperature shock. Mortality also occurred due to storm events. No mortality was attributed to disease-related problems. The company found no outwardly noticeable signs of disease; however, fish necropsies were not performed to confirm this.

Shellfish aquaculture in the Peconic bays has taken place since the 1890s when seed oysters from Connecticut were planted in Gardiners Bay, Great Peconic Bay, and Little Peconic Bay (Anderson and Spatz 1997). According to Anderson and Spatz (1997), oyster production declined in the 1940s in the Peconic Estuary possibly as a result of phytoplankton blooms of "small forms," which may have clogged gills of hard clams and oysters. There were other commercial oyster seeding efforts in the Peconics through the 1970s; however, by 1979, efforts ceased due to multiple bankruptcies.

Over the past decade, the Towns of East Hampton, Southampton, and Southold, and Cornell Cooperative Extension have been involved in oyster, hard clam, and bay scallop reseeding efforts. According to Anderson and Spatz (1997), in 1996, the Town of Southold supplemented their waters with 3 million hard clams, 1 million oysters, and 500,000 bay scallops. Cornell Cooperative Extension and the Suffolk County Marine Environmental Learning Center are involved in culturing and growing oysters, hard clams, and bay scallops at 10 grow-out sites encompassing approximately 12 ha (30 ac) in the Peconic Estuary (Anderson and Spatz 1997).

From an economic standpoint, the majority of shellfish aquaculture production is from the transplant operations of Raritan Bay hard clams to approximately 30 ha (75 ac) of underwater land in Little Peconic Bay and Southold Bay. In 1996, relay operations consisted of transplanting approximately 55,000 bushels of hard clams from uncertified waters in Raritan Bay to certified waters in Little Peconic Bay and Southold Bay for a minimum cleansing period of 21 days at a water temperature of 10 °C (50 °F) or higher (D. Barnes, NYS Department of Environmental Conservation, pers. comm., 1998). Raritan Bay transplant operations in the Peconics equal approximately $4.1 million per year (Anderson and Spatz 1997).

Some of the overall benefits of aquaculture are that it provides a food resource in response to the steadily growing demand for seafood that potentially relieves fishing pressure on wild stocks. Mollusc farming can actually reduce pollution by enhancing water quality. For example, approximately 35 - 40% of the total organic matter ingested by a mollusc is used for growth and therefore removed from the system (Goldburg and Triplett 1997). Impacts to marine systems can occur from aquaculture operations by introducing excess nutrients from waste products (which, in the Peconics, is quite small compared to other nutrient sources), disease and parasites, and potentially spreading nonindigenous species. These impacts can potentially lead to changes in competition, predation, and species diversity, hybridization, change in genetic diversity, and changes in disease and parasite resistance (Sindermann 1992).

Sea turtles

Sea turtles found in the Peconic Estuary and other Long Island waters are hatched from eggs laid on beaches in the southern U. S., the Caribbean and Gulf coasts, and probably as far south as Central and South America. The major nesting beach for the Kemp's ridley (*Lepidochelys kempii*) is on the northeastern coast of Mexico near Rancho Nuevo in southern Tamaulipas. Despite the vast distance, the numbers of Kemp's ridley turtles recorded in Long Island waters represent the largest concentrations ever documented outside the Gulf of Mexico (Morreale *et al.* 1992). In the Peconics during the summer, there are even greater numbers of loggerhead turtles, along with a few young green turtles (*Chelonia mydas*) and an occasional adult leatherback turtle (*Dermochelys coriacea*).

As hatchlings, turtles swim to open ocean waters, with some of them taking advantage of currents such as the Gulf Stream. It is believed that they remain for their first few years in the pelagic environment feeding on and hiding among *Sargassum* seaweed floating in surface waters (Lerman 1986). Little more is known about their pelagic existence. When they reach a certain size, which varies according to species type (Table 2), juveniles (approximately 2 to 5 years) of Kemp's ridley, loggerhead (*Caretta caretta*), and green turtles undergo a shift in behavior and migrate to inshore waters, including areas along the Gulf and Atlantic coasts. In the Northeast, this inshore migration occurs annually during summer months. This change of habitat is believed to correlate with a shift in feeding behavior.

Morreale and Standora (1993) discovered a direct link between juvenile sea turtles in Long Island waters and populations found off the southern coasts of the U. S. Until their work, there was a common belief among scientists that small turtles were carried beyond their control to inhospitable northern waters such as Long Island and New England by eddies and meanders of the Gulf Stream. Morreale and Standora (1993) contend that juvenile turtles are strong swimmers that control their movements rather than being moved passively by currents and eddies. Although turtles have not been monitored while moving into the Peconic bays, once there, tracking studies indicate that their movements are purposeful and somewhat predictable.

Morreale and Standora (1993) tracked individual turtles using sonic, radio, and satellite telemetry and found that after residing in the Peconics over the summer, they leave the Estuary and travel south to overwintering habitats off the coasts of the Carolinas, Georgia and Florida (Figure 2).

From late spring and early summer through fall, juvenile turtles enter the Peconic Estuary and reside in specific, relatively confined areas throughout the bays for up to many weeks (Sadove and Cardinale 1993; Morreale and Standora 1993). Their residence in these shallow waters is most likely influenced by the abundance of food in the Peconics (examples of individual turtle movements are provided in Figures 3 - 5). Dietary studies examining fecal material of captured turtles and gut contents of dead animals indicate that green turtles feed primarily on submerged aquatic vegetation such as sea lettuce, (*Ulva lactuca*), green fleece (*Codium fragile*), and eelgrass (*Zostera marina*; Sadove and Cardinale 1993; Morreale and Standora 1993). Alternatively, Kemp's ridley turtles in Long Island waters feed heavily on slow moving crabs such as spider crabs (*Libinia emarginata*) and rock crabs (*Cancer irroratus*), even though they are not the most abundant crab species at locations where turtles are consistently observed (Morreale and Standora 1993; Standora *et al.* 1989). From these studies it was concluded that juvenile turtles are probably foraging in inshore waters for the first time and are inexperienced at feeding on benthic prey. Therefore these turtles feed on slow moving crabs and, as they become older and more experienced predators, they feed on faster swimming (e.g. lady, blue) crabs as well (Morreale and Standora 1993). Spider crabs are also a dominant prey item of loggerhead turtles; however, they tend to have much broader diets, which include larger proportions of molluscs.

During the period of time sea turtles reside in the Peconics and other inshore waters of New York, many exhibit high growth rates. Within a single season, loggerhead turtles were observed to have a impressive increases in carapace length of up to 4.8 cm (average length of juveniles in New York is 49 cm [19 in]; Morreale *et al.* 1992) with weight gains of more than 3.2 kg (7.1 lb). Likewise, Kemp's ridleys were observed to have increases in carapace length of up to 2.3 cm (average length of New York's juveniles is 30 cm [11.8 in]; Morreale *et al.* 1992) and weight gains of 1.4 kg (3.1 lb; Morreale and Standora 1993). Some of the Kemp's ridley turtles examined in Long Island waters doubled their weight in a 4 month period (Sadove and Cardinale 1993).

By Fall, turtles begin to move in an easterly direction out of the Peconic bays to open waters, and then southward to warmer waters before temperatures rapidly decline below 15 °C (59 °F) after mid-October. The timing of turtle migrations in and out of the Estuary is also demonstrated by timing of live captures in pound nets. More turtles tend to get caught in July and during the first week of October, the times of peek migratory activity. Pound nets are stationary nets intended to capture schools of fish swimming along the shore by obstructing their passage with a net that leads them away from shore to an enclosed center pen net (Figure 6). Approximately 76% of the turtles examined over a six-year period were captured alive in pound nets (Morreale and Standora (1993). Because of this bias, the distribution of live turtles, as illustrated in Figure 7, strongly reflects the locations of pound nets, which tend to be concentrated in the eastern portion of the Peconics. In 1993, 64 pound net traps were in the Peconic Estuary at one point during the year (Colletti 1993).

Beginning in late November when water temperatures are less than 8 °C (46.4 °F), turtles cold-stunned from hypothermia can be found washed up on beaches, or floating in the Peconics and throughout Long Island waters. From 1985 to 1987, 130 cold-stunned turtles were collected in Long Island waters (Morreale *et al.* 1992) and many more in following years. However, of the 228 live turtles captured and tagged during summer months over a six-year period, only three were later found cold-stunned (Morreale and Standora 1993). The small number of cold-stunned turtles that were previously feeding in the Peconics and Long Island waters during summer months indicates that most of the summer residents are no longer present in inshore waters by the time cold-stunning begins. Morreale and Standora (1993) believe that cold-stunning occurs when water temperatures drop rapidly and, although Long Island's turtles may leave for warmer waters, turtles migrating in from more northern waters may not have a chance to make it out in time.

Worldwide, sea turtle populations have diminished dramatically over the years as a result of many factors including harvest for food (including their eggs), leather, and jewelry, and the incidental take by shrimp trawling and other fishing efforts, and habitat loss. All sea turtles are protected under the Federal Endangered Species Act of 1973 (ESA). The Kemp's ridley is listed as endangered under the ESA, the International Union for Conservation of Nature and Natural Resources (IUCN) Red Data Book, and the 1986 IUCN Red List of Threatened Animals. This species is also listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The New York Natural Heritage Program ranks Kemp's ridley as G1, which means they are "critically imperiled globally because of extreme rarity...or especially vulnerable to extinction because of some factor of its biology." Loggerhead and green sea turtles are listed as Federally threatened except for breeding populations of green sea turtles in Florida and the Pacific coast of Mexico, which are listed as Federally endangered (U. S. Fish and Wildlife Service 1998). The New York Natural Heritage Program ranks loggerhead and green sea turtles as G3, which means they are "either rare and local throughout its range...or found locally...in a restricted range..., or vulnerable to extinction throughout its range because of other factors." The leatherback turtle is listed as Federally endangered throughout its range.

A potentially large threat to sea turtles in the Peconic Estuary is the heavy boat traffic. In a single summer, approximately 40% of dead turtles collected in Long Island were estimated to have died from being struck by boats (Morreale and Standora 1993). Degradation of marine habitats (e.g. loss of eelgrass and possibly loss of sand and mud flats to bulkheading and conversions to hardened shorelines) is also a potential threat by leading to decreases in prey quantity and quality. Results of trawl surveys by Weber *et al.* (1998) raise questions about whether there may have been shifts in the type and abundance of certain benthic species that turtles prey on in the Estuary. In the initial years of their annual survey, Weber *et al.* (1998) caught mostly forage fish (e.g. bay anchovy and Atlantic silverside). Since 1990, they caught predominantly lady crabs. It is unknown why this shift occurred and whether there has also been a change in spider crab populations as well. Catch of spider crabs remained relatively stable from 1992 to 1994 and decreased by almost half in 1995 (Table 3). Due to lack of data, spider crab catch comparisons cannot be made to earlier years when catch of lady crabs increased dramatically. Fluctuations in benthic crustacean populations may be part of a natural, cyclical trend or may result from a variety of factors including brown tide, fishing pressures, and habitat degradation. Overall, the Peconic Estuary provides important developmental habitat and key resources for Kemp's ridley, loggerhead, and green sea turtles during their early life stages (Morreale and Standora 1993). These productive bays and critical feeding habitats probably have played an essential role, both presently and historically, in maintaining the populations of sea turtles in the western Atlantic.

Diamondback Terrapins

The diamondback terrapin, *Malaclemys terrapin,* is the only species in the world limited to estuarine waters along the Atlantic and Gulf coasts. They are typically found in salinities between 9 and 21 psu. Diamondback terrapins feed on a variety of crustaceans, molluscs, and other invertebrates (Palmer and Cordes 1988). Middaugh (1981) found diamondback terrapins feeding on Atlantic silversides in estuarine waters of South Carolina. Terrapins hibernate in the winter by burrowing in the mud of tidal creeks and ponds. With the onset of spring, diamondback terrapins mate in the water and females lay eggs in nests dug in unshaded sandy areas above the high tide line (Morreale 1992; Palmer and Cordes 1988). Larger females tend to lay more eggs; clutch sizes range from 4 to 18 eggs (Palmer and Cordes 1988). Female diamondback terrapins are larger than males. In Long Island waters, Morreale (1992) found male mean plastron (carapace) lengths equal to 102.5 mm (SD ± 6.9) and female mean plastron lengths equal to 161.9 mm (SD ± 24.2).

In the late 1800s to the late 1920s, diamondback terrapin meat was regarded as a delicacy, and as such, was over harvested and became rare in Long Island waters until about the 1960s (Morreale 1992; Palmer and Cordes 1988). Today, there are healthy, robust populations throughout Long Island waters (Morreale 1992). Based on analyses of sex composition and size distribution by Morreale (1992), diamondback terrapin populations do not appear to be under stress from hunting or over collecting and probably have not been under harvesting pressure in recent years.

Morreale (1992) identified 993 diamondback terrapins in different types of estuarine habitats throughout the Peconic Estuary (45 sites), Long Island Sound (10 sites), and along Long Island's south shore Atlantic ocean beaches (18 sites). Occurrences of diamondback terrapins were found in a wide variety of habitats including bays, harbors, salt marshes, and tidal creeks. Highest densities of terrapins occurred in areas where there were large expanses of salt marsh and associated tidal creeks and channels. Many of these areas are currently protected by federal, state, or town government or private entities. The Cedar Beach Creek network, the Hubbard Creek complex, Scallop Pond and West Cove Creek, and the Sag Harbor complex consisting of Sag Harbor Cove, Morris Cove, and Paynes Creek support some of the highest densities of diamondback terrapins located in New York waters (Table 4). The majority of turtles temporarily captured by Morreale (1992) for analyses appeared to be among older age classes. Morreale (1992) suggests that young diamondback terrapins may inhabit a different microhabitat than older terrapins and therefore may not be subject to capture by standard techniques.

The largest threats to diamondback terrapins include loss of habitat from shoreline development and destruction of salt marshes. Morreale (1992) warns that loss of salt marsh and available nesting habitat could have devastating effects on terrapin populations over a relatively short time. Associated with human encroachment to diamondback terrapin habitat is the potential for increased predation by pets (Morreale 1992). Other predators include raccoons, gulls, and crows, which prey upon terrapin eggs (Morreale 1992). Egg mortality can also be caused by rootlets of beachgrass (*Ammophila breviligulata*) invading nests (Palmer and Cordes 1988). Although not quantified, Palmer and Cordes (1988) suspect that motorized boats or off road vehicles may play a significant role in terrapin mortality in some areas.

Since 1983, the diamondback terrapin has been listed in New York as a species of special concern, which does not confer direct legal protection, but does require the state to recognize additional monitoring is needed to determine its population status in the state. Additional protection was regulated in 1990, which includes the establishment of a closed season for the taking or selling of terrapins, size limits of terrapins that can be taken, and licensing requirement governing any taking of terrapins. Included in these New York State regulations is a prohibition preventing the taking or disturbance of terrapin eggs.

Marine Mammals

At different times throughout the year, whales, dolphins, and seals can be found in the Peconic Estuary. The northern right whale, *Eubalaena glacialis*, has been sighted in Gardiners Bay from March through June, apparently moving through the area (Sadove and Cardinale 1993). Right whales are a globally endangered species. The minke whale, *Balaenoptera acutorostrata,* has also been sighted on occasion in the Peconics. Although the humpback whale, *Megaptera novaeangliae*, is found regularly in Gardiners Bay, its abundance in these waters fluctuates widely. Sadove and Cardinale (1993) report that humpback whales will stay for extended periods of time (for over a week between June and September) if an abundance of food is available. Humpbacks are baleen whales, which means they have baleen plates to strain plankton, krill, herring, sand lance, and other small fish out of the water. Humpbacks are also a globally endangered species. Less than 10% of their original population exists worldwide (Marine Mammal Center 1997).

Although federally listed as threatened, the harbor porpoise, *Phocoena phocoena*, population appears to be increasing in Long Island waters. Found throughout the Peconic Estuary, sightings of harbor porpoise occur mostly in April and May (Sadove and Cardinale 1993). It is not known whether these animals are feeding on prey in the Estuary. Stomach contents of stranded porpoises in Long Island waters consisted mostly of squid and herring (Sadove and Cardinale 1993). The bottlenosed dolphin, *Tursiops truncatus*, is also found in Gardiners Bay during summer months. There is a paucity of information on their feeding habits in this region (Sadove and Cardinale 1993).

The harbor seal, *Phoca vitulina*, is the most common species of seal in Long Island waters. Harbor seals are found occurring in a number of areas in the Peconic Estuary. During the last decade, harbor seals have been reported to remain in the area year-round (Sadove and Cardinale 1993). The largest abundance of all age classes of harbor seals are found from November through May. Harbor seals concentrate at haul-out areas; sites have ranged from approximately 20 to 350 individuals (Sadove and Cardinale 1993). Sites of pupping events include Fishers Island and Great Gull Island. Occasionally harp seals, *Phoca groenlandica*, and grey seals, *Halichoerus grypus*, are sighted among the harbor seals. Seals are assumed to feed on variety of marine organisms that include herring, mackerel, squid, flounder, green crabs, mussels, cod, and whiting (Sadove and Cardinale 1993).

Although not well-documented in the Peconic Estuary, the biggest threat to marine mammals is human activity. Oil spills, boat collisions, floatable debris, and competition with people for food are only some of the ways in which human activities may threaten these animals. Worldwide, marine mammals suffer from incidental catches in commercial fishery activities, pollution, and habitat loss and degradation, particularly in coastal areas (United Nations Environment Programme 1998).

Benthic Communities

Benthic or bottom communities of the Peconic Estuary consist of a diverse group of organisms that range from microscopic bacteria to crustaceans, shellfish and other invertebrates, eelgrass and other submerged aquatic vegetation. In fact, throughout the marine environment, there are representatives of every animal phylum making up the benthos (Lerman 1986).

Most benthic organisms depend on organic matter or detritus (partially decayed or freshly dead plant and animal matter and organic wastes) that continuously rains down from the water column and becomes deposited on the sediment. This link between the pelagic and benthic environment is especially important in estuaries. For example, bacteria in and on the sediment remineralize available organic matter, which results in a continuous recycling of nutrients from bottom sediments back to the overlying water column.

The occurrence of particular benthic organisms vary depending on horizontal (grain size) and vertical (presence of dissolved oxygen) zonation of substrate. Biological (e.g. bioturbation) and physical (e.g. bottom scour from tidal currents) factors appear to combine and create conditions that lead to the dominance of a particular species in a distinct habitat. In general, coarse sediments (e.g. sand and gravel) are found in high energy environments where currents tend to scour the bottom. In these environments, it is difficult for organisms to build permanent burrows in the substrate; however, there is a large food supply in the overlying water column moving across the sediments. Therefore, suspension feeders (e.g. sponges, clams), which extract food from the water column are the dominant type of benthic organism found in sandy sediments (Lerman 1986). Fine sediments such as mud, silt, and clay are deposited in low energy environments. The calm conditions allow organic detritus to accumulate and animals to build permanent burrows in these stable substrates. Therefore, deposit feeders (e.g. polychaete worms, amphipods), which extract food from the sediment, are the dominant organisms in muddy environments (Lerman 1986).

Vertical zonation of estuarine sediments tend to consist of an oxidized surface layer with less and less oxygen present at depth resulting in a reduced (anoxic) sediment layer. Benthic organisms' production and use of metabolites play an important role in maintaining the chemical profiles typically found in marine sediments (Parsons *et al.* 1988). Bacteria are the most important, ubiquitous benthic organisms present in sediments. Their metabolic activity largely controls the chemical nature of the sedimentary environments (Parsons *et al.* 1988). For example, bacteria that use oxygen to oxidize organic matter occur in the surface sediment while anoxic sediments at depth consist of anaerobic bacteria that use various organic and reduced inorganic compounds for anaerobic respiration such as fermentation and chemosynthesis (Parsons *et al.* 1988). Bioturbation or the mixing of sediment as a result of biological activity can result in mixing dissolved oxygen to greater depths in the sediment profile creating greater oxidized sedimentary environments.

In addition to deposit and suspension feeding organisms in the benthos, numerous organisms obtain food as scavengers and predators. Crabs, lobsters, shrimps, and other crustaceans, snails, brittle stars, and demersal fish (e.g. flounder) both scavenge detritus and prey on other organisms (Lerner 1986).

Macrofauna

Benthic organisms such as hard clams, oysters, bay scallops, whelks (locally called conch; *Busycon* spp.), soft shell clams, and mussels are an important commercial resource of the Peconic Estuary. Until the onset of brown tide in 1985, one-fourth of all bay scallops harvested in the U. S. (and 90% of New York's bay scallop harvest) was from the Peconic Estuary (Lewis *et al.* 1997).

Lewis and Rivara (1997) and Lewis *et al.* (1997) surveyed the shallow (0.3 to 1.85 m) and deep (1.8 to 8.5 m) waters of the Peconic Estuary to evaluate distribution and abundance of sediment type, shellfish, and other macrofauna. The shallow water, including tidal creeks, were surveyed in the spring and summer of 1997. Lewis and Rivara (1997) found that the majority of the commercial shellfish harvest was from shallow water regions. However, overall abundance of shellfish appeared to be low and patchy in nature. Low abundance may have been attributed in part to limitations of the boat accessing very shallow (< 0.3 m [1 ft]) areas. Individuals were observed harvesting clams in these very shallow areas. Despite the heterogeneous distribution of different sizes of hard clams, the chowder sized clams (≥ 41 mm [1.6 in]) accounted for 41% of the clams present. Lewis and Rivara (1997) concluded that while seed clams were identified in areas surveyed (except for Gardiners Bay) low recruitment may be occurring as a result of smaller sized clams being preferentially harvested.

The survey also found bay scallop abundance and distribution to be low. Bay scallops were found at only five stations. However, this would not have likely been the case if surveys were performed before the onset of brown tide in 1985. Oysters were limited to only one station in Three Mile Harbor near the Town of East Hampton's aquaculture program. Huge abundances of soft shell clams were found only within the Sag Harbor complex ranging from 83 to 41 clams per 9 m^2 (1 ft^2). This is low when compared to Mt. Sinai Harbor where abundances are greater than 500 clams per 9 m^2 (Lewis and Rivara 1997).

An interesting finding by Lewis and Rivara (1997) was the presence of hairy cucumbers (*Sclerodactyla briarus*). They suggest that although the feeding habits of hairy cucumbers are not well known, they may be filtering hard clam larvae, which would make them a possible predator on as well as competitor of hard clams.

In Fall 1995, Lewis *et al.* (1997) surveyed the deep waters of the Peconics. Comparisons were made to an earlier survey conducted in 1979 and 1980 by the NYSDEC in deep waters west of Shelter Island. Lewis *et al.* (1997) identified a total of 31 animal species and four algal species. They found a general increasing trend in species richness and abundance from west to east in the Estuary and from deep waters in the center of bays to shallow, nearshore waters within the Estuary. Slipper shells (also called quarter deck, *Crepidula fornicata*) were the most abundant species collected. Slipper shells were also widely distributed throughout shallow waters. Lowest abundance of species was associated with deeper areas with fine-grained sediment and presence of tubes of terrebellid worms. Most of the fine-grained, muddy stations were in waters deeper than 7.0 m (23 ft). All the stations had shell and stone present except for lower Noyac Bay, lower Northwest Harbor, and the center of Great Peconic Bay. Highest abundances of species occurred in shallow waters in sandy areas with shell and stone (Lewis *et al.* 1997).

Brittle stars were dominant in the deep waters of Great Peconic Bay and hydroids were abundant off the coast of Shelter Island (Lewis *et al.* 1997). Hard clams were found throughout the Estuary with highest abundances in shallow waters. Chowder size clams (> 41 mm [1.6 in]) were the most abundant size class. Hard clam abundance significantly decreased from the 1979/1980 survey (Lewis *et al.* 1997).

Bay scallop abundance was low with only legal sized (> 57 mm [2.3 in]) scallops found at five stations around Shelter Island. Smaller-sized scallops might have been underestimated as a result of the large bar spacing (19 mm [0.8 in]) of the dredge used to collect samples (Lewis *et al.* 1997). In the 1979/1980 survey, significantly more bay scallops were found in the Estuary in Flanders Bay and along the northern shore west of Shelter Island.

It is unknown whether natural shellfish populations have changed over time and, if so, what are the possible causes of these changes. It is also not clear whether effects of brown tide can be separated from other possible effects such as habitat loss, changes in predator-prey relationships, and overharvesting.

Lewis and Rivara (1997) found an abundance of lady crabs throughout the Estuary. Over the past seven years, the NYSDEC also found lady crabs to be the dominant catch in their annual trawl survey of young of the year, juvenile, and small fish populations such as forage fish and macroinvertebrates in the Peconic Estuary. Prior to 1990, bay anchovies and Atlantic silversides were the dominant NYSDEC catch (Weber and Grahn 1997). The cause of this apparent population shift is not clear. It is unknown whether there may be a relationship between increases in lady crab populations and brown tide blooms. It is also unknown whether there is a relationship between population shifts in lady crabs and juveniles of the dominant finfish species in the Peconic Estuary.

There is very little known about the abundance, distribution, size frequency, and taking of whelk, sea star (*Asterias forbesii*), and horseshoe crabs (*Limulus polyphemus*). Considered a "nuisance" species by New York because they prey on commercially important bivalves, state law prohibits returning live whelk and starfish to the Peconic Estuary if caught as bycatch. Although there is a whelk fishery in the Peconics, there is no information on the amount harvested annually, seasonal harvesting cycles or variations in harvesting from year to year. There is also a lack of information on the population density needed to support a whelk fishery, if there are specific areas in the Estuary where whelk is harvested and whether this changes from year to year, and the number of people involved in the commercial harvest of whelks. Lewis and Rivara (1997) found low abundances of whelk within the tributaries and embayments of the Peconic Estuary.

Pound net fishermen consider horseshoe crabs a "nuisance" and sell them as bait to eel pot fishermen. Eels are attracted to scavenge on the body parts of female horseshoe crabs. Horseshoe crab eggs laid on beaches in May are an important food source for migratory birds flying northward from their wintering habitats in Central and South America. Red knots, sanderlings, ruddy turnstones, sandpipers, as well as gulls, song sparrows, grackles, mourning doves, and even pigeons feast on horseshoe crab eggs (Baltimore National Aquarium 1991). There is growing concern that the impact of beach stabilization practices (such as bulkheading) along with the rise in sea level have limited the availability of suitable spawning habitat, making the remaining stretches of open, sandy beach critical to the reproductive success of this species (Botton *et al.* 1988).

One of the threats to bottom communities in the Peconics is the initiation and persistence of algal blooms as a result of excess nutrients in the Estuary. Blooms of algae may lead eventually to lowered dissolved oxygen conditions (hypoxia) as they sink out of surface waters and become decomposed by bacteria. Hypoxia can kill sedentary benthic organisms and cause mobile species to relocate.

Eutrophication resulting from excess nutrients can also lead to the fining of sediment grain size in some areas of the Peconic Estuary. This can lead to benthic community changes favoring more deposit feeders over suspension feeders as substrate changes from sands to muds. Historically waste from numerous duck farms was discharged to the Peconic bays. Duck waste contributed a significant amount of fine-grained organic matter and nitrogen to the sediment. Today in the Peconic Estuary, approximately 54% of the nitrogen loading is from sediment flux equaling about 14,000 lbs per day (Minei and Dawydiak 1998). Groundwater and direct rainfall contribute 28 and 16%, respectively of the total nitrogen load. The remaining nitrogen loading (2%) is from stormwater and sewage treatment plants (Minei and Dawydiak 1998). Dissolved inorganic nitrogen from muddy substrates to the overlying water column appears to be the most significant source of sediment nutrient flux. Muds contribute 61% of the annual total nitrogen loading to the Estuary (Minei and Dawydiak 1998).

Dredging can also threaten benthic organisms. Dredging has altered current patterns in some of the small embayments and creeks, which has led to changes in sediment distribution, concentration of suspended solids in the water column, and benthic community composition. Yearly dredging occurs at numerous creeks within the Peconics (Table 5). A total of 62 sites make up all the projects which routinely require maintenance dredging. However, only 20 of these sites averaging approximately 57,375 m^3 (75,000 yd^3) are dredged annually.

Other threats to the benthos include turbidity resulting from boating or any other activities that persistently scour and resuspend sediment, and toxicity. Many metals and toxic contaminants are particle-reactive, which means they adsorb to sediment. Bioaccumulation of toxic contaminants in organisms can occur in areas where sediment has become a sink for toxic contaminants. Bioaccumulation is the build up of contaminants in body tissues due to an organism's inability to metabolize or pass the toxic contaminants out of the body. Biomagnification can also occur, which results in an increased concentration of a contaminant in an organism at the next trophic level as a result of contaminants that have bioaccumulated in the prey organism (Clark 1992). In some instances, this can lead to toxicity-related health effects of consumers.

Macroflora (SAVs)

Eelgrass and other types of underwater vascular plants and macroalgae that make up submerged aquatic vegetation (SAVs) communities in estuaries throughout the U. S. are widely regarded as keystone species and primary indicators of water quality conditions (Submerged Aquatic Vegetation Workgroup of the Living Resources Subcommittee, Chesapeake Bay Program 1995). Eelgrass beds, an important SAV in the Peconic Estuary, are among the most productive ecosystems in the world, contributing significantly to the overall primary productivity of the Estuary while also supporting high biodiversity of fish and invertebrates (Homziak *et al.* 1982). Energy present in seagrasses also enters the estuarine food web as detritus (Lewis and Peters 1984). In fact, 90% of net energy production is made available to higher trophic levels through detritus (Cashin Associates 1996). Seagrasses such as eelgrass and widgeon grass (*Ruppia maritima*) found in the waters of the Peconics provide food for waterfowl and sea turtles, and shelter and nursery grounds for fish, shellfish, and invertebrates. Eelgrass supports a whole host of epiphytes (which are plants growing on another plant on which it depends for mechanical support) such as benthic diatoms and other algae. As many as 19,000 diatoms have been found to live on a square inch of an eelgrass blade (Perry 1985). Other organisms living on blades of eelgrass consist of protozoans (ciliates, flagellates, foraminifera), nematodes, and copepods (Perry 1985). Sessile (attached) animals living on the blades and at the base of eelgrass shoots include crustaceans, sponges, anemones, bryozoans, tube worms, polychaetes, barnacles, and other arthropods and tunicates (Perry 1985). As juveniles, the commercially important bay scallop, *Argopecten irradians*, use the eelgrass canopy (i.e., near the ends of eelgrass shoots) to seek refuge from predators such as crabs, eventually migrating to the base of eelgrass shoots when becoming adults (Pohle *et al.*1991). Strieb *et al.* (1995) measured up to 225 mud crabs (*Dyspanopeus sayi*) m^{-2} in eelgrass beds in Lake Montauk, Napeague Harbor, Northwest Harbor, and Hallock Bay. Mud crabs were scarce in unvegetated substrates (Strieb *et al.* 1995). Numerous other animals forage in eelgrass meadows including the oyster toadfish, a variety of crabs, molluscs, and horseshoe crabs. The Atlantic brant (*Branta bernicla*), a small goose that overwinters in many Long Island bays, feeds directly on eelgrass.

Seagrasses are found in shallow waters where there is enough light penetrating the water column for these plants to flourish. In Peconics waters, seagrasses are found in water depths ranging from 0.4 to 3.4 m (1.5 to 11 ft; Cashin Associates 1996). Seagrasses tolerate a wide salinity range with widgeon grass typically found in fresher/brackish waters (< 20 psu) and eelgrass distributed more widely (5 to 30 psu). Higher or lower than average temperatures can effect eelgrass health. For example, periods of prolonged high or low water temperatures have resulted in declines in eelgrass beds (Cashin Associates 1996).

Seagrasses and other SAVs provide oxygen to the water column, reduce wave energy, and promote deposition of sediment suspended in the water column. They take up nutrients (e.g. nitrogen and phosphorus) during their growing season (spring to fall) and re-release nutrients through organic decay. Their presence in particular areas may change from year to year depending on water clarity and ambient nutrient concentrations. Eelgrass blades typically die within three months except during dry and/or cooler summers when survival can extend up to over a year (Williams and Orth 1998).

In 1996, Cashin Associates performed a SAV survey for the Peconic Estuary Program. They reviewed historical patterns of SAV abundance and distribution and performed field surveys throughout the Estuary. Their survey encompassed stations throughout the Estuary in areas where shellfish growing areas or eelgrass beds currently exist or may have occurred in the past based on anecdotal and qualitative information from marine scientists, harbor masters, bay constables, and other local officials (Cashin Associates 1996). More detailed surveys were performed in North Sea Harbor, Three Mile Harbor, West Neck Harbor, and Long Beach Bay. They also used aerial photos from October 1994 to add stations around Shelter Island and to the east and to determine spatial extent of eelgrass beds and other SAVs between sampling stations. A total of 214 stations were sampled between September and October 1994. Aerial coverage was estimated by visual surveys within an approximately 30 m (100 ft) radius of each sampling station.

A total of 36 different species of macroalgae were observed in the Peconic Estuary (Table 6). Cashin Associates (1996) noted this was not an exhaustive list; merely a "snapshot" of samples collected over a six-week period. For example, the SAV, "slip gut," was not found in their survey; however, it is known to occur in winter and spring months in the Peconics (Cashin Associates 1996).

Cashin Associates (1996) estimated a total area of 98 km^2 (24,200 ac) of SAVs in the Peconic Estuary. Of all the SAVs, eelgrass amounted to the highest unit dry weight biomass, averaging 370 g m^{-2} with a total dry weight biomass for the entire Estuary equal to 2,334 metric tons (mt). The estimated average SAV dry weight biomass increased from approximately 38 mt km^{-2} in the inner Estuary, 128 mt km^{-2} in the middle Estuary, and 435 mt km^{-2} in the outer Estuary. Despite the general increasing trend in SAVs from west to east, Cashin Associates (1996) found that SAV beds were patchy in distribution throughout the Estuary. They noted that there may be SAVs in tidal creeks and some embayments that were missed; therefore not all SAVs may be documented on their map. For example, eelgrass is located in Bullhead Bay in the Town of Southampton, in an area where Cornell Cooperative Extension has recently been involved in SAV monitoring. Yet these eelgrass beds were not identified as part of the Cashin (1996) survey.

Eelgrass was located only in, around, and east of Shelter Island covering a total of 8.5 km^2 (2,100 ac; Figure 8). The farthest west eelgrass was identified was in the northern part of Southold Bay. The eelgrass bed in Southold Bay appeared to be damaged from scallop harvesting (Cashin Associates 1996). Eastward of Shelter Island along the South Fork, eelgrass beds were found only in protected embayments such as Napeague Harbor and Lake Montauk. It is unknown to what extent eelgrass occurred historically in the western bays of the Peconic Estuary; however, anecdotal information from baymen and other people familiar with Peconic bays contend that prior to the onset of brown tide, eelgrass was found in patches throughout the western bays.

Beds of eelgrass mixed with green fleece (*Codium fragile*) were found off the southeast coast of Shelter Island and in Lake Montauk. Based on an earlier survey of SAVs in Lake Montauk by Flagg and Greene (1981 from Cashin Associates 1996), a shift appears to have occurred along the northern end of the lake changing from a dense monoculture of eelgrass to eelgrass mixed with green fleece. The most abundant eelgrass beds were found in Gardiners Bay and Block Island Sound.

Widgeon grass was found at only two stations (i.e., Goose Creek, Southampton and Broadwater Cove off Cutchogue Harbor, Southold); however, widgeon grass is also known to occur in Bass Creek in Shelter Island and in Hubbard Creek in Riverhead.

The most abundant algae found by Cashin Associates (1996) was green fleece. This species was unintentionally introduced to the Peconic Estuary in 1957 in the Town of Southold, possibly with oyster transplants that came from Europe (Cashin 1996). Green fleece grows rapidly in Peconic waters and may outcompete many of the native seaweeds. The algae produces filaments that act as holdfasts to hard substrate such as shells. Larger plants can become buoyant enough to pull up the shell or other material to which the plant is attached and become adrift in the water. It is not clear whether green fleece is spreading in the Estuary and what the environmental factors are that promote its expansion. It is also unknown whether green fleece holds the same habitat value for similar biological communities as eelgrass in the Peconics. Some people have observed bay scallops in green fleece (C. Smith, Cornell Cooperative Extension, pers. comm. 1998).

Sea lettuce was found only west of Shelter Island in mostly quiet, shallow waters of tidal creeks and in the northern portions of Little Peconic Bay, Great Peconic Bay, and Flanders Bay. Very low densities of sea lettuce were observed east of Little Peconic Bay. Although found naturally in the Peconics, sea lettuce and hollow green weeds (*Enteromorpha* spp.) have been observed to proliferate in eutrophic waters (Cashin 1996). It is currently unknown whether the range of sea lettuce is expanding throughout the Estuary as a result of eutrophication.

Red macroalgae was also found throughout the Estuary. Lacy redweed (*Euthora cristata*) and brushy redweed (*Cystoclonium purpureum*) were the most abundant red macroalgae surveyed (Cashin Associates 1996). The most abundant brown macroalgae in the Estuary is rockweed (*Fucus* spp.).

Cashin Associates (1996) did not find consistent estuary-wide historical trends in eelgrass from analyses of aerial photography taken from 1969 to the 1980s and from the 1980s to 1994. They also could not find an overall decline in eelgrass abundance as a result of brown tide events in the 1980s. They observed that eelgrass beds were more extensive along the eastern coast of Shelter Island in 1969 and along the southeastern shore of Gardiners Island in 1980 than they are today. Eelgrass beds in Orient Harbor, Southold Bay, and along the eastern shoreline of Napeague Harbor did not appear to change significantly over the past 25 years; however, they found an increase in eelgrass beds south of Long Beach in Gardiners Bay (Cashin Associates 1996). They suggest that some type of physical (i.e., tidal exchange, depositional areas) change may have occurred that resulted in an expansion of eelgrass beds bordering Long Beach and a subsequent contraction of eelgrass beds just south along the northeastern tip of Shelter Island.

On a shorter time-scale, Cashin Associates (1996) noted an apparent die-off of eelgrass in the middle and outer waters of the Peconic Estuary since the late summer of 1994. This die-off is consistent with decreasing regional trends along the northeastern Atlantic coast (Short *et al.* 1993; Cashin Associates 1996).

The Cashin Associates (1996) survey was unable to provide information on long-term trends as well as year-to-year variation in eelgrass distribution and abundance. Additional field surveys are required to understand annual variation in eelgrass beds and whether any given trend in distribution and abundance represents longer-term variation (Cashin Associates 1996).

In 1997, Cornell Cooperative Extension began what is intended to become a long-term SAV monitoring program in the Peconics for the Peconic Estuary Program. Dumais and Smith (1997) collected samples in the summer at eelgrass beds in Orient Harbor (July), Bullhead Bay (August), which may be the westernmost occurrence of eelgrass in the Estuary, and Northwest Harbor (September). Depths ranged from < 1 m in Bullhead Bay to 2.8 m in Northwest Harbor. Results of sediment grain size analysis found mostly sandy substrate at Northwest Harbor, sand and some gravel at Orient Harbor, and a mixture of mostly sand and silt with some clay at Bullhead Bay. Percent organic matter differed among stations with Bullhead Bay having the highest values, which is consistent with finer-grained substrate at this site (Table 7).

Other SAVs were found growing among eelgrass with some algae growing as epiphytes on the eelgrass. Green fleece, banded weed (*Ceramium* sp.), and the brown algae, slippery tangle weed (*Sphaerotrichia divaricata*), were found growing among eelgrass at Orient Harbor. Some of the banded weed was growing epiphytically on the eelgrass. Epiphytic red algae, *Lomentaria baileyana*, and encrusting bryozoans also were found growing on some of the older leaves. Banded weed was epiphytic on eelgrass at Bullhead Bay. Both hollow green weeds and sea lettuce were identified along the edge of the eelgrass bed at Bullhead Bay. Banded weed and the red algae (*Spyridia filamentosa*) were found growing among the eelgrass in Northwest Harbor (Dumais and Smith 1997). The ratio of macroalgae to eelgrass densities (by weight) was high at Northwest Harbor compared to the other two sites.

Eelgrass shoot density was lowest at Northwest Harbor (Table 8). There were more flowering shoots at Bullhead Bay than at the other stations. However, both the total number and percent of shoots flowering are likely a function of time of sampling. Photosynthetically active radiation (PAR) was measured at each site just below the surface and at depths of 1 and 2 m. There were variations in light attenuation (i.e., amount of scatter, absorption, and reflection) among sites in part due to weather conditions at time of sampling. At all sites, Dumais and Smith (1997) found light attenuation to be less than the maximum for SAV survival. Small numbers of hard clam (*Mercenaria mercenaria*) and bay scallops were found in eelgrass beds at all three sites.

There have been a number of efforts to restore eelgrass in the Peconic Estuary. In 1987, Cornell Cooperative Extension conducted an eelgrass revegetation effort to assess viability of eelgrass seedlings during a brown tide event (Dennison *et al.* 1988). Flowering plants collected from Northwest Harbor were maintained in an outdoor aquarium to collect seeds. In the fall of 1987, seeds were planted at densities of 500 per 0.25 m^2 at six sites throughout the Peconic Estuary (Sag Harbor, West Neck Harbor, Northwest Harbor, Accabonac Harbor, Napeague Harbor, and Lake Montauk). Germination success, assessed six months later, varied between 2 to 8%. Three of the reseeding sites (Northwest, Accabonac, and Napeague Harbors), had no viable plants, which was possibly due to wave scour. The other three sites had viable seedlings. The results suggest that site selection and sediment stability are crucial for reseeding success. Dennison *et al.* (1988) also found natural revegetation occurring along the edges of eelgrass beds possibly in response to brown tide.

More recently, the Town of East Hampton in cooperation with Cornell Cooperative Extension, has been conducting eelgrass restoration in Northwest Creek, Three Mile Harbor, Napeague Harbor, and Accabonac Harbor. Their efforts have received mixed results. In the summer of 1997, small (approximately 0.45 ft^2) plots of eelgrass were transplanted from one side of Napeague Harbor to another to evaluate the transplanting method (M. Billerman, EEA, Inc., pers. comm., November 20, 1997). Two types of transplant methods were used. The first method consisted of removing individual eelgrass shoots from sediment, stapling them together, and replanting in the transplant site's substrate. The second method entailed transplanting a portion of the entire eelgrass bed by keeping shoots and sediment in which the eelgrass was rooted intact as much as possible (somewhat like sod). Recent observations found that eelgrass transplanted using staples was entirely gone while the sod-type eelgrass transplant was present but eelgrass shoots were in limited numbers (M. Brown, EEA, Inc., pers. comm., March 23, 1998). Maria Brown of EEA Inc. noted that shortly after eelgrass was transplanted in Napeague Harbor, there was a significant die off of eelgrass in the harbor, possibly due to elevated water temperatures (above 20 °C). EEA divers also found extensive coverage of epiphytes on the transplanted eelgrass (M. Brown, EEA, Inc., pers. comm., March 23, 1998). It is unknown whether the transplanted eelgrass underwent reproductive processes (pollination and fertilization) to produce seeds. Results of seeding may not be observed for at least three years (M. Brown, EEA, Inc., pers. comm., March 23, 1998). The Town of East Hampton and Cornell Cooperative Extension will continue to work on restoration efforts in Napeague Harbor, Cedar Beach, and Cutchogue (Northwest Creek), focusing on transplanting techniques with EEA Inc.

In an effort to assess ambient conditions of the Estuary that will adequately support thriving eelgrass beds, the Peconic Estuary Program awarded a contract to EEA, Inc. to assess existing water quality, flow conditions, sediment grain size, and levels of total organic carbon in 14 areas where eelgrass density is highest, lowest, transitional, stressed, non-existent, and where small plots of eelgrass have been transplanted. Preliminary findings by EEA Inc. suggest that water quality may not be the limiting factor controlling the presence or absence of thriving eelgrass in areas where it occurred according to anecdotal information (M. Billerman, EEA Inc., pers. comm. 1998). However EEA Inc.'s interpretation of their findings may not agree with the results of Cornell Cooperative Extension's long-term SAV monitoring efforts.

It is unknown whether eelgrass transplantation could result in changes to the overall genetic diversity of eelgrass in the Peconic Estuary. Williams and Orth (1998) did not find a loss of genetic diversity in transplanted eelgrass beds in Chesapeake and Chincoteague Bays; however, their results differed from results of research conducted in southern California that found less genetic diversity in transplanted eelgrass. One of the most significant differences in these two studies is that sexual reproduction (and therefore the opportunity for genetic recombination) may have been more significant in the Chesapeake (Williams and Orth 1998). Seeds from detached, floating shoots may also enhance gene flow. Williams and Orth (1998) concluded from their research that a single eelgrass population will not contain most of a bay's genetic diversity; therefore, eelgrass restoration should be from different donor sites to conserve natural genetic diversity of eelgrass in an estuary.

There has not been comprehensive research quantifying the abundance and diversity of species colonizing transplanted eelgrass in the Peconics. Studies by Homziak *et al.* (1982) in North Carolina found similar macrofauna in artificially established and natural eelgrass meadows. The dominant species found in the restored eelgrass bed consisted of oligochaetes and spinoids. A total of 89 taxa were collected in the restored eelgrass bed. Homziak *et al.* (1982) assumed their sampling methods likely missed some epifaunal and cryptic species.

Based on anecdotal information and analyses of recent aerial photographs by Cashin Associates (1996), there appears to be an ongoing eelgrass decline in the Peconic Estuary at least since 1994. It is unknown how these declines in eelgrass are effecting the detrital-based food web, primary productivity of the Estuary, and trophic dynamics of top predators feeding on organisms that are part of the community assemblage supported by eelgrass in the Estuary.

In the 1930s, eelgrass in the Peconics as well as along the entire east coast of the U. S. and Canada declined dramatically as a result of a wasting disease caused by a ubiquitous slime mold, *Labyrinthula zosterae*. It is unknown whether there have been recurrences of this disease in the Peconics. There is also a paucity of information on whether there are eelgrass populations that are genetically more susceptible or resistant to the wasting disease pathogen.

Other possible, naturally occurring impacts on eelgrass include storm events and lowered seedling recruitment due to predation. Laboratory work by Wigand and Churchill (1988) on predation of eelgrass seedlings collected from Northwest Creek found extensive predation when offered as the sole food source. Crustaceans (*Ovalipes ocellatus* and *Pagurus longicarpus*), which are common inhabitants of eelgrass meadows, were the most active predators consuming or damaging approximately 93% of the seeds (Wigand and Churchill 1988). However, when alternative food was present (i.e., clams and scallop bits), predation on seeds and seedlings by the crabs was reduced to 5%.

Research in other estuaries have documented some of the direct (e.g. mechanical damage, physical removal, wasting disease, nitrogen) and indirect (e.g. decreases in water clarity, eutrophication [nutrient loading], release of toxins) impacts to eelgrass and other SAVs; however, virtually no work has been done in the Peconics. Although these activities occur in the Estuary, little is known about the magnitude and extent of impacts from eutrophication, brown tide, navigational dredging, shellfish dredging and raking, boating activities (propeller scarring, boat wakes) and other activities on SAVs.

One of the most significant water quality concerns in Peconics has been excess nitrogen. High concentrations of nutrients can reduce water clarity by supporting an increase in phytoplankton blooms. Algae blooms reduce water clarity blocking light to SAVs. A reduction in water clarity has adverse effects on SAV growth by reducing shoot densities and flowering of seagrasses (Dumais and Smith 1997). Excess nutrients may also fuel the overgrowth of epiphytes that can limit photosynthetic activity by seagrasses and other SAVs. Nitrate in high concentrations in the water has been found to adversely affect the physiology of eelgrass (Burkholder *et al.* 1992). Shoreline stabilization such as bulkheading prevent natural dissipation of waves which could result in a high energy environment that no longer is suitable to seagrasses.

Navigational and clam dredging in eelgrass can physically damage eelgrass beds or cause water clarity problems when occurring near eelgrass beds, particularly in areas of mud and silt substrates (Submerged Aquatic Vegetation Workgroup of the Living Resources Subcommittee, Chesapeake Bay Program 1995).

Cashin Associates found an eelgrass bed in Southold Bay to be damaged from scallop harvesting (Cashin Associates 1996). Dumais and Smith (1997) speculate that the patchy nature of the eelgrass bed they surveyed in Northwest Harbor may be due to clamming activity. Peterson *et al.* (1987; from Dumais and Smith 1997) found that repeated and frequent harvesting of clams by raking is detrimental to eelgrass beds. Shellfish dredging is used in the Peconics by some baymen to harvest scallops and clams in eelgrass beds and soft bottom, unvegetated substrates. Although not studied specifically in the Peconic bays, studies in North Carolina found shellfish dredging to significantly reduce eelgrass biomass and shoot numbers (Fonseca *et al.* 1984). They found significant loss of eelgrass colonized in soft bottoms where dredging uprooted the whole plant (meristem, roots, and rhizomes). It is important to note, however, that their study took place in March. The harvest season in North Carolina is from December to May whereas in the Peconics, peak season is in the fall.

Cumulative localized navigational dredging and filling can threaten the persistence and productivity of seagrasses by smothering (turbidity and burial) and removing plants, as well as potentially altering the current regime (Short and Wyllie-Echeverria 1996). Other activities found to degrade eelgrass meadows include construction of docks and floating racks (from aquaculture) which shade beds, moorings (which causes holes in eelgrass beds from the swing of the anchor chain), trawling or dragging nets over beds (can reduce shoot density and plant biomass), and certain methods of clam digging (Short and Wyllie-Echeverria 1996). Cumulative damage by propeller scarring and boat wakes has recently been demonstrated as significant impacts to seagrass habitats in other estuaries (Cashin Associates 1996 from Fonseca *et al.* 1992).

It is unknown whether toxic contaminants have had any effect on SAVs in the Peconics. Work by Cornwell and Stevenson (1988) in the Chesapeake Bay in areas adjacent to agriculture did not find toxic substances such as herbicides to be affecting the growth and survival of SAVs. They concluded that toxics are not the major cause of eelgrass loss in the Chesapeake Bay and that nutrient inputs and turbidity are more likely threats. However, non-lethal effects of herbicides may act with other environmental stresses that results in SAV loss to the Estuary Cornwell and Stevenson (1988).

Intertidal and Shoreline
Tidal wetlands

Along the Peconic Estuary coast, tidal wetlands (or salt marshes consisting of vegetated wetlands and unvegetated wetlands such as sand and mud flats) are found around small embayments especially in areas where tidal creeks enter the Estuary. The typical pattern of vegetation in salt marshes is correlated with elevation and tidal flooding (Daiber 1982; Strieb 1993). Portions of salt marsh that are covered for more prolonged periods by tides are called the low marsh. The high marsh is the area covered by only very high (spring) tides, which occur during new and full moons or during storms. The soil in these high marshes is usually saturated with water; however, all parts of salt marshes are exposed to the air during low tides (Strieb 1993).

The low salt marsh is dominated by salt marsh cordgrass (also called smooth cordgrass or saltwater cordgrass; *Spartina alterniflora*), interspersed with algal mats growing on the sediment that are rich in cyanobacteria and benthic diatoms. The salt marsh cordgrass community is one of the most productive habitats in terms of biomass (Perry 1985). Snails, crabs, a variety of insects, and some birds feed directly on salt marsh cordgrass. The base of the food web in the low salt marsh is primarily detritus. Dead salt marsh cordgrass is decomposed by bacteria and fungi, which, in turn, is food for numerous estuarine organisms (Perry 1985; Strieb 1993). During high tides, pelagic finfish and benthic invertebrates such as crabs are found in salt marsh habitat feeding on both detrital and living matter. Pernell and Peters (1984) found that detritus of salt marsh cordgrass origin is an important component of the Atlantic menhaden diet. They concluded that juvenile menhaden derive much of their energy from detritus from marsh plants rather than a phytoplankton-based food web. This is only one example of the important relationship between productivity of tidal marshes, particularly *Spartina* spp., and productivity of coastal fisheries.

Organisms that live in salt marsh habitat include meiofauna (e.g. nematodes, harpacticoid copepods, amphipods, polychaetes, oligochaetes), ribbed mussels (*Geukensia [=Modiolus] demissa*), salt marsh snails (*Melampus bidentatus*.), fiddler crabs (*Uca* spp.), grass shrimp (*Palaemonetes* spp.) and many different types of insects (Daiber 1982; Strieb 1993). Tidal processes wash much of the salt marsh detritus out into the Estuary, which is decomposed by bacteria and fungi that are then fed on by numerous estuarine organisms.

Numerous organisms use salt marsh habitat as a site for reproduction. Several species of birds nest in these areas including willets (*Catoptrophorus semipalmatus*), rails (*Rallus* sp.), marsh wren (*Cistothorus palustris*), and seaside sparrow (*Ammodramus maritimus*; Reschke 1990). The Atlantic silverside reproduce in the low marsh and deposit their eggs on the stalks of the cordgrass.

The high marsh is landward of the low marsh and is inundated only by spring high tides and storms. The high salt marsh is usually dominated by salt meadow grass (also called salt hay grass; *Spartina patens*). Salt meadow grass tends to bend in matlike clumps where grass accumulates as it dies off and forms a protective mat that persists through the next year (Perry 1985). These mats provide shelter for numerous small animals and helps maintain moisture in the soil (Perry 1985). The rapid cycling of nutrients associated with the short span of cordgrass and salt meadow growth and decay is significant throughout the estuarine system (Perry 1985). Other plants that are found growing in or near the low and high marsh are black grass (*Juncus gerardii*), spike grass (*Distichlis spicata*), salt marsh aster (*Aster tenuifolius*), sea lavender (*Limonium carolinianum*), salt marsh bulrush (*Scirpus robustus*), glassworts (*Salicornia* spp.), groundsel bush (sea myrtle, *Baccharis halimifolia*), black grass or black rush (*Juncus gerardii*), and marsh elder (*Iva frutescens*). Some of the rare plant species found in salt marshes of the

Peconic Estuary include creeping spike rush (*Eleocharius fallax*), marsh straw sedge (*Carex hormathodes*), slender blue flag (*Iris prismatica*), slender marsh pink (*Sabatia campanulata*), and marsh fimbry (*Fimbristylis castanea*) as well as other numerous state rare plant species (Pleuthner 1995).

Salt panne communities are also found in low and high salt marshes along the Peconic Estuary. Salt pannes are shallow depressions where the marsh is poorly drained (Reschke 1990). During spring tides, salt pannes get flooded and collect water which eventually evaporates leaving very high salinity pore water in the soil. Conversely, fresh water collects during rainfall, lowering salinity levels. Typical plant species found in salt pannes include dwarf forms of salt marsh cordgrass, glassworts, marsh fleabane (*Pluchea odorata*), and salt marsh sand spurry (*Spergularia marina*; Reschke 1990).

Along the upland border of the high marsh where salt stress is less and freshwater seepage and runoff is more dominant, species include Olney three-square (*Scirpus americanus*, formerly *S. olneyi*), common three-square (*S. pungens*), rose mallow (*Hibiscus moscheutos*), marsh mallow (*Althea officinalis*), narrow-leaved cattail (*Typha angustifolia*), and seaside goldenrod (*Solidago semipervirens*). Poison ivy (*Toxicodendron radicans*) and common reed (*Phragmites australis*) are also common in some salt marshes.

Tidal flats are unvegetated intertidal areas seaward of salt marshes that consist of mud or sand depending on the speed of tidal currents. The boundaries of tidal flats correspond to the limits of spring and neap tides. Some tidal flats are covered in areas by green algae (e.g. sea lettuce, hollow green weeds [*Enteromorpha* spp.]), blue-green algae, and microscopic diatoms. Most of the organisms inhabiting tidal flats consist of bivalves and small invertebrates such as molluscs, crabs, and worms (McLusky 1981; Perry 1985). One of the most often sighted organism on intertidal flats in the Peconics is the fiddler crab (*Uca* spp.). Many of the animals found inhabiting intertidal mudflats are feeding on the detritus and algae.

The U. S. Environmental Protection Agency contracted the U. S. Fish and Wildlife Service to map all classes of wetlands including salt marshes and intertidal flats along the Peconic Estuary shoreline and analyze trends in wetland distributions over time. The U. S. Fish and Wildlife Service found a diverse assemblage of wetland species in the Peconics. They identified a total of 167 plant species that consist of a variety of trees, shrubs, woody ground cover, grasses, herbs, vines, mosses/lichens, and aquatic vegetation. Estuarine wetlands (e.g. salt marshes and intertidal flats) accounted for 2,271 ha (5,679 ac) in the Peconic watershed (Table 9; Tiner *et al.* 1998). Approximately 72% of the estuarine wetlands consist of vegetated wetlands. Only 8% of the estuarine emergent wetlands (high and low salt marsh) were dominated by common reed (*Phragmites australis*). There were less than 73 ha (183 ac) of estuarine scrub-shrub wetlands characterized by marsh elder (*Iva frutescens*). Marine wetlands, which were limited to intertidal beaches, mud and sand flats, and rocky shores made up about 348 ha (870 ac) with intertidal mud and sand flats representing approximately two-thirds of the total (Tiner *et al.* 1998).

A 500 ft buffer around each wetland (marine, estuarine, and palustrine) was examined for change. Changes in wetlands and their buffers were compared using aerial photography from 1972 and 1994. Overall, 1,860 ha (4,650 ac) changed in the 500 ft buffer with approximately 50% of the change resulting from golf course construction (520 ha [1301 ac]) and residential housing (410 ha [1027 ac]; Tiner *et al.* 1998).

Some of the trends mapped in the U. S. Fish and Wildlife reflect changes occurring in salt marsh quantity and quality. Some of theses changes are from physical alteration of the land and seascape and chemical contamination of the water by pollutants derived primarily from land-based sources. Low lying marshes and swamps historically have been ditched and drained for mosquito control, or filled for construction or agriculture. In some areas, this disturbance has led to changes in vegetation of lower habitat quality (i.e., replacement of salt meadow cordgrass and salt marsh cordgrass, *Spartina* spp., with the common reed, *Phragmites* spp.). Filling for roads and railroads has cut off water flow to a number of tidal wetlands while other tidal wetlands receive stormwater runoff from nearby roads. Over time, vegetation has changed, and marsh has either become freshwater wetlands or gradually filled and become upland.

It is unknown at this time to what extent the Peconic Estuary is losing edge marsh, *Spartina alterniflora,* to boat wakes, shoreline hardening, and other impacts. Also incremental loss of salt marsh is occurring as a result of sea level rise; however, the amount has not been quantified.

Beaches and Dunes

Beaches make up transitional shorelines composed of unconsolidated sands bordering the Peconic Estuary. Beaches move by accretion and erosion as a result of waves, wind, currents, and storms. Therefore, they are considered dynamic environments both spatially and temporally.

In general, beaches extend from the low tide line to areas impacted by storm surges, approximately 2 m above the high tide line (Strieb 1993). In the Peconic Estuary, beaches tend to be smaller than Long Island's south shore beaches. Beaches are widely dispersed and tend to be scalloped shape or sand spits on ends of peninsulas. Dunes or bluffs form on the landward side of only some of the beaches.

The unstable nature of beaches limits the type and number of organisms that can live there. Also, environmental conditions are harsh due to large fluctuations in temperature, prolonged exposure to the air caused by water draining rapidly through beach sediments, strong winds, and the abrasion caused by sifting sand (Strieb 1993). Small amphipods, tinntinnids, rotifers, and worms live between sand grains and filter detrital material or plankton from the surf zone (Strieb 1993). Some of the species also feed on diatoms and other microalgae living on the surface of the sediments (Strieb 1993).

Near the high tide line a line of wrack can be found. Wrack is a band of dead vegetation (consisting of beach grass, *Spartina* spp., submerged aquatic vegetation or both), shells, and other debris that is normally deposited on beaches by tidal action. The organic material in the wrack decomposes by bacteria and fungi and nutrients are released, which support primarily plants. A variety of amphipods, insects, and birds feed on the organic matter in the wrack. Burrowing worms, small arthropods, crustaceans, and insects that live in the swash zone and upper beach are also prey for birds.

A number of beaches in the Peconic Estuary support rare plants, animals, and natural communities such as piping plover (*Charadrius melodus*) and roseate tern (*Sterna dougallii*). These two species are listed as endangered or threatened under the Federal Endangered Species Act (U. S. Fish and Wildlife Service 1997; Pleuthner 1995). Many beaches in the Peconics support the globally rare seabeach knotweed (*Polygonum glaucum*; U. S. Fish and Wildlife Service 1997; Pleuthner 1995).

Dunes form from aeolian processes. The higher a dune grows, the more resistance it poses to the wind resulting in sand deposition on its face or over the dune crest (Perry 1985). American beach grass (*Ammophila breviligulata*) grows on dunes by means of horizontal rhizomes that are only a few inches below the surface.

Peconic Estuary beaches provide breeding and nesting sites for plovers, terns, and diamondback terrapins. Horseshoe crabs also move onto sandy beaches to breed in the spring during new and full moons (Baltimore National Aquarium 1991).

The largest threat to beaches in the Peconic Estuary is shoreline hardening. The use of bulkheads, rip-rap, jetties, groins, and other hardened structures has been widely permitted to stabilize shoreline in front of waterfront property throughout the Estuary. These structures have replaced beach with upland, increased shoreline erosion and altered accretion patterns leading to loss of wetlands and beaches, and have caused scouring of shallow areas with impacts to shallow water benthic communities including eelgrass (Submerged Aquatic Vegetation Workgroup of the Living Resources Subcommittee, Chesapeake Bay Program 1995; Herrmann 1997). In areas of landward-retreating shorelines, hardened structures remain fixed in place while the beach in front slowly narrows and ultimately disappears (Herrmann 1997). This can occur very slowly, and sometimes unnoticed, typically over two to four decades. In many instances, changes associated with bulkheads may be quite localized and subtle, with no apparent impairment. However, many small changes can lead to widespread cumulative damage of natural communities throughout the system. According to a study performed in the Town of Southampton along the Atlantic coastal beaches, beaches in front of seawalls and beaches downdrift of groins and jetties were significantly narrower than unarmored, natural beaches (Herrmann 1997). Herrmann (1997) also confirmed that groins and jetties increased the width of beaches updrift of these structures at the expense of degrading the width of downdrift beaches. The report concludes that further hardened stabilization should be avoided and structures should be relocated landward to: 1) adequately respond to a global recessional trend in beaches due to sea level rise; 2) prevent property damage; and, 3) preserve and reestablish wider beaches and dunes that serve as natural barriers to storm surges (Herrmann 1997). Preservation and re-establishment of beaches would also provide essential habitat to numerous colonially nesting waterbirds. It is unknown at this time how much of the Peconic Estuary shoreline is hardened from bulkheads or other rigid shoreline structures or at what rate they are being constructed. It is also unknown how the shoreline has changed with time as a result of shoreline hardening.

Birds

Shorebirds

Shorebirds are an integral part of the ecosystem, providing an interchange in energy flow between land and water (Buckley and Buckley 1976). There are a variety of shorebirds found nesting, feeding, and breeding along the shores of the Peconic bays and islands in the Estuary (Table 10). A number of these shorebirds are federally listed as threatened or endangered or are rare in the State of New York such as the piping plover, least tern (*Sterna antillarum*), roseate tern, and common tern (*Sterna hirundo*).

Piping plovers, least terns, roseate terns, common terns, and black skimmers (*Rynchops niger*) nest above the high tide line on sparsely vegetated sandy and cobbly beaches throughout the Peconics (Figures 9-11). Piping plovers prefer early successional habitat, such as the ends of sand spits (Orient, Shell Beach in Shelter Island, Cedar Point) and washover areas, and will not use a site if a beach becomes too narrow or is heavily vegetated with beachgrass (Hecht *et al.* 1996).

Piping plovers arrive in the Peconics in March. They lay four eggs, which are incubated for 25 days. It takes 30 to 35 days for chicks to fully fledge. First attempts at nesting in early spring tend to be most successful (chicks then fledge before the July 4th holiday, one of the most heavily visited beach day of the year; Hecht *et al.* 1996). If plover nests are disturbed, the birds will nest again but subsequent nests are generally less productive (S. Antenen, The Nature Conservancy, pers. comm., 1998). In 1996, the average piping plover productivity on Long Island was an estimated 1.14 chicks per pair. During the same year in the Peconics, average productivity was 1.23 chicks per pair (based on monitoring of 9 sites). Pairs at some of the smaller sites along the Peconic Estuary shoreline have fledged 2 to 3 chicks per pair, which is unusually high on Long Island (Sommers and Alfieri 1997).

Piping plover adults and chicks feed on invertebrates found along the intertidal zone, sand and mudflats, and in wrack habitat. Studies of Cape Cod beaches have found wrack habitat to be the preferred feeding habitat for piping plover chicks (Hoopes 1993 from Goldin 1993).

Least terns often co-occur with piping plovers, nesting in colonies on the open beach (Figure 10). Largest colonies of least terns range from 50 to 200 pairs; however, colony size at any given site can fluctuate widely from year to year (Sommers and Alfieri 1997). For example, in 1994 at Orient, there were 16 pairs of least terns. In 1996, there were 108 pairs (Sommers and Alfieri 1997). Cartwright Island decreased from 200 pairs of least terns in 1994 to 49 pairs in 1996 (Sommers and Alfieri 1997).

Common terns nest in large colonies. Great Gull Island in the Town of Southold supports a population of 7,750 to 9,000 pairs of birds (Sommers and Alfieri 1997). Gardiners Point, an island approximately a mile and a half north of Gardiners Island supports 248 pairs. Common terns prefer more vegetated habitat than plovers and least terns; however, they will abandon a site if it becomes too heavily vegetated (Burger and Lesser 1978; Kotliar and Burger 1986). Great Gull Island also supports approximately 1,500 pairs of roseate terns (Sommers and Alfieri 1997). Roseate terns prefer sites with dense vegetation and seaside goldenrod (*Solidago sempervirens*; Figure 11; S. Antenen, The Nature Conservancy, pers. comm., 1998).

Least, common, and roseate terns arrive in mid-May and start to lay eggs by the end of May. Incubation lasts about 20 days. Parents bring prey to chicks, relying on forage fish as their primary food source. While common and roseate terns feed on a variety of forage fish, roseate terns appear to feed their chicks a specialized diet of American sand lance fish and to a lesser extent juvenile bluefish and herring fishes. Common tern chicks receive a more varied diet of American sand lance, herring fishes, and juvenile bluefish, butterfish, pipefish, bay anchovy, and Atlantic mackerel among others (Safina *et al.* 1990).

Bluefish population levels may dictate the degree of common tern reproductive success in an area within a given breeding season (Safina 1990; Ethan C. Eldon Associates, Inc. 1995). Research performed by Safina (1990) at the eastern end of the Peconic Estuary found roseate tern foraging success on a seasonal basis was depressed by bluefish feeding activity. However, this was not the case for common terns. On a daily basis, bluefish, and to a lesser extent striped bass, increased the availability of forage fish in the surface of deep waters where prey fish are otherwise out of reach of these birds (Safina 1990). Safina (1990) suggests that relative to all terns, bluefish appear to function as keystone predators based on their advantage to access fish prey, their effects on roseate tern feeding behavior, and their potential ability to put common terns at a competitive advantage over roseate terns. In the absence of bluefish, roseate terns have higher mean fishing success frequencies (Safina 1990).

Threats to shorebirds are from habitat loss (directly from development and indirectly from beach dynamics) and predators such as crows, raccoons, dogs, and feral cats, human disturbance, and flooding (Hecht *et al.* 1996). Off-road vehicles directly threaten piping plovers as well as degrade important wrack habitat in which plovers forage for invertebrate prey (Goldin 1993; National Park Service 1998). Goldin (1993) and the National Park Service (1998) found that removal of off-road vehicles played a role in increased reproductive and fledgling success of piping plovers at the Gateway National Recreation Area on the western tip of Long Island and the Fire Island National Seashore, respectively. Similar results were reported at Chincoteague National Wildlife Refuge, Virginia, Novia Scotia, and Massachusetts (Goldin 1993).

Loss in beach habitat threatens colonial shorebirds because they have a natural tendency to be fairly densely concentrated in small areas while breeding. Therefore, numerous individuals are vulnerable to a single disturbance (Buckley and Buckley 1978). Approximately 85% of the northeastern U. S. roseate tern population is concentrated on Bird island in Massachusetts and Great Gull Island (Ethan C. Eldon Associates, Inc. 1995).

Changes in bird breeding habits and habitat preferences may be occurring as a result of other human disturbances. For example, Goldin (1993) found piping plover chicks retreated to upper beach and dune areas where there is less food when large numbers of people were at the beach. This can result in a reduction in foraging efficiency as a result of human activity.

Shorebirds are also impacted by changes in their diet. Numerous studies throughout the world have linked food shortages of several fish-eating birds with changes in reproductive success (Safina *et al.* 1988). Safina *et al.* (1988) performed research on common terns and their prey at Cedar Beach on the south shore of Long Island and found lowered reproductivity corresponding to lower food availability. They also found earlier clutch initiation and increases in clutch and brood size in years of greater food availability. They suggest that although their work was limited to tern populations, other seabird populations may also be limited by availability of fish prey in other bays and estuaries.

Ospreys

The osprey (*Pandion haliaetus*) is listed as a state threatened species (Pleuthner 1995). Until the 1950s, the coast from New York to southern Massachusetts supported some of the highest densities of ospreys in the world, with at least 1,000 active nests (Spitzer *et al.* 1983). During the 1950s and 1960s, the population suffered severe impacts from the pesticide DDE: (1,1'-Dichloroethenylidene)-bis-(4-chlorobenzene). DDE exposure resulted in reduced reproduction and abnormally thin eggshells (Spitzer *et al.* 1983). By 1969, only 150 active nests were documented from New York to southern Massachusetts. With the ban on DDE use, osprey populations began to rise.

The east end of Long Island has historically had some of the highest numbers of ospreys compared to the rest of Long Island. Prior to 1940, Gardiners Island had one of the world's largest nesting populations (300 pairs). Today, there are approximately 25 nests on Gardiners Island (M. Scheibel, The Nature Conservancy, pers. comm. 1998). Osprey nests are well-distributed throughout the Peconics. In the 1970s, Long Island supported approximately 70 to 75 nesting pairs. By 1997, Long Island has 286 nesting pairs (M. Scheibel, The Nature Conservancy, pers. comm. 1998).

An important change that has occurred in osprey nesting is that most ospreys on Long Island use human-made, artificial platforms. Robins Island is the only area in Long Island where ospreys are known to nest on natural structures (M. Scheibel, The Nature Conservancy, pers. comm. 1998).

Osprey prey predominantly on winter flounder when they first arrive to the Long Island region in mid-March. Osprey eat a variety of fish; however, by late April, these raptors eat mostly Atlantic menhaden (M. Scheibel, The Nature Conservancy, pers. comm. 1998).

Egg-laying occurs in April with the incubation period lasting about 35 days. Osprey eggs hatch in late May and they fledge 7 to 8 weeks later (late June to early July). By the beginning of September, osprey migrate south to areas throughout South America (e.g. Venezuela, Brazil; M.

Scheibel, The Nature Conservancy, pers. comm. 1998). The most significant predators of osprey eggs and chicks are the raccoon and great horned owl.

Waterfowl and Other Birds

A variety of waterfowl consisting of dabbling ducks, diving ducks, and sea ducks are found overwintering in and around the Peconic Estuary. Dabbling ducks, also called puddle ducks, are found in shallow waters, such as tidal creeks, feeding along the waters' edge. Dabbling ducks feed on vegetative matter such as *Spartina* spp. seeds and acorns and invertebrates such as earthworms and snails found in the salt marsh. The most common dabbling duck found in the Peconic Estuary is the black duck (*Anas rubripes*). Mallards (*Anas platyrhynchos*) and gadwall are also found but to a lesser extent than black ducks. Diving ducks occur in deeper (2 to 18 m [6 to 60 ft]) water, feeding on submerged aquatic vegetation and bivalves such as hard and soft clams. Greater scaup (*Aythya marila*) and canvasbacks (*Aythya valisineria*) are the primary diving ducks found in the Peconic Estuary (C. Kessler, Ducks Unlimited, pers. comm., December 1997). Sea ducks live almost exclusively in deep (6 to 18 m [20 to 60 ft]) waters (except when they are breeding). Sea ducks use their diving abilities to feed on crustaceans and molluscs, particularly on blue mussels (*Mytilus edulis*). Sea duck concentrations occur off Robins Island and Gardiners Island (C. Kessler Ducks Unlimited, pers. comm., December 1997). The most abundant sea duck found in the Peconic Estuary is the scoter (white wing, *Melanitta fusca*; surf, *Melanitta perspicillata*; and black, *Melanitta nigra*). Other sea ducks inhabiting the Peconic Estuary include oldsquaw (*Clangula hyemalis*) and common eider (*Somateria mollissima*), which are limited to the waters off Montauk.

Napeague Bay and Napeague Harbor, Fort Pond Bay, and Lake Montauk waters and adjacent saltmarshes are particular areas in the Estuary that have been identified as feeding and nesting waterfowl wintering locations for greater and lesser scaup (*Aythya affinis*), red-breasted and common mergansers (*Mergus merganser* and *M. serrator*), Canada goose, black duck, bufflehead (*Bucephala albeola*), common goldeneye (*Bucephala clangula*), least bittern (*Ixobrychus exilis*), mallard, and northern harrier (U. S. Fish and Wildlife Service 1997). The Peconic Estuary also supports wood duck (*Aix sponsa*), American widgeon (*Anas ameriana*), pie-billed grebe (*Podiceps grisegena*), American bittern (*Botaurus lentiginosus*), mute swan (*Cygnus olor*), great blue heron (*Ardea herodias*), great egret (*Casmerodius albus*), snowy egret (*Egretta thula*), double-crested cormorant (*Phalacrocorax auritus*), glossy ibis (*Plegadis falcinellus*), and black skimmer (Pleuthner 1995).

Some of the primary threats to waterfowl and other birds are loss of habitat. Loss of wetland habitat and submerged aquatic vegetation are the biggest threats to dabbling ducks in the Peconic Estuary. Boat traffic may affect ducks; however, studies to confirm this have not been performed. In general, disturbance to bottom resources may affect waterfowl food availability.

Researchers from the Wildlife Conservation Research Center at the University of Connecticut are in the process of determining whether and to what extent contaminants pose hazards to birds in the Peconic Estuary. Being high up in the food chain, birds are especially vulnerable to contamination (as well as to prey declines). These researchers are analyzing heavy metals and organic contaminants (some of which are known endocrine disrupters) in greater scaup as well as their prey and other organisms in the food web including bivalves, macroalgae, gastropods, plankton, and marine invertebrates to determine whether there are relationships between contaminants in diving duck populations and their habitat (Cohen and Barclay 1997). Greater scaup populations were collected on or near Department of Interior trust wildlife refuges in Rhode Island, Connecticut, New York, and New Jersey. The two collection sites in New York were Oyster Bay National Wildlife Refuge (NWR) and near the Morton NWR and Conscience Point NWR in Flanders Bay. Preliminary studies indicate that Flanders Bay data are similar to other sites with measurable levels of metals found in muscle tissues (Figure 12). They are still analyzing data on metals in livers, kidneys, sediments, plankton, algae, bivalves, and whelks. Whether levels of these metals in these organisms are of concern is still being studied. They expect to have more definitive results in the near future.

Uplands

Oak Forest

Oak dominated and co-dominated forests can be classified generally as "maritime" or "coastal." Maritime forests are found in immediate proximity to the marine environment and are therefore often strongly influenced by salt spray, high winds, dune deposition, shifting substrate, and overwash. These forests usually exhibit stunted trees with contorted branches and wilted leaves, and often occur in narrow bands less than 50 m wide (Hunt 1997). Maritime oak forests may occur on exposed bluffs and sand spits, often bordering salt marshes; generally oak forests are dominated by two or more oak species, such as post oak (*Quercus stellata*), black oak (*Q. velutina*), scarlet oak (*Q. coccinea*), or white oak (*Q. alba*). There is a dense shrub thicket in these forests, composed of bayberry (*Myrica pensylvanica*), black huckleberry (*Gaylussacia baccata*), black cherry (*Prunus serotina*), and often catbrier (*Smilax rotundifolia*). Eastern towhee (*Pipilo erythrophthalamus*) and white-tailed deer (*Odocoileus virginianus*) are characteristic animals (Hunt 1998).

In the Peconics region of Long Island, the maritime post oak forest community is best represented at the Mashomack Preserve on Shelter Island. This area is considered an outstanding, intact example of a mature, diverse maritime post oak forest, with low levels of exotic plant invasion. Other examples of this habitat occur at Jessup's Neck and at Flanders Marsh in the Town of Southampton, and at Orient Point in the Town of Southold (Hunt 1998).

Coastal forests, by contrast, are non-maritime areas occurring within the Coastal Plain, *i.e.*, areas not in immediate proximity to the marine environment. Trees in the coastal forest are generally not stunted or deformed, and occur in wide matrices or large patches (Hunt 1997). Coastal oak forests occur on sandy or loamy sand soils on the outwash plains and moraines of the Atlantic Coastal Plain. Usually these forests are dominated by two or more species of oak, with community variations based on the co-dominant species; typical co-dominants are beech (*Fagus gradifolia*), holly (*Ilex opaca*), hickory (*Carya* spp.), or laurel (*Kalmia latifolia*). There may be a sparse shrub layer including blueberry (*Vaccinium* spp.) and huckleberry (*Gaylussacia baccata*, with sedges (*Carex* spp.) occurring in the groundlayer. White-tailed deer often inhabit coastal oak forests, and characteristic birds include eastern towhee and vireos (*Vireo* spp.; Hunt 1998).

Coastal oak forest communities in the Peconic Estuary watershed encompass several variants. Coastal oak-beech and coastal oak-hickory forests occur at the Mashomack Preserve on Shelter Island. Coastal oak-heath forest, a variant that occurs in the mosaic of habitats making up the pine barrens, exists in the Long Pond Greenbelt in the Town of Southampton and the Hither Hills area of the Town of East Hampton. Hither Hills also exhibits the coastal oak-laurel forest variant; this forest habitat is also in the Noyack Hills area of the Town of Southampton. Finally, the coastal oak-holly forest occurring on Montauk Point in the Town of East Hampton is an exemplary, and possible the only, example of that habitat type in New York State (Hunt 1998).

Pine Barrens

Pine barrens habitats occur on acidic, well-drained, sandy soils that have developed on the sand dunes, glacial till, and outwash plains of the Coastal Plain (Reschke 1990; U. S. Fish and Wildlife Service 1997). They are generally characterized by a 60% or greater canopy cover composed of pitch pine (*Pinus rigida*) and one or more oak species (*Quercus* spp.), with a heath shrub understory and sparse herbaceous layer (U. S. Fish and Wildlife Service 1997). The vegetative composition in these communities is influenced primarily by the depth of the water table, soil composition, the fire regime, and human disturbance (U. S. Fish and Wildlife Service 1997). Fire is particularly important for pine barrens vegetation, as it regulates the relative abundance of pitch pine and oak, and results in a mosaic of successional stages throughout the ecosystem (Town of East Hampton 1995). This habitat type exhibits a spectrum of shrublayer densities, and often barrens encompass or are found adjacent to grassland habitats (Reschke 1990). Bird species associated with pine barrens communities include prairie warbler (*Dendroica discolor*), brown thrasher (*Toxostoma rufum*), pine warbler (*Dendroica pinus*), and eastern towhee (*Pipilo erythrophthalmus*).

Pine barrens are a distinctive habitat in the northeastern United States, as their dry communities occur in a humid, temperate climate that would normally result in sites dominated by deciduous forests. This habitat type can exist under these conditions as a result of evolutionary adaptation by the principal plant species to the stressful environment (U. S Fish and Wildlife Service 1997). Pitch pine, for example, is easily out-competed in locations where nutrients and moisture are more abundant (U. S. Fish and Wildlife Service 1997). In the New York area, there are extensive pine barrens in four locations: the New Jersey Pinelands, the Albany Pine Bush, the Shawangunk Ridge, and the Long Island Pine Barrens. The Long Island Pine Barrens once extended west from the Ronkonkoma Moraine on the South Fork of the island into the town of Oyster Bay, running up to the edge of the Hempstead Plains prairie. This area has been greatly reduced, but some remnant pine barrens communities occur in patches to the west; the main pine barrens complex exists on the outwash plains north and south of the Ronkonkoma Moraine in eastern Long Island over the Magothy aquifer (U. S. Fish and Wildlife Service 1997).

In the Peconic Estuary region of Long Island, types of existing pine barrens habitats include the dwarf pine plains, pitch pine-oak-heath woodlands, and coastal oak-heath forest (Reschke 1990; Hunt 1997; Hunt 1998). The dwarf pine plains of Long Island, located south of the Ronkonkoma Moraine along the outwash plain in the Town of Southampton, is a type of dwarf pine barrens habitat with scrub oak (*Quercus ilicifolia*) occurring as a co-dominant. This habitat is composed of pines and co-dominant trees no greater than 3 m in height, and is located at the most dry and fire-prone areas of the barrens (U. S. Fish and Wildlife Service 1997). In these areas pines occur almost exclusively as the closed cone type, and have long-lived seeds and thick, resistant bark--characteristics developed as a result of frequent fire exposure. They also exhibit other adaptations such as rapid growth, root-sprouting branches, and extensive root systems that facilitate nutrient uptake (U. S. Fish and Wildlife Service 1991). The dwarf pine plains habitat supports a number of rare insect species, including dusted skipper (*Atrytonopsis hianna*), the noctuid moth *Chaetaglaea cerata*, pine barrens underwing (*Catocala herodias gerhardi*), and the notodontid moth *Heterocampa varia*. Also, the largest and best New York population of buck moth (*Hemileuca maia*, NYS special concern species), inhabits the scrub oak of this habitat (U. S. Fish and Wildlife Service 1997; Reschke 1990; NYS Department of Environmental Conservation 1993). The northern harrier (*Circus cyaneus*, NYS threatened species), a ground-nesting raptor, has established a breeding population of regional significance within the Long Island dwarf pine plains (U. S. Fish and Wildlife Service 1997; U. S. Fish and Wildlife Service 1991).

Other barrens communities include the central pinelands around the Bald Hill Pine Barrens or Manorville Hills area, and the coastal oak-heath forest (formerly classified as pitch pine-oak forest) mosaic in the Town of East Hampton (U. S. Fish and Wildlife Service 1991; Town of East Hampton 1995; Reschke 1990; Hunt 1998; Hunt 1997). These areas support rare insects such as the frosted elfin (*Incisalia irus*), Edward's hairstreak (*Satyrium edwardsii)*, the Aureolaria seed borer (*Rhodocia aurantiago*) and the chain fern borer (*Papaipema stenocilis*; Town of East Hampton 1995; U. S. Fish and Wildlife Service 1997; Pleuthner, 1995). More than 50 species of birds nest in these pine barrens complexes, including the pine warbler (*Dendroica pinus*) and the prairie warbler (*Dendroica discolor*), and these areas are important for declining neotropical songbirds like the whip-poor-will (*Caprimulgas vociferus*; Town of East Hampton 1995; U. S. Fish and Wildlife Service 1997). The pine barrens are also extremely important in maintaining the water quality of groundwater recharge areas (Town of East Hampton 1995).

A major threat to the pine barrens is habitat fragmentation. Maintaining contiguous forest areas is imperative to provide connectivity of habitat for mobile species, and to preserve wildlife diversity. The suppression of fire in the system, as a result of proximity to human development, may result in negative impacts to this habitat. Natural diversity is maintained by periodic fire exposure, and many of the rare and endangered species present in the pine barrens are adapted to this regime. In addition, the suppression of periodic, small fires in the system may result in wildfires, because the load of dry fuel has built up to high levels. These present an even greater threat to adjacent development, and may also result in damage to the barrens habitat (Town of East Hampton 1995). Finally, invasive species like multiflora rose (*Rosa multiflora*) and Japanese honeysuckle (*Lonicera japonica*) present a threat to the integrity of rare communities like the moorlands (Town of East Hampton 1995).

Maritime Heathlands and Grasslands

Maritime grasslands occur on well-drained, nutrient-poor, sandy soils of glacial outwash plains. This community is influenced by the maritime climate, with its moderate temperatures; extended frost-free season; strong, desiccating ocean winds; and salt spray (U. S. Fish and Wildlife Service 1991; Town of East Hampton 1995; Long Island Sound Study unpublished). Another key element appears to be fire. Human uses have also influenced grassland development and maintenance: clearing by fire and grazing occurred throughout precolonial and colonial times (U. S. Fish and Wildlife Service 1997; Town of East Hampton 1995). These grasslands are generally dominated by bunch-forming grasses such as little bluestem (*Schizachyrium scoparium*), common hairgrass (*Deschampsia flexuosa*), and poverty-grass (*Danthonia spicata*), often with low heath shrubs and reindeer moss (*Cladonia rangiferina*; U. S. Fish and Wildlife Service 1997; Reschke 1990; Pleuthner 1995).

The remaining native grassland communities on Long Island are small, unconnected habitats occurring in localized areas. These areas represent relict fragments of what was once a more widespread community on Long Island (U. S. Fish and Wildlife Service 1997). At one time, Long Island supported two extensive prairies in addition to the smaller grasslands created by human clearing and use of the land. The largest prairie, the Hempstead Plains, once stretched across the entire length of Nassau County in western Long Island. The Hempstead Plains once covered approximately 38,000 acres; however, this prairie has been almost entirely lost to development, with only 30 acres remaining (Town of East Hampton 1995; Long Island Sound Study unpublished; Reschke 1990).

The second prairie, the Montauk Downs, whose name is thought to derive from a comparison with the Downs of Sussex in England, once covered most of the Montauk peninsula in eastern Long Island (Town of East Hampton 1995). A 1923 survey of the vegetation of Montauk listed the most common species occurring in these grasslands as little bluestem, rush (*Juncus greenii*), hairgrass, Indiangrass (*Sorghastrum nutans*), milkwort (*Polygala polygama*), toothed white-topped aster (*Seriocarpus asteroides*), plantain-leaved pussytoes (*Antennaria plantaginifolia*), and sandplain gerardia (*Agalinis acuta*; Town of East Hampton 1995). Sandplain gerardia, once blooming by the "untold millions" (Town of East Hampton 1995) in the Montauk Downs, is now listed as Federally and State endangered (New York Natural Heritage Program 1997; NYS Department of Environmental Conservation 1989). The Montauk Downs have been greatly reduced in size and fragmented by vegetative succession and residential development, but are still present in some areas (Town of East Hampton 1995).

In the Peconic Estuary watershed the grasslands community type occurs almost exclusively on the South Fork. While the North Fork is likely to have formerly supported the maritime grasslands community, the heavy agricultural use of this area as far back as the late 17th century would have eliminated the native grassland communities long ago. While grazing by cattle has been cited as a possible factor in the development and maintenance of grassland communities, plowing destroys this community, altering the soil profile and increasing erosion by wind and water. Also, the practice in Colonial times of planting trees to delineate the boundaries of fields may have contributed to the process of vegetative succession in the North Fork grasslands into shrub- and woodlands (Long Island Sound Study unpublished).

On the South Fork, this community is represented today by small maritime grasslands within the Conscience Point National Wildlife Refuge and at Shinnecock Hills in the Town of Southampton, as well as by the remnants of the Montauk Downs in the Town of East Hampton. The Montauk community currently exists as a network of four maritime grasslands, at Shadmoor Ditch Plains, Montauk Downs, Big Reed Oyster Pond, and Hither Hills, encompassed by a system of maritime communities that includes the entire Montauk Peninsula east of Napeague Harbor (U. S. Fish and Wildlife Service 1997). The grasslands often occur as small pockets, especially on hilltops (Town of East Hampton 1995). These grasslands support several federally listed, candidate, and regionally rare plants and insects (U. S. Fish and Wildlife Service 1997; Pleuthner 1995).

The mosaic of maritime plant communities that includes native grasslands also encompasses heathlands and shrublands. This mosaic occurs throughout much of the Montauk Peninsula area and these collective communities are often referred to as moorlands (U. S. Fish and Wildlife Service 1997). Maritime heathlands on the Montauk Peninsula, such as occur at Montauk Mountain, are dominated by low heath shrubs with greater than 50% cover, such as bearberry (*Arctostaphylos uva-ursi*), beach heather (*Hudsonia tomentosa*), blueberry (*Vaccinium angustifolium*), black huckleberry (*Gaylussacia baccata*), bayberry (*Myrica pensylvanica*), and beach plum (*Prunus maritima*; U. S. Fish and Wildlife Service 1997; Reschke 1990). Similar to maritime grasslands, heathland communities occur on rolling glacial outwash plains and are influenced by the ocean climate (Reschke 1990).

By contrast, maritime shrublands occur on bluffs and exposed headland areas, and are lower in diversity. These areas usually support one or more shrub or stunted tree species, such as black cherry (*Prunus serotina*), sumac (*Rhus glabra* and *R. copallinum*), bayberry, arrow-wood (*Viburnum dentatum* var. *lucidum*), hawthorn (*Crataegus* spp.), beach plum, wild rose (*Rosa virginiana*), sand rose (*Rosa rugosa*), catbrier (*Smilax rotundifolia*), and blackberry (*Rubus* spp.; U. S. Fish and Wildlife Service 1997; Reschke 1990). Birds like great egret (*Casmerodius albus*) and black crowned night heron (*Nycticorax nycticorax*) may be found here (Reschke 1990). Heathland and shrubland communities both provide an important buffer for the remnant grasslands (Pleuthner 1995).

The South Fork grassland communities, on the Montauk peninsula and in Southampton at Shinnecock Hills and Conscience Point, provide essential habitat for a number of regionally and globally rare plant species. Two of only 12 known remaining populations of sandplain gerardia in the world occur in the Montauk grasslands (U. S. Fish and Wildlife Service 1997; Town of East Hampton 1995). Nantucket juneberry (*Amelanchier nantucketensis*), a New York State endangered species and a Federal species of concern, is endemic to these sandplain communities and on Long Island occurs only on Montauk and the Shinnecock Hills (U. S. Fish and Wildlife Service 1997; U. S. Fish and Wildlife Service 1991; New York Natural Heritage Program 1997). The only known extant population of silvery aster in New York occurs at Shinnecock Hills (U. S. Fish and Wildlife Service 1997). Other protected and rare plants found in the maritime grasslands and heathlands at Montauk, Shinnecock Hills, and/or Conscience Point include bushy rockrose (*Helianthemum dumosum*, Federal species of concern), New England blazing-star (*Liatris scariosa* var. *novae-angliae*, Federal species of concern), lance-leaved loosestrife (*Lysimachia hybrida*, NYS threatened species), pine barren gerardia (*Agalinis virgata*, NYS rare species), Emmon's sedge (*Carex emmonsii*, NYS rare species), dwarf plantain (*Plantago pusilla*), whorled mountain-mint (*Pycnanthemum verticillatum* var. *verticillatum*, NYS threatened species), grassleaf ladies'-tresses (*Spiranthes vernalis*, NYS rare species), fringed boneset (*Eupatorium hyssopifolium* var. *lacinatum*), sandplain flax (*Linum intercursum*, NYS threatened species), and orange fringed orchid (*Platanthera ciliaris*, NYS threatened species; U. S. Fish and Wildlife Service 1997; NYS Department of Environmental Conservation 1989).

A variety of bird species live in grassland habitats, including grasshopper sparrow (*Ammodramus savannarum*, NYS special concern species), Eastern meadowlark (*Sternella magna*), Northern harrier (*Circus cyaneus*, NYS endangered species, Federal threatened species), Savannah sparrow (*Passerculus gramineus*), and upland sandpiper (*Bartramia longicauda*, NYS special concern species; Long Island Sound Study unpublished; NYS Department of Environmental Conservation 1993). This latter species was once abundant in the Montauk grasslands, but disappeared as vegetative succession proceeded (U. S. Fish and Wildlife Service 1997). Other species--such as American Kestrel (*Falco sparverius*), red-tailed hawk (*Buteo jamaicensis*), and common barn owl (*Tyto alba*, NYS special concern species)--feed in grasslands and moorlands on rodents like the meadow vole (*Mictrotus pennsulvanicus*), deer mouse (*Peromyscus maniculatus*), and nocturnal jumping mouse (*Zapus hudsonius*). The short-eared owl (*Asio flammeus*, NYS special concern species) and a variety of hawks use these areas as over-wintering habitat (U. S. Fish and Wildlife Service 1997; Long Island Sound Study unpublished; NYS Department of Environmental Conservation 1993). Other wildlife found in and around grassland habitats include the brown bat (*Eptesicus fuscus*), spadefoot toad (*Scaphiopus h. holbrookii*), and eastern hognose snake (*Heterodon platyrhinos*, NYS special concern species; Long Island Sound Study unpublished; U. S. Fish and Wildlife Service 1997).

Coastal Bluffs

Bluff habitats are steep coastal slopes created by wave erosion and sea level rise. Bluffs are composed of glacial soils that are formed by a characteristic erosion pattern, with the toe eroding and undercutting the face. These undercut face areas slough off, leaving bare patches of soils exposed to additional erosion. This harsh environment results in rare and specialized plant and animal communities, such as the dwarf beech forest. Species common on mature Long Island bluffs may include beech (*Fagus grandifolia*), red maple (*Acer rubrum*), hickory (*Carya* spp.), witch hazel (*Hamamelis virginiana*), and huckleberry (*Gaylussacia baccata*). Younger communities may contain black cherry (*Prunus serotina*), sassafras (*Sassafras albidum*), pitch pine (*Pinus rigida*), bayberry (*Myrica pensulvanica*), and highbush blueberry (*Vaccinium corymbosum*; Lopez 1985).

Bluffs are particularly susceptible to activities that increase erosion. Unlike beach habitats, bluffs will never rebuild former configurations as a result of accretion; eroded portions of a bluff are permanently lost. Beaches fronting bluff habitat are closely tied to bluff erosion: it is the material eroding from the face of the bluff that supplies the beach with sediment. An indicator of stability in the bluff-beach habitat is a narrow beach composed of coarser, wave-resistant sands. Processes influencing bluff erosion include winter storm wave action, surface water runoff, groundwater seepage, and anthropogenic intervention in natural erosion and sediment supply processes (Lopez 1985).

Freshwater Streams

Rivers and streams encompass a diverse assemblage of habitat types, influenced by physical structure, chemical characteristics, and biogeography. Large, low gradient river systems (such as those that have been historically impounded) often have a soft-bottom benthos, open water plankton, and foraging fishes. They are often bordered by forest ecosystems and palustrine wetlands.

Riparian forests contribute to the quality of aquatic habitat by providing cover, bank stability, and a supply of organic matter, while adjacent wetlands also outwell food resources, improve water quality, and store flood water. River systems in turn function as material and nutrient transport systems from upstream to downstream areas. Finally, some migratory marine fish travel up river corridors to reach upstream spawning areas; sustainable recreational and commercial fisheries, both marine and riverine, require therefore that migratory corridors remain passable and healthy.

The Peconic River, the longest river on Long Island, flows west to east, serving as a partial boundary for the Towns of Brookhaven, Riverhead, and Southampton, and empties into Flanders Bay. The river is fresh for about 24 km (15 mi) of its length, while the estuarine portion is about 3.2 km (2 mi) long. Approximately 195 km^2 (75 mi^2) of land surrounding the river drain to the Peconic River basin. Average flow for the Peconic River (measured from 1942-1974) is 0.97 $m^3 s^{-1}$ (34.6 $ft^3 s^{-1}$; Newton 1981).

Most discharge into the river is the result of groundwater flow, as the Peconic River basin lies between the North and South Fork Groundwater Divides (Newton 1981). The Peconic River is the longest groundwater river in New York State (U. S. Fish and Wildlife Service 1997). The basin also serves in turn as a groundwater recharge area for the aquifers that feed groundwater supplies. The elevation of the water table in the Peconic River basin ranges from 12 m (40 ft) above sea level in Brookhaven, to 7.6 m (25 ft) above sea level at Calverton, to approximately 3 m (10 ft) above sea level in the Estuary (Newton 1981).

Peconic River waters are naturally acidic, low in nutrients, and relatively warm. The headwaters are "stained" reddish-brown, a result of tannins and iron in the water and sediments (Newton 1981; U. S. Fish and Wildlife Service 1997). This river is accurately classified using the "coastal plain stream" characterization articulated by the New York Natural Heritage Program (Reschke 1990).

The acid, nutrient-poor conditions in Peconic River waters have resulted in the formation of sphagnum bogs both streamside and in nearby ponds, despite the moving waters. These bogs support many rare, specialized plants, including the sundews (*Drosera intermedia, D. filiformis*), bladderworts (*Utricularia juncea, U. fibrosa*), and pitcher-plant (*Sarracenia purpurea*; Newton 1981; Reschke 1990). This community undergoes succession from bog to shrub swamp, and from shrub swamp to swamp forest, regulated by changes in water levels and by wildfires-- the mosaic pattern of these successional communities in the Peconic River basin demonstrates the result of these processes (Newton 1981; U. S. Fish and Wildlife Service 1997). Swamp forests such as the Coastal Plain Atlantic white cedar swamp community are rare in New York State-- Cranberry Bog County Park in the river basin in the Town of Southampton is an example of this once common community (Reschke 1990; NYS Department of State 1987). Decline of the Coastal Plain Atlantic white cedar swamp community has led to a reduction of the globally rare Hessel's hairstreak butterfly (*Mitoura hesseli*).

The Peconic River supports productive, naturally-reproducing warm water fisheries, including largemouth bass (*Micropterus salmoides*), chain pickerel (*Esox niger*), bluegill (*Lepomis macrochirus*), carp, brown bullhead (*Ictalurus nebulosus*), yellow perch (*Perca flavescens*), black crappie (*Pomoxis nigromaculatus*), white perch (*Roccus americana*), American eel (*Anguilla rostrata*), and pumpkinseed or common sunfish (*Lepomis gibbosus*). The upper Peconic provides habitat for the most significant population of banded sunfish (*Enneacanthus obesus*) in New York State, one of only two locations in the state supporting this species (NYS Department of State 1987; Newton 1981; U. S. Fish and Wildlife Service 1997). The river also provides an important migratory corridor for alewives in the spring (Newton 1981). The Peconic river is also among the few locations on Long Island to support river otter (*Lutra canadensis*; U. S. Fish and Wildlife Service 1997).

Spotted turtle (*Clemmys guttata*, SC), stinkpot or musk turtle (*Sternotherus oderatus*), and tiger salamander (*Ambystoma tigrinum*, E) are also found in the wetland and pond habitats of the Peconic River system. The Peconic River system, along with several other wetland areas in Eastern Long Island, encompasses the only remaining habitat for the endangered tiger salamander in New York State. Terrestrial animals inhabiting the area include white-tailed deer, mink, raccoon, and red fox (NYS Department of State 1987; Newton 1981; U. S. Fish and Wildlife Service 1997).

Aquatic plant species diversity in the Peconic River may become threatened by the invasion of exotics, such as parrot's-feather (*Myriophyllum brasiliens*). This invasive species has been found in the Peconic, and can be traced to the backyard aquarium trade.

River habitat is degraded by the cumulative impacts of both point and non-point source pollution. Cumulative point source pollution from individual outfalls can result in hypoxia or anoxia, domination by pollution-tolerant nuisance species, and/or eutrophication. Non-point source pollution is derived from terrestrial runoff, usually caused by changes in adjacent land use, and may also result in eutrophication or in high loadings of toxic compounds. In addition, activities that devegetate river banks, or interfere with normal flow patterns, will generally increase erosion of the bank. This will lead to siltation, which negatively impacts visually-feeding fish species and alters the physical characteristics of the downstream river basin. Also, river flow may be affected by patterns of groundwater extraction.

The Peconic River channel and water flow have been anthropogenically modified by the construction of dams, built to generate power and to form bogs for cranberry cultivation (Newton 1981; NYS Department of State 1987). As early as 1659 there was an operational water-powered saw mill on Little River (a tributary of the Peconic River), and by the 1690s there were two additional water-powered mills nearby. In the 1790s, a water-powered iron forge was built upriver of the mills, using iron nodules found in river sediments as its source material. The construction of mills continued through most of the 19^{th} century, when water power was supplanted by coal and oil-fired steam. The largest impact associated with the mills was the construction of dams for each local grouping of mills, altering the natural flow of the river and therefore impacting bank structure, natural vegetation, and the quality and quantity of native habitats (Newton 1981).

Water quality of the Peconic River has been altered through point and non-point sources of pollution. The main point sources of pollution are sewage treatment outfalls serving several communities and the Brookhaven National Laboratory (BNL), and one remaining operational duck farm within the Peconic River basin (Newton 1981; Hardy 1976; NYS Department of State 1987). The duck farming industry originated in the early 1900s on Peconic River tributaries, and were the cause of tremendous water quality problems until they became subject to Federal and State regulations in the 1950s (Newton 1981). Total phosphorus levels in the upper Peconic measure unusually high; however, no specific source has been linked to this condition (U. S. Fish and Wildlife Service 1997).

Treated effluents from the Brookhaven National Laboratory sewage treatment plant are discharged directly into the headwaters of the Peconic River. Impacts to the Peconic River ecosystem from current technology employed by the treatment plant and other BNL facilities are believed to be minimal. However, a recent study was conducted to examine the extent of contamination due to historical discharges, either accidental or resulting from technological limitations of equipment in earlier phases of facility operations (Brookhaven National Laboratory Final Operable Unit Five Remedial Investigation Report 1998). The laboratory performed ecological risk assessments based on data gathered from soil, groundwater, surface water, and sediment sampling. These assessments show that aquatic communities are most at risk from silver, copper, and mercury contamination. Sediment toxicity tests revealed that bioavailability of contaminants was low; however, benthic invertebrates may be at risk in areas of high mercury or silver concentrations. The largest potential risk to terrestrial plants is posed by chromium and silver contamination in the soils. Food chain models demonstrate that risks to target species exist as a result of mercury, PCBs, DDT, and silver, especially through consumption of contaminated fish by piscivorous consumers. Remedial action objectives have been developed by Brookhaven National Laboratory articulating the need to protect the Peconic River ecosystem, and to prevent exposure to contaminants and their bioaccumulation in aquatic species (Brookhaven National Laboratory Final Operable Unit Five Remedial Investigation Report 1998).

Much land located within the Peconic River watershed is State or county parkland. The Brookhaven National Laboratory and the U. S. Navy own large parcels of land surrounding the headwaters area of the river. However, development continues to threaten Peconic River habitat, as much of the additional lands adjacent to the river have been zoned for industrial and residential use (Newton 1981).

Alewife Creek is a small, free-flowing freshwater tributary draining Big Fresh Pond into North Sea Harbor, in the Town of Southampton, Long Island. The creek becomes brackish and tidal below Noyack Road. Alewife Creek is a significant alewife fish run (NYS Department of State 1987).

Many of the other streams draining to the Peconic Estuary are small and support important freshwater wetlands. Therefore, their habitat will be described below in the wetland section of this report.

Freshwater wetlands, Tidal Creeks, Coastal Plain Ponds, and Interdunal Swales

A number of freshwater wetland habitat areas occur in the Peconic Estuary Program region. The Peconic River basin exhibits the best examples in New York of the coastal plain Atlantic white cedar swamp community. The Cranberry Bog County Park cedar swamp is the largest on Long Island; there is another benchmark example of this habitat type at Owl Pond in the Flanders Bay drainage area (U. S. Fish and Wildlife Service 1997).

Also at the Cranberry Bog County Park site is an example of the coastal plain poor fen community, one of only two in the Long Island Pine Barrens. This site occurs in association with Sweezy Pond (U. S. Fish and Wildlife Service 1997), and is considered rare statewide (Reschke 1990). The poor fen habitat is a weakly acidic, minerotrophic peatland occurring on the coastal plain, dominated by *Sphagnum* species, with scattered sedges (*Carex* spp.); shrubs (e.g. sweet pepperbush--*Clethra alnifolia*, water willow--*Decodon verticillatus*, sweet gale--*Myrica gale*); and stunted trees (e.g. Atlantic white cedar--*Chamaecyparis thyoides*, red maple--*Acer rubrum*; Reschke 1990; LISS unpublished).

Freshwater wetland communities occur throughout the Flanders Bay marsh complex. Four freshwater tributaries flow through this complex: Goose Creek, Birch Creek, Mill Creek, and Hubbard Creek. The brackish and freshwater marshes in this area support Eastern mud turtle (*Kinosternon s. subrubrum*), spotted turtles, and Eastern hog-nosed snake (*Heterodon platyrhinos*; NYS Department of State 1987; U. S. Fish and Wildlife Service 1997).

Freshwater wetlands include the transition zone between non-tidal aquatic habitats and adjacent terrestrial communities, as well as isolated palustrine systems. In these areas the water table is at, or near, the surface of the soil for much of the year; alternatively, water may be trapped above the water table by clay layers in the soil. Freshwater wetlands may be dominated by trees, such as red maple; shrubs, such as swamp azalea (*Rhododendron viscosum*); or cattail (*Typha* spp.) and bulrush (*Scirpus* spp.). Non-tidal freshwater wetlands should be distinguished from tidal wetlands, some of which may also be fresh.

Alewife and Scoy Pond wetlands represent a complex of wetland and stream habitats, and is located between Northwest Harbor and Three Mile Harbor in the Town of East Hampton.

Scoy Pond is a freshwater habitat, connected to Alewife Pond by way of a small stream. Alewife Pond, a brackish environment, is connected to Northwest Harbor by a tidal creek. This stream and pond complex serves as an alewife migration and spawning habitat. In addition to alewife, this area supports chain pickerel and other freshwater fisheries, and supports large concentrations of spotted salamander (*Ambystoma maculatum*, SC), marbled salamander, and bull, wood (*Rana sylvatica*), green, southern leopard (*Rana utricularia*, SC), and gray tree frogs. Snapping, painted, and spotted turtle are also found in the Alewife and Scoy Pond Wetlands. Bird species using the area include northern harrier (*Circus cyaneus*, T), acadian flycatcher (*Empidonax virescens*), black duck, mallard, Canada goose (*Branta candensis*), and mute swan (*Cygnus olor*; NYS Department of State 1987).

Big and Little Reed Ponds encompass a large freshwater habitat of Big Fresh Pond, the brackish pond and marsh habitat of Little Reed Pond, and a small stream flowing from Big Reed Pond into Little Reed Pond. In addition to alewife spawning habitat, these ponds and associated streams provide habitat for other significant wetland species including the blue-spotted salamander (*Ambystoma laterale*, SC). Bird species breeding in the area include northern harrier (*Circus cyaneus*, T), red-shouldered hawk (*Buteo lineatus*, T), least bittern (*Ixobrychus exilis*, SC), Canada goose (*Branta canadensis*), mallard, redhead (*Aythya americana*), black duck, and blue-winged teal (*Anas discors*; NYS Department of State 1987).

Freshwater stream and wetland habitat also exists in the Culloden Point area in the Town of East Hampton. The unusual knob and kettle terrain and stream system support a large population of blue-spotted salamander (*Ambystoma laterale*, SC), as well as eastern newt. There is little documentation of usage by other wetland or stream species (NYS Department of State 1987).

Freshwater wetlands may be found in conjunction with the coastal plain pond community, a somewhat rare natural community in New York State. These groundwater-fed ponds occur in kettle holes and shallow depressions, and may contain abundant aquatic vegetation. These ponds are habitat for chain pickerel, and banded sunfish, a New York State species of concern; as well as breeding area for the tiger salamander, a New York State endangered species. Coastal plain ponds in Pine Barrens areas are often associated with shrub-dominated wetlands, with a moss ground layer.

These wetlands usually exhibit high species diversity, due to habitat heterogeneity and the presence of abundant live vegetation and detrital organic matter. They aid in ground water recharge and the storage of flood waters, and provide critical habitat for many rare plant and animal species. Because they trap and recycle nutrients, and absorb heavy metals, toxins, and other compounds, these habitats are very important in maintaining and enhancing estuarine water quality. Wetlands may also seasonally release a substantial quantity of nutrients and organic matter to adjacent areas.

There are several complexes of coastal plain ponds in the Peconics region. The Long Pond Greenbelt area has been identified by the Department of State, the U. S. Fish and Wildlife Service, the NYS Natural Heritage Program, The Nature Conservancy, Suffolk County, and the

Town of Southampton as a significant habitat area containing rare coastal plain pond communities (U. S. Fish and Wildlife Service 1997; NYS Department of State 1987). This complex includes a series of ponds in the region between Bridgehampton north to Sag Harbor.

This habitat type is comprised of small ponds occurring in shallow depressions in the glacial moraine and outwash plain. They are fed by groundwater, and water levels fluctuate seasonally or annually with the height of the water table; these fluctuations are critical to the maintenance of plant communities in this regionally rare habitat (U. S. Fish and Wildlife Service 1997; Town of East Hampton undated; LISS unpublished). High water levels are periodically necessary to extinguish the seedlings of invading upland woody plants, while low water periods are required for the germination and growth of coastal plain pond plant species. Distinctive plant zonation occurs in the coastal plain pondshore community based on elevation, soil moisture, and duration of flooding (U. S. Fish and Wildlife Service 1997). These water fluctuations also prevent or diminish the presence of predatory fish in these ponds, a factor which is very important to species like the blue-spotted salamander (*Ambystoma laterale*), a protected species in New York (Town of East Hampton undated).

The Long Pond Greenbelt ponds are surrounded by coastal oak-hickory forest, dominated by scarlet, white, black, chestnut, and red oaks (*Quercus* spp.), with a blueberry (*Vaccinium* spp.) and black huckleberry understory. The transition zone between forest and the coastal plain pondshore consists of wetland shrub thicket, similar to a pine barrens shrub swamp. The coastal plain pondshore is comprised of concentric rings of vegetation, from upper (dryer) to lower (wetter) elevations, including a seasonally-flooded herbaceous fringe, a semi-permanently flooded sandy pond bottom with annual species, and an intermittently exposed organic pond bottom zone. The pondshore community varies from year to year, but generally supports sedge, grass, and flowering herb species, such as Walter's sedge (*Carex walteriana*), tall beaked-rush (*Rhynchospora macrostachya*), panic grasses (*Panicum* spp.), bladderworts, and gratiola (*Gratiola aurea*). The ponds themselves exhibit such species as water shield (*Brasenia schreberi*), white water lily (*Nymphaea odorata*), bayonet-rush (*Juncus miltaris*), naiad (*Najas flexilis*), waterweed (*Elodea* spp.), and pondweed (*Potamogeton oakesianus*) (U. S. Fish and Wildlife Service 1997; LISS unpublished).

These ponds support many regionally rare species, including the state-listed endangered tiger salamander, drowned beaked-rush (*Rhynchospora inundata*), water-pennywort (*Hydrocotyle verticillata*), white boneset (*Eupatorium leucolepis leucolepis*), and pygmyweed (*Tillaea aquatica*). State-listed threatened and special concern animals, including the osprey (*Pandion haliaetus*), spotted salamander (*Ambystoma maculatum*), and spotted turtle, are also found here (U. S. Fish and Wildlife Service 1997).

Another region encompassing coastal plain pond complexes is the Peconic River headwaters area. Several of these complexes are recognized as priority areas and/or managed as conservation areas by The Nature Conservancy, Suffolk County, and the NYS Department of State. There are approximately one dozen coastal plain ponds in the headwaters system; the Calverton Ponds system occurs downstream of the headwaters, the Lake Panamoka/Tarkill Pond complex occurs just north of the headwaters, and, finally, the Sears-Bellows Ponds area in

Hampton Bays to the east contains a complex of coastal plain ponds. These complexes also exhibit the distinct coastal plain pondshore zonation that results largely from fluctuating water levels. The zones extend from the upper elevation pine barrens, to shrub swamp, to emergent marsh, and finally to coastal plain pond waters. Several of the ponds in this region contain islands, which are dominated by Atlantic white cedar (U. S. Fish and Wildlife Service 1997).

Many globally rare plant species are found in the headwaters ponds complex, including dwarf bulrush (*Lipocarpha micrantha*), reticulated nutrush (*Scleria reticularis reticularis*), slender blue flag (*Iris prismatica*), Carey's smartweed (*Polygonum careyi*), and others. These ponds also support rare insect species such as lateral bluet damselfly (*Enallagma laterale*), painted bluet damselfly (*Enallagma pictum*), barrens bluet damselfly (*Enallagma recurvatum*), round-necked damselfly (*Nehalennia intergricollis*), violet dart (*Euxoa violaris*), pink sallow (*Psectraglaea carnosa*). The Sears-Bellows area supports Hessel's hairstreak, a regionally rare butterfly. Many amphibians also use these coastal plain ponds, including the spotted salamander (*Ambystoma maculatum*), common red-backed salamander (*Plethodon cinereus*), wood frog (*Rana sylvatica*), northern spring peeper (*Pseudacris crucifer crucifer*), and eastern spadefoot toad (*Scaphiopus holbrooki holbrooki*). Regionally rare species like spotted turtle and eastern hognose snake (*Heterodon platyrhinos*) are also found here (U. S. Fish and Wildlife Service 1997).

Near the seacoast, in locations such as the Napeague Dunes and Atlantic Double Dunes, there are occurrences of the maritime interdunal swales community. This wetland type is formed when areas among the dunes are sufficiently low to be level with the groundwater table. Similar to coastal plain pond communities, the water levels of the interdunal swales community fluctuate seasonally and annually. Soils in this community are composed of sand or peaty sand, which support primarily sedges and herbs. Plant species composition generally varies between different locations of this community, and diversity is generally low. Characteristic plants found in the interdunal swales include twig-rush (*Cladium mariscoides*), cyperus (*Cyperus* spp.), marsh rush (*Juncus canadensis*), sundew (*Drosera* spp.), and cranberry (*Vaccinium macrocarpon*; Reschke, 1990).

A historic impact to freshwater wetlands has been filling or draining for building construction (Town of East Hampton undated; LISS unpublished). Both of these categories of activity result generally in a decrease in the area's overall quantity of water. Intentional draining for construction purposes has been accomplished by digging channels through the wetland. Draining also can occur unintentionally as a result of excessive groundwater extraction. Diversion of surface waters supplying wetlands may also contribute to or cause a similar impact. Diversion of wetland supply waters might also result from crop irrigation. Filling for construction is accomplished using additional off-site soils, often from dredging operations. Wetlands have also been subject to use as landfill sites, and have been filled with garbage. Unintentional filling also may occur, generally as a result of siltation from runoff from disturbed upland areas or from re-direction of storm water runoff into wetland areas (LISS unpublished).

Wetlands may also be lost when they become flooded. Impoundments and dams have historically been built on Long Island to power mills, forges, and hydroelectric plants. These types of structures result in the formation of permanently flooded areas, causing a shift in the type of vegetative communities present. This is more generally true of riverine wetlands, but is applicable to palustrine and other wetland communities as well (LISS unpublished).

An additional impact to the integrity of freshwater wetland habitat is the invasion of nuisance species such as common reed (*Phragmites australis*). Both species tend to form dense, monotypic stands after invasion, thereby reducing species diversity and reducing the availability of critical nesting habitat for certain species (LISS unpublished).

A primary historical impact to wetlands and coastal plain ponds has been filling, resulting in an altered hydrologic regime, or total loss of habitat. Activities causing changes in wetland hydrology, including excessive groundwater withdrawal, in turn affect nutrient cycling and species composition in the plant community. Changes in aerobic/anaerobic conditions in wetland soils will also impact nutrient and metals cycling, and breakdown and retention of organic matter. In addition, high contaminant loading will exceed wetland absorptive capacity, causing degradation and leaching into adjacent waters.

Impacts occurring to freshwater wetlands in the watershed of the Peconic Estuary have occurred for over a century in response to the cultivation of cranberries. Cranberry cultivation was established in the Peconic River basin as early as 1870. It had a tremendous impact on the geomorphology and hydrology of the river and freshwater wetlands. Cranberry bogs were dredged out of natural wetlands and filled with upland sand in which the cranberry plants grew. Constructed channels were relied upon to control water flow during the seasonal flooding cycle. Cranberry cultivation, therefore, both altered natural flow patterns (with associated indirect impacts to vegetation and fauna), and resulted in the direct loss of natural wetland vegetation and habitat. This industry was operational as late as 1974, when the last bog ceased production (Newton 1981).

The most significant impact possible in the coastal plain pond habitat is the disruption of hydrologic regime. Specifically, excessive groundwater drawdown, resulting in a permanently lowered water table, can cause invasion by upland woody species. Conversely, permanent flooding will prevent the growth of pondshore species. Maintaining contiguous, adjacent wetland and forest habitat is important for many mobile species and for species spending portions of their life cycle in different habitats. Nutrient enrichment and other water quality issues may result in the competitive exclusion of rare, native pondshore species by nutrient- or pollution-tolerant nuisance species. Unofficial stocking of these ponds by local, recreational fishermen with non-native species also often results in competitive displacement of native fish and amphibian species. In addition, native plant species such as spikerushes are especially vulnerable to high concentrations of swans and geese feeding in the coastal plain pond habitat (U. S. Fish and Wildlife Service 1997).

CUMULATIVE & ESTUARY-WIDE THREATS

Estuaries throughout the world have been altered by humans. The addition of nutrients, toxic contaminants, and other pollution from point and nonpoint sources, draining wetlands, building along the coast and in the watershed, shoreline hardening, boating, and fish and shellfish harvesting, are only a few activities that have played a role separately and together in modifying the "natural" state of estuaries. As population increases along the coast, these impacts and their cumulative effects will also likely increase (Steele 1998).

Cumulative impacts to any waterbody from incremental development are difficult to assess; nevertheless, they are extremely important to understand. In some instances, multiple, small-scale, unrelated land development changes that appear to have little effect individually can have greater effects on natural systems than larger-scale projects. These impacts may decrease water quality, result in habitat loss or fragment wildlife habitat, requiring disturbance of more land for access roads, and potentially contributing to greater erosion. Indirect and secondary impacts are important but not often considered by decision makers who tend to focus on direct effects (Marine Law Institute 1994). For example, a direct impact of dredging may be removal or burial of benthic organisms. A secondary impact may be increased boat use leading to long-term decreases in water quality due to releases of oil, sewage, and debris (Marine Law Institute 1994).

In the Peconic Estuary, urbanization of the watershed has been occurring incrementally, but steadily. An average of approximately 550 ac per year are being converted from agriculture and open space to developed uses -- mostly to residential homes (Suffolk County Department of Planning 1998). Over the past 19 years, approximately 10,500 ac have been converted from agriculture and open space to developed uses (Suffolk County Department of Planning 1998). These calculations, however, underestimate the gross amount of development occurring because they do not take into consideration the intensification of the same use or conversion from one developed use to another (Suffolk County Department of Planning 1998). It is likely that vacant and agriculture land will continue to be developed at this incremental level until potentially all of the estimated 52,000 ac of available land is developed. With these incremental changes comes the potential for additional, cumulative environmental impacts on the living resources of the Peconic Estuary. For example, the U. S. Fish and Wildlife Service found that from 1972 to 1994, a total of 287 new docks were constructed in the Peconic watershed. During this same time, 61 docks were removed, resulting in a net increase of 226 docks (Tiner *et al.* 1998).

To understand the significance of cumulative impacts on the living resources of the Peconic Estuary, there must first be an understanding of associations among organisms that live in the Estuary. A change in the abundance of one type of organism can potentially impact other types of organisms. Human impacts that are thought to only affect one or a few species in a single habitat actually can influence a wide variety of organisms in all the habitats of the Peconic bays. For example, harvesting or removal of commercially and recreationally important fish may shift distribution and abundance of both their prey and predators. The physical removal of these fishes combined with natural fluctuations effect other trophic levels throughout the Estuary. In fact, accumulation of localized or small impacts on fisheries results in impacts to regional and global fisheries (Burns 1991).

Estuary-wide impacts of all kinds can potentially result from the accumulation of localized changes to the system. The effects of chemical pollution, eutrophication, brown tide, and physical changes can reverberate throughout the Peconic ecosystem. Chemical pollution occurs when excessive amounts of natural elements or compounds or small amounts of toxic, anthropogenic contaminants are released to the system. Toxic contaminants can directly affect the health and reproduction of fish, shellfish, and wildlife. The degree to which toxic contaminants stress living resources in the Estuary is a function of the combined exposure to all contaminants from all sources and the interactions of these contaminants with environmental factors such as temperature, salinity, turbidity, level of organic matter in the water column, etc. (Hartwell and Jordan 1991). In some instances, effects of toxic contaminants are only sublethal, affecting fecundity or growth, while in other instances exposure results in mortality. Sensitivity of different organisms and the same organism at different developmental stages also plays a role in toxicity. For example, fish eggs and larvae are more sensitive to toxic contaminants than adult fish (Hartwell and Jordan 1991).

Nutrient pollution (i.e., excess nitrogen and phosphorus resulting in eutrophication) from sewage discharges, duck farms, agriculture, septic systems, ground water, and stormwater have all played a role in affecting water quality and leading to the loss of important habitat in the Peconic bays. However, 11 years of water quality monitoring data collected by Suffolk County indicates that except for the extreme western portion of the Estuary (e.g. Meetinghouse Creek, Peconic River) and some other localized areas (e.g. East Creek in Jamesport, Fish Cove in Southampton, Flanders Bay), overall the Estuary currently has good water quality (Nuzzi and Waters 1998).

Other impairments to the Peconic Estuary include brown tide; however, it is unknown whether its onset, duration, and cessation are naturally occurring or related to development and use of fertilizers in the watershed (LaRoche *et al.* 1997). There have also been physical changes to the system as a result of commercial and recreational boating, harvesting techniques, shoreline hardening, dredging, and other activities. Unfortunately stresses on the Peconic Estuary ecosystem from many of these activities have not been fully quantified and analyzed to understand their cumulative impacts. However, research on the affect of these activities on other waterbodies can provide some insight to their possible effect in the Peconics. For example, Garrad and Hey (1987) concluded that large numbers of boats plying rivers in England resulted in increased levels of turbidity resulting from the stirring up of bottom sediments. Mele (1993) estimates that in the U. S., outboard motors emit on average 798 kg (1,760) lbs of hydrocarbons for every 3,800 liters (1,000 gal) of fuel consumed. Approximately 35 to 40% of the hydrocarbons remain in the water.

A number of coastal managers and scientists are now recognizing that changes affecting the health of the Peconic Estuary have broad spatial and temporal dimensions and are the end result of numerous actions and choices which may alone have had relatively minor impacts (Vestal and Rieser 1995). Given that incremental changes to the Estuary and in the watershed can affect the entire Estuary, it is important to view and understand the Peconic Estuary as a holistic system. Scientific understanding of the system is critical and is currently a constraint given the paucity of information on many aspects of the Peconic ecosystem. To accurately understand cause and effect relationships, more scientific inquiry and monitoring of the Peconic Estuary and its watershed is needed. A long-term perspective including, if possible, pre-disturbance state and trend analyses of biological changes as a result of use and development is needed to support a cumulative impact assessment (Vestal and Rieser 1995). According to Vestal and Rieser (1995), if scientists and managers develop assessment tools and management techniques capable of identifying and controlling cumulative effects, they cannot succeed on their own without the support and understanding of the general public. The community living and working in the Peconic Estuary watershed must concur that the resources of the Estuary are important, a need for balancing wise use and protection is essential, incremental change can pose a problem, and ecosystem-wide management is necessary to address cumulative and potentially irreversible impacts to the Estuary.

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Table 1. Top species of finfish taken in the Peconic estuary ranked in order of total amount landed by weight.

	1950s	1960s	1970s	1980s	1990s (through 1992)
1	Scup	Scup	Scup	Scup	Menhaden
2	Swellfishes	Swellfishes	Menhaden	Squid (loligo)	Bluefish
3	Menhaden	Winter Flounder	Weakfish	Bluefish	Squid (loligo)
4	Winter Flounder	Menhaden	Bluefish	Menhaden	Lobster
5	Butterfish	Butterfish	Striped Bass	Weakfish	Scup

Source: Weber and Grahn 1995

Table 2. Size at which sea turtles migrate to inshore waters.

Sea Turtle Species	Size (cm)
Kemp's ridley	20 - 30
Green	20 - 30
Loggerhead	40 - 50

Source: Morreale and Standora 1993

Table 3. Crabs collected in annual trawl survey by NYSDEC. Data on spider crabs began in 1992.

Year	Lady Crab	Spider Crab	Blue Claw
		Total catch (cpue)*	
1987	5,575 (16)	nr**	49 (0.1)
1988	7,967 (19)	nr	12 (0.03)
1989	58,358 (139)	nr	23 (0.1)
1990	91,365 (212)	nr	343 (0.8)
1991	139,120 (350)	nr	251 (0.6)
1992	240,369 (585)	2,681 (6)	186 (0.5)
1993	141,100 (341)	2,145 (5)	56 (0.1)
1994	100,449 (235)	2,923 (7)	72 (0.2)
1995	112,271 (299)	1,605 (4)	60 (0.2)

* cpue means catch per unit effort
** nr means not recorded

Source: Weber *et al.* 1998

Table 4. Diamondback terrapin occurrences in the Peconic Estuary.

Occurrence	Town	Area (ha)	Number of Individuals	Population Estimate
Cedar Beach Creek network	Southold	10	164	341
Hubbard Creek complex	Southampton	176	70	> 70
Scallop Pond complex	Southampton	330	71	> 146
Sag Harbor complex	Southampton	300	48	> 48

Source: Morreale 1992.

Table 5. Peconic Estuary dynamic sites requiring regular yearly maintenance.

Locations	
East Creek, Riverhead	Miamogue Lagoon, Riverhead
Hawks Creek, Riverhead	Wooley Pond, Southampton
Red Creek, Southampton	Fresh Pond, Southampton
North Sea Harbor, Southampton	Little Creek, Southold
Cedar Beach, Southold	Brushes Creek, Southold
Wickhams Creek, Southold	Deep Hole Creek, Southold
New Suffolk Boat Ramp	

Total Area of Maintenance Dredging

Location	Number of Sites*	m^3 (yd^3)**
Riverhead	5	
Southampton	27	
East Hampton	7	
Southold	17	
Shelter Island	6	
Total	62	57,375 (75,000)

* Approximately 20 of these sites are dredged annually.

** The volume of dredging per location varies each year; however, no more than a total of 57,375 m^3 (75,000 yd^3) are dredged annually in the Peconic Estuary.

(Source: Suffolk County Department of Public Works)

Table 6. Submerged aquatic vegetation identified during field sampling in the Peconic Estuary by Cashin Associates (1996).

Seagrasses (Spermatophyta)	
Eelgrass	*Zostera marina*
Widgeon grass	*Ruppia maritima*
Red Algae (Rhodophyta)	
Lacy Redweed	*Euthora cristata*
Brushy Redweed	*Cystoclonium purpureum*
Tubed Weeds	*Polysiphonia* spp.
Banded Weeds	*Ceramium* spp.
Irish Moss	*Chondrus crispus*
	Lomentaria baileyana
Chenille Seaweed	*Dasya pedicellata*
Pod Weed	*Chondria* spp.
	Agardhiella sublata
	Antithamnion spp.
Grinnell's Pink Leaf	*Grinnellia americana*
Sea Oak	*Phycodrys rubens*
	Gracilaria tikvahiae
	Spermothamnion spp.
Barrel Weed	*Champia parvula*
Wire Weed	*Ahnfeltia plicata*
Green Algae (Chlorophyta)	
Green Fleece	*Codium fragile*
Sea Lettuce	*Ulva lactuca*
Hollow Green Weeds	*Enteromorpha* spp.
	Chaetomorpha spp.
Brown Algae (Phaeophyta)	
Rockweed	*Fucus* spp.
Knotted Wrack	*Ascophyllum nodosum*
Gulfweed	*Sargassum filipendula*
Broad-leaf Kelp	*Laminaria saccharina*
Smooth Cord Weed	*Chorda filum*
	Stilophora rhizodes
Slippery Tangle Weed	*Sphaerotrichia divaricata*
	Acrothrix novae-angliae

Table 7. Percent organic matter (by weight) of SAV substrate monitored by Cornell Cooperative Extension (Dumais and Smith 1997).

Percent Organic Matter		
Orient Harbor	Bullhead Bay	Northwest Harbor
1.12	2.07	0.63
1.13	8.21	0.76
1.28	8.95	0.72
Nd	6.09	nd

nd means no data

Table 8. Eelgrass shoot density of eelgrass monitored by Cornell Cooperative Extension (Dumais and Smith 1997).

Eelgrass Shoot Density Shoots per 0.25 m^2 quadrat (reproductive shoots)		
Orient Harbor	Bullhead Bay	Northwest Harbor
141 (2)	316 (6)	41 (0)*
174 (6)	164 (25)	55 (0)*
115 (6)	144 (20)	61 (0)*
	86 (12)	

* No reproductive shoots are likely due to time of sampling.

Table 9. Wetland coverage in the Peconic Estuary based on analysis of 1994 aerial photographs by the U. S. Fish and Wildlife Service.

	Estuarine Wetlands
Emergent (Salt Marsh)	1436 ha (3591 ac)
Emergent - *Phragmites*	125 ha (313 ac)
Scrub-Shrub (Salt Shrub Swamp)	73 ha (183 ac)
Forested (Dead)	< 1 ha (< 1 ac)
Streambed	< 1 ha (< 1 ac)
Tidal Flat/Beach	636 ha (1590 ac)
Total Estuarine Wetland	2271 ha (5679 ac)

Source: Tiner *et al.* 1998

Table 10. Selected species of shorebird using the Peconics from 1994 to 1996. Active sites means sites used within the last 5 years (all sites are not used every year).

		Number of nesting pairs			
Shorebird	Number of active sites	1994	1995	1996	Approximate percent of total on Long Island
Piping plover†	51	62	72	86	29 - 33
Roseate tern*	7	1647	1679	1668	90 - 92
Least tern☆	42	662	617	628	17 - 26
Common tern⁎	18	7885	8266	9088	44 - 48
Black skimmer✦	6	20	26	15	< 1

† 1994 to 1996 showed a 30% increase in pairs. Largest sites are Orient, Shell Beach, and Cedar Point.

* Great Gull Island accounts for ~ 99% of roseate terns in and around the Peconic Estuary.

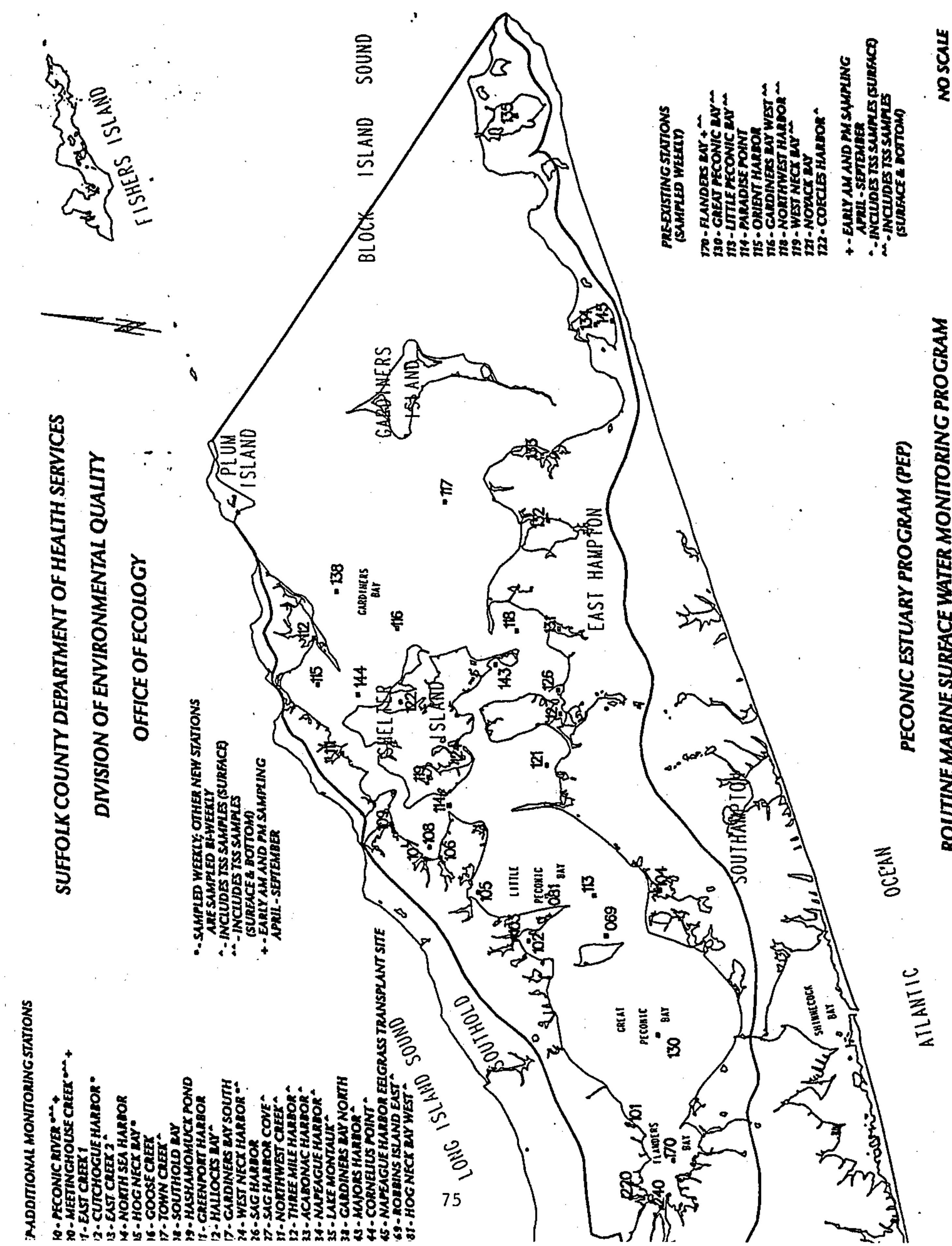
☆ Cartwright Island, Cedar Beach, Orient, Jamesport, and Port of Egypt have the largest colonies in 1994 to 1996.

⁎ Great Gull Island accounts for 98% of the common terns in and around the Peconic Estuary.

✦ Black skimmers were not recorded on Long Island before the 1930s. Their major nesting sites are along the Long Island south shore.

Source: Sommers and Alfieri 1997

Figure 1. Map of the Peconic Estuary.



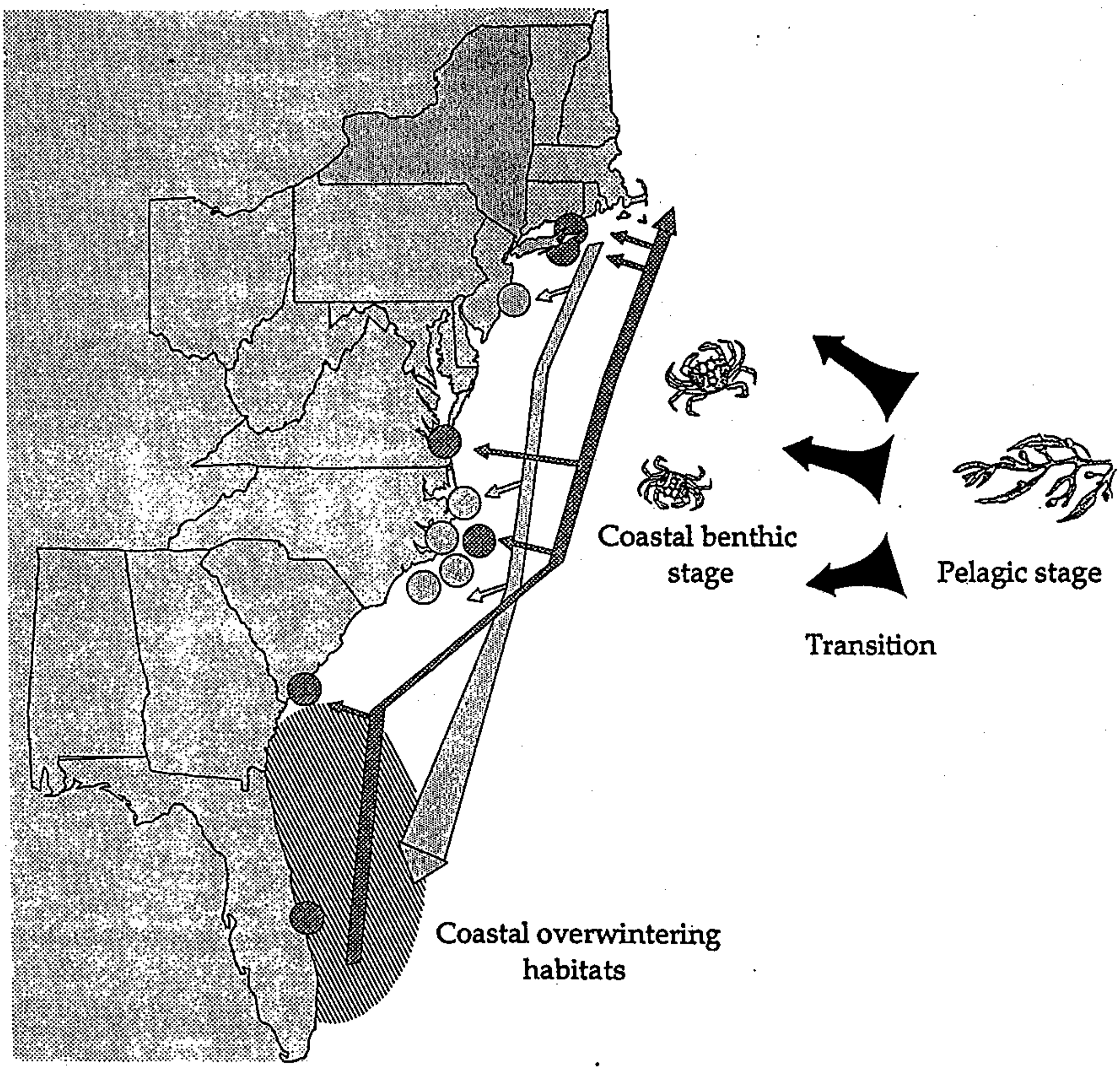


Fig. 2 . Hypothesized transition between early life stages and a generalized scheme of subsequent migration patterns of juvenile sea turtles along the coastal U.S. Stippled circles represent within-season recovery locations of turtles tagged in New York; arrow represents their probable emigration route based on satellite telemetry data. Cross-hatched symbols represent recoveries in a subsequent season and probable paths of migration northward from overwintering sites.

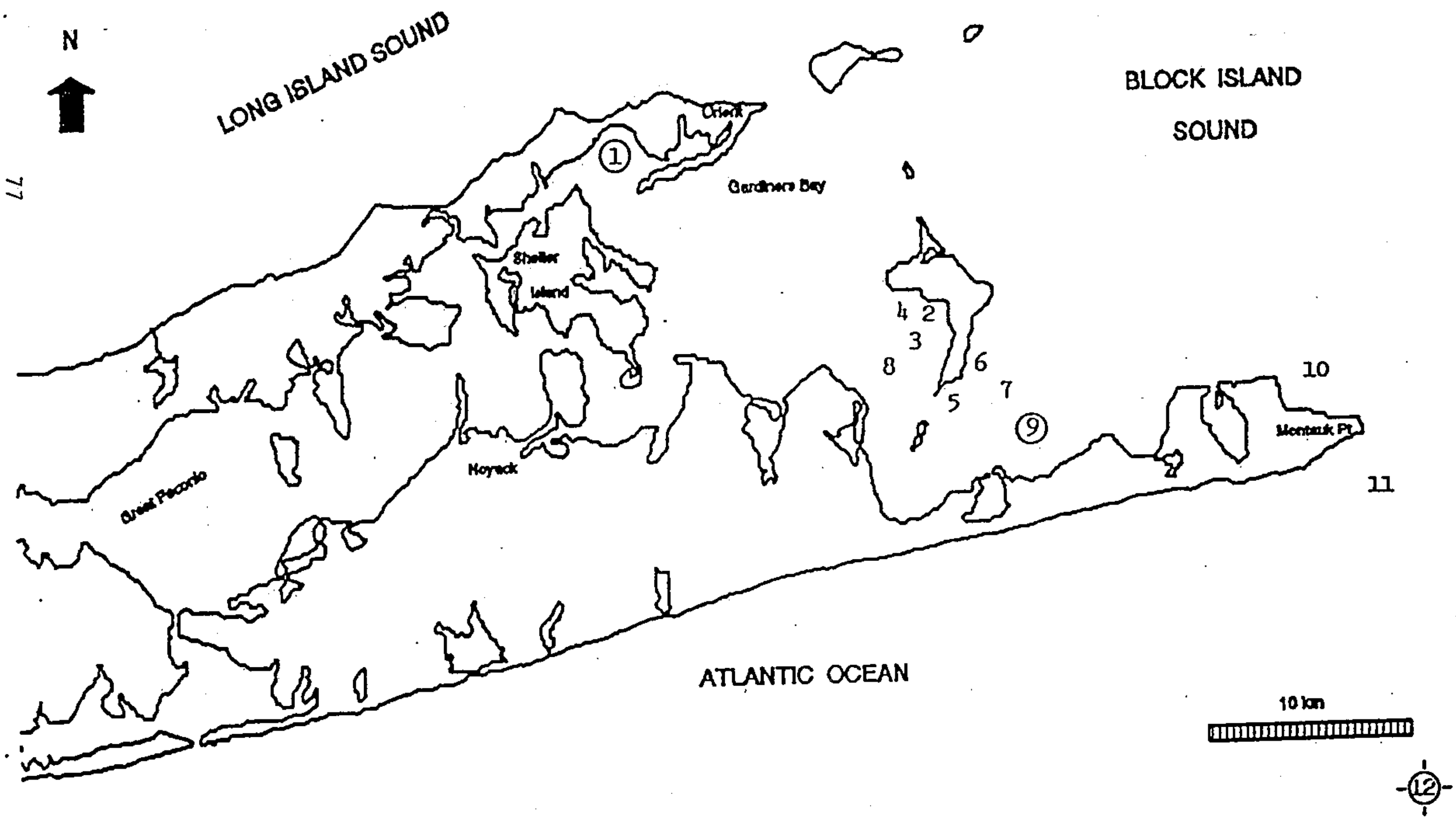
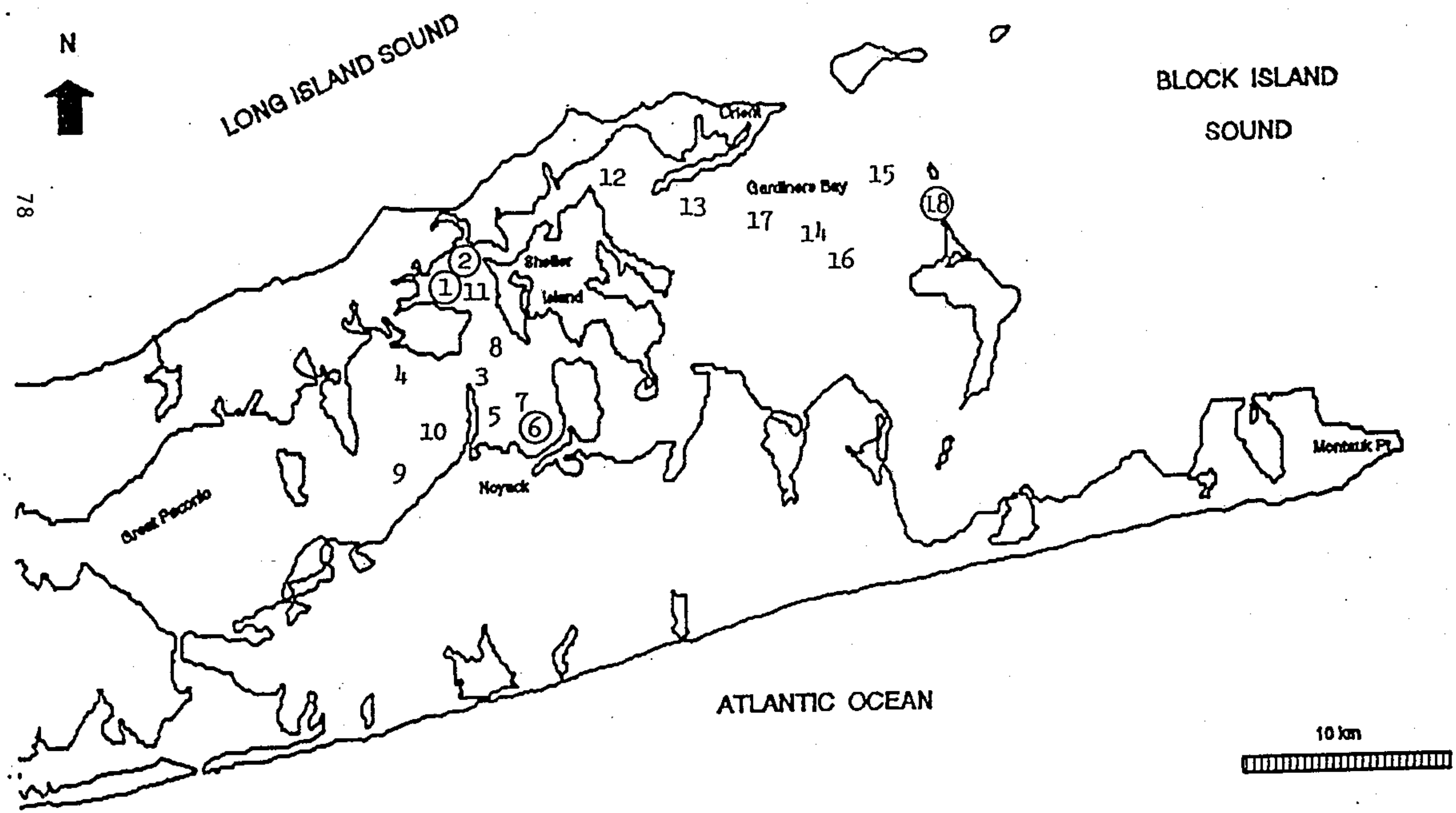


Fig.3 . Movements of a Kemp's ridley, PPY039, in New York waters based upon data from radio and sonic telemetry over a period of 17 days. 1=release 8 Oct. 1989. 9=recapture. 23 Oct. 12=last recapture 23 km south of Montauk Pt. 25 Oct.

Fig. 4 Movements of a Kemp's ridley, PPY021, in New York waters based upon data from radio and sonic telemetry over a period of 27 days. 1=release 10 Sept. 1989. 2=recapture 14 Sept. 6=recapture 25 Sept. 18=last contact 7 Oct.



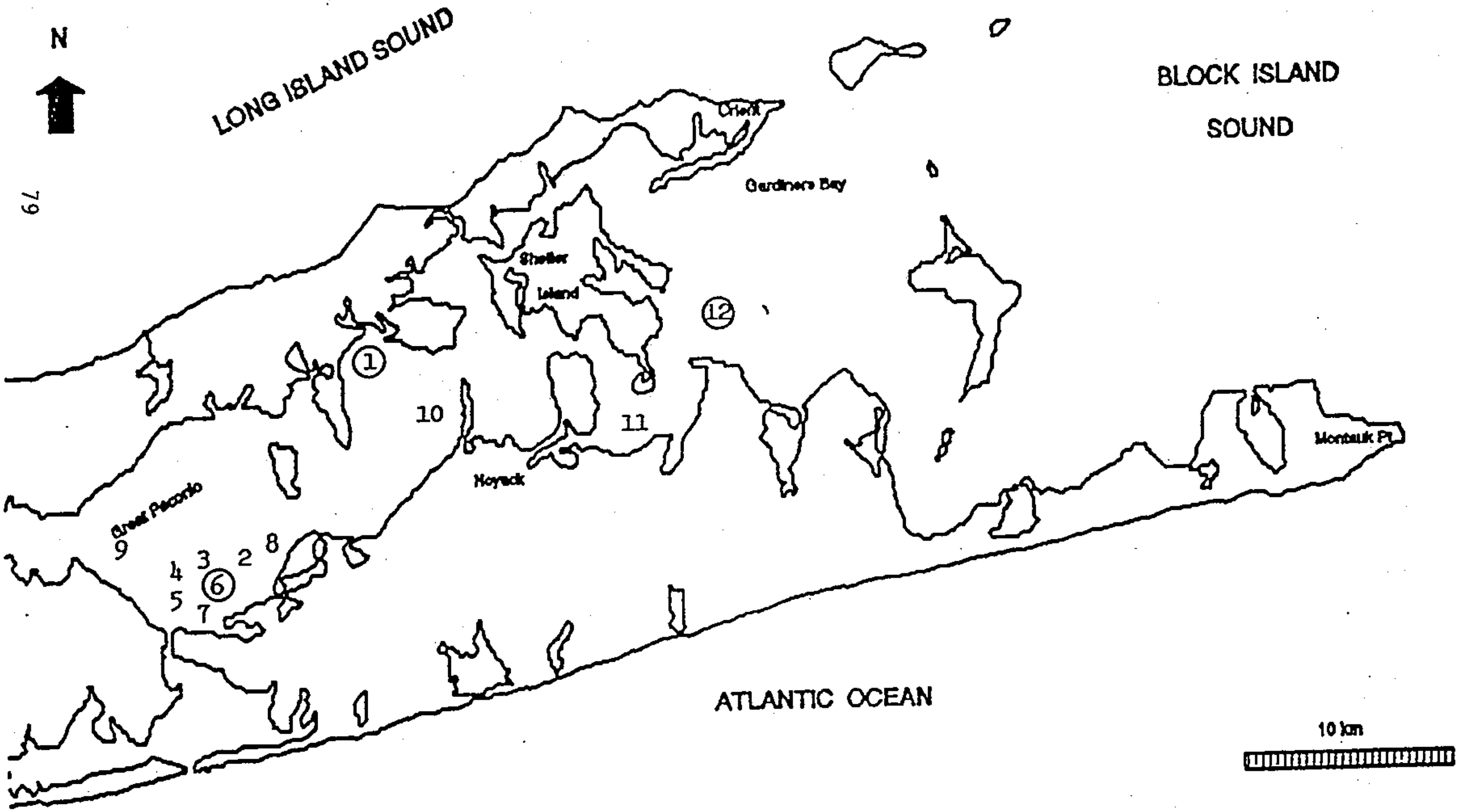


Fig.5 . Movements of a Kemp's ridley, PPY010, in New York waters based upon data from radio and sonic telemetry over a period of 45 days. 1=release 16 Aug. 1989. 6=recapture 3 Sept. 12=last contact 30 Sept.

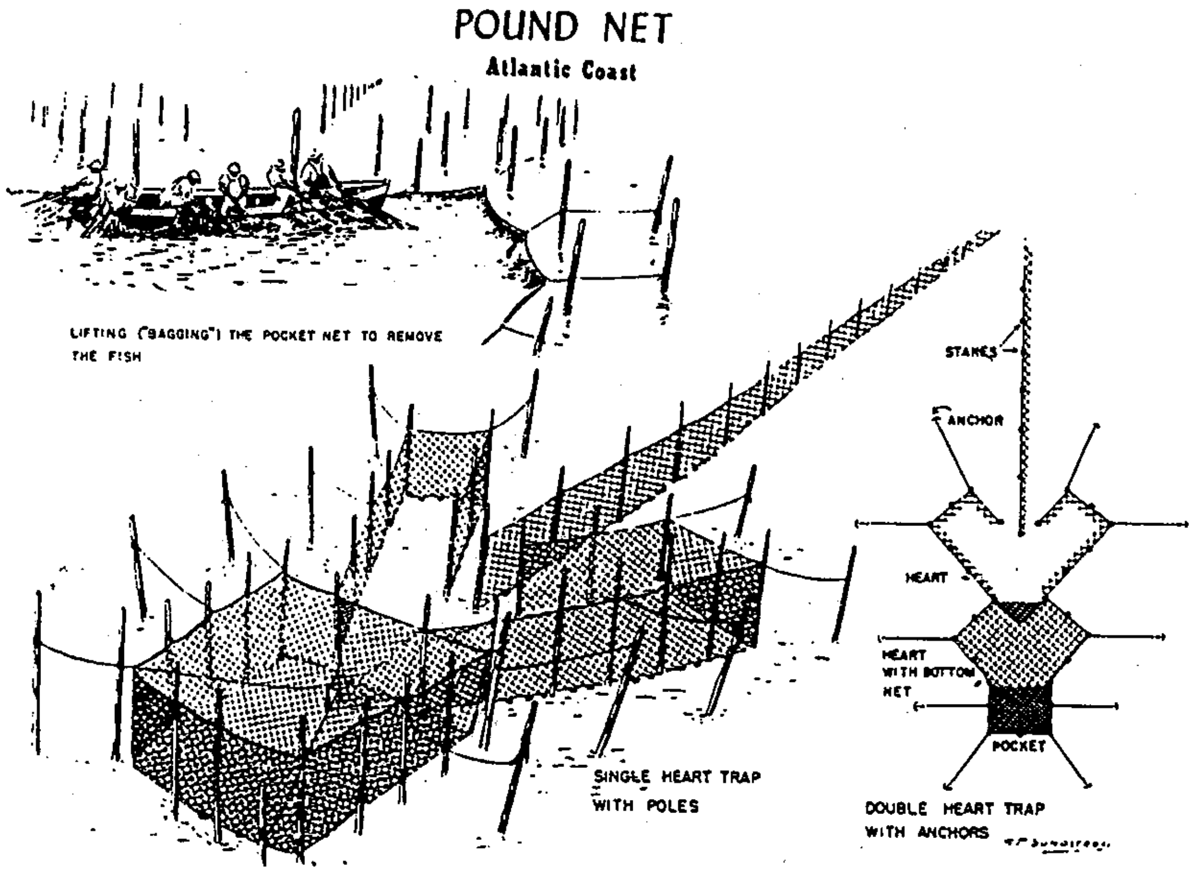


Figure 6. Schematic of pound nets found in the Peconic Estuary.

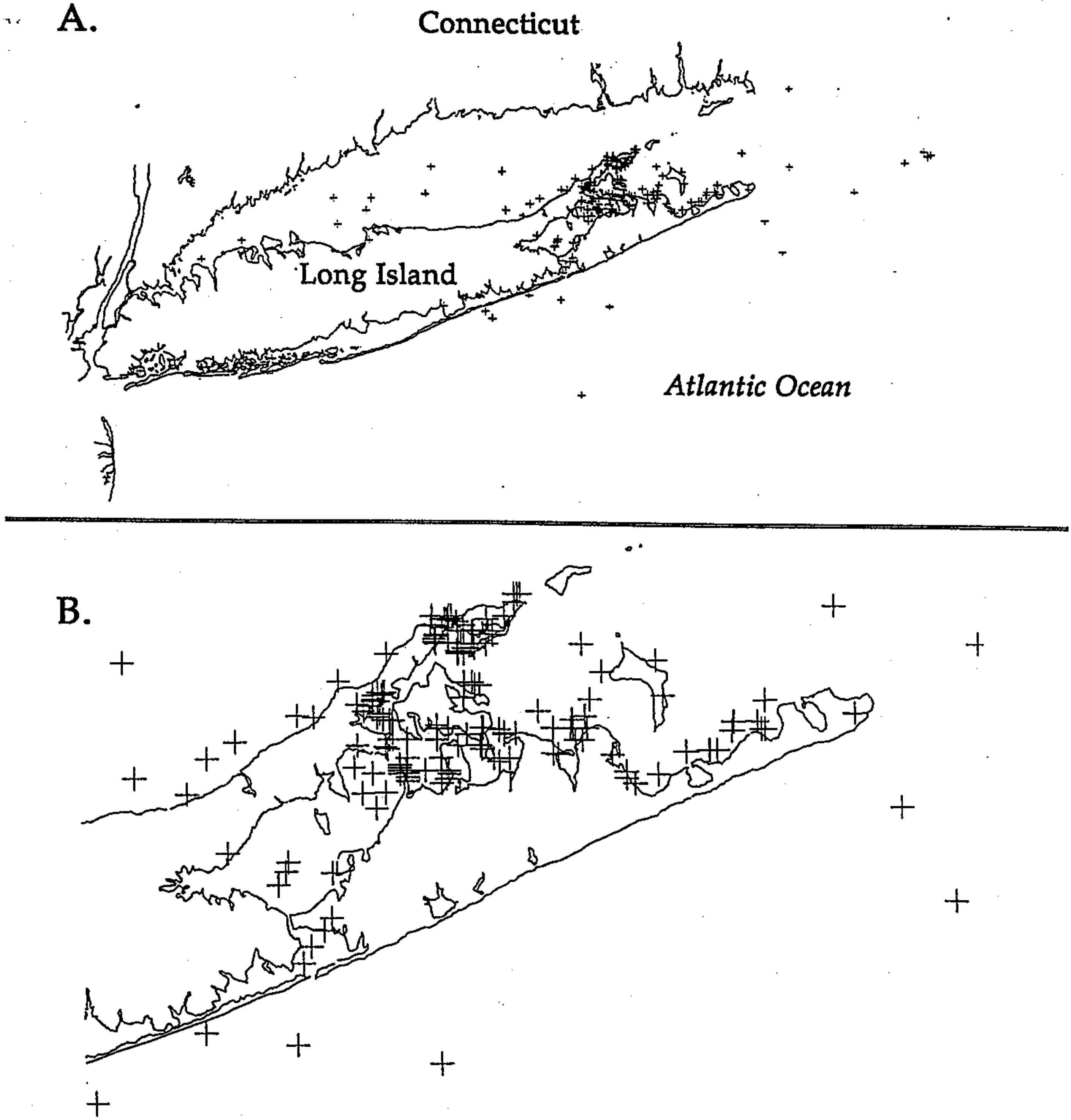


Fig. 7. A) The geographic distribution of live sea turtles captured in New York waters from 1987 through 1992. Crosses represent individual captures at that location. B) A close-up view of the high concentration of captures in eastern Long Island reflecting, for the most part, the locations of pound nets.

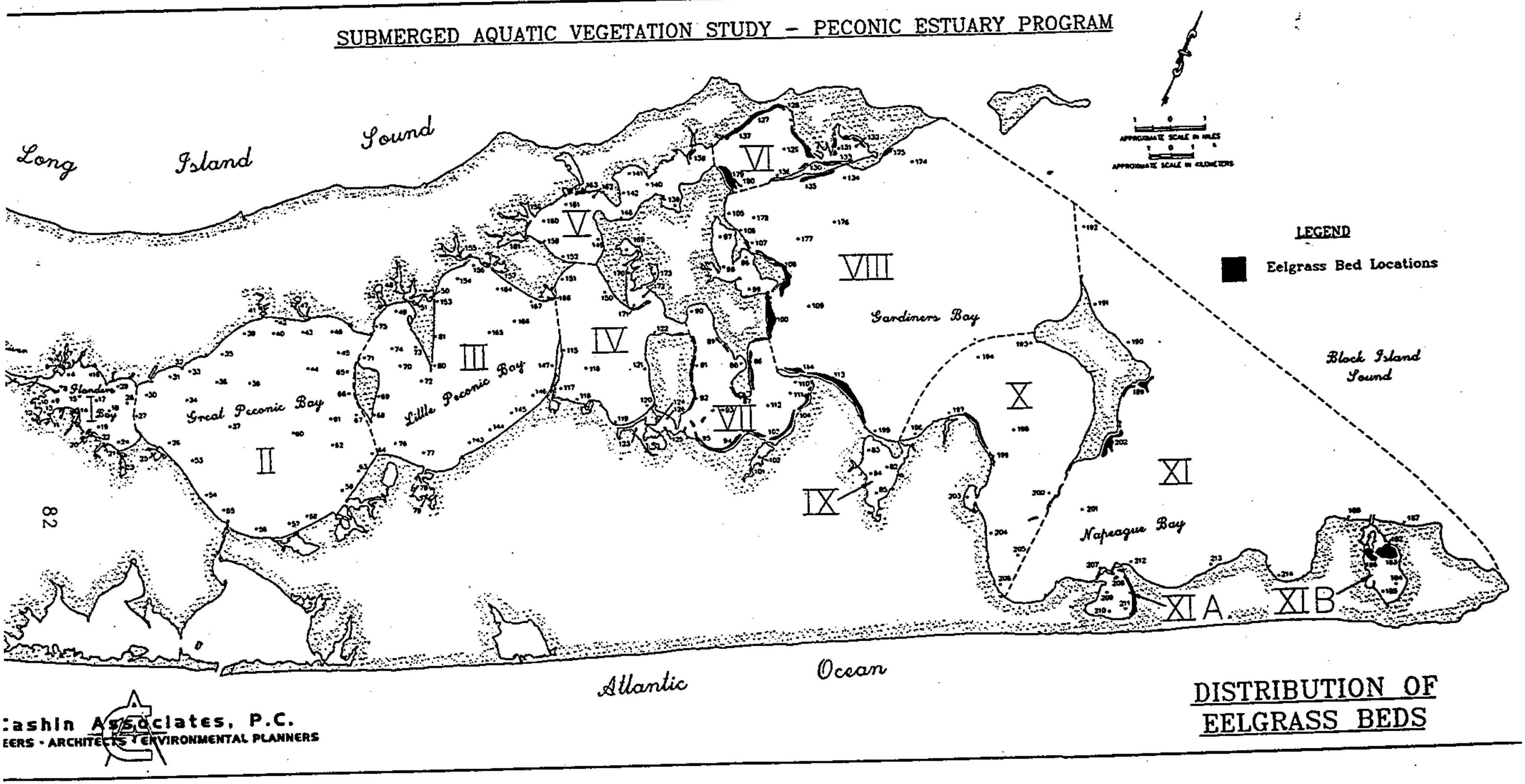


Figure 8. Map of eelgrass in the Peconic Estuary.

Figure 9.

Occurrences of the Piping plover (Charadrius melodus) in the Peconic Estuary Watershed

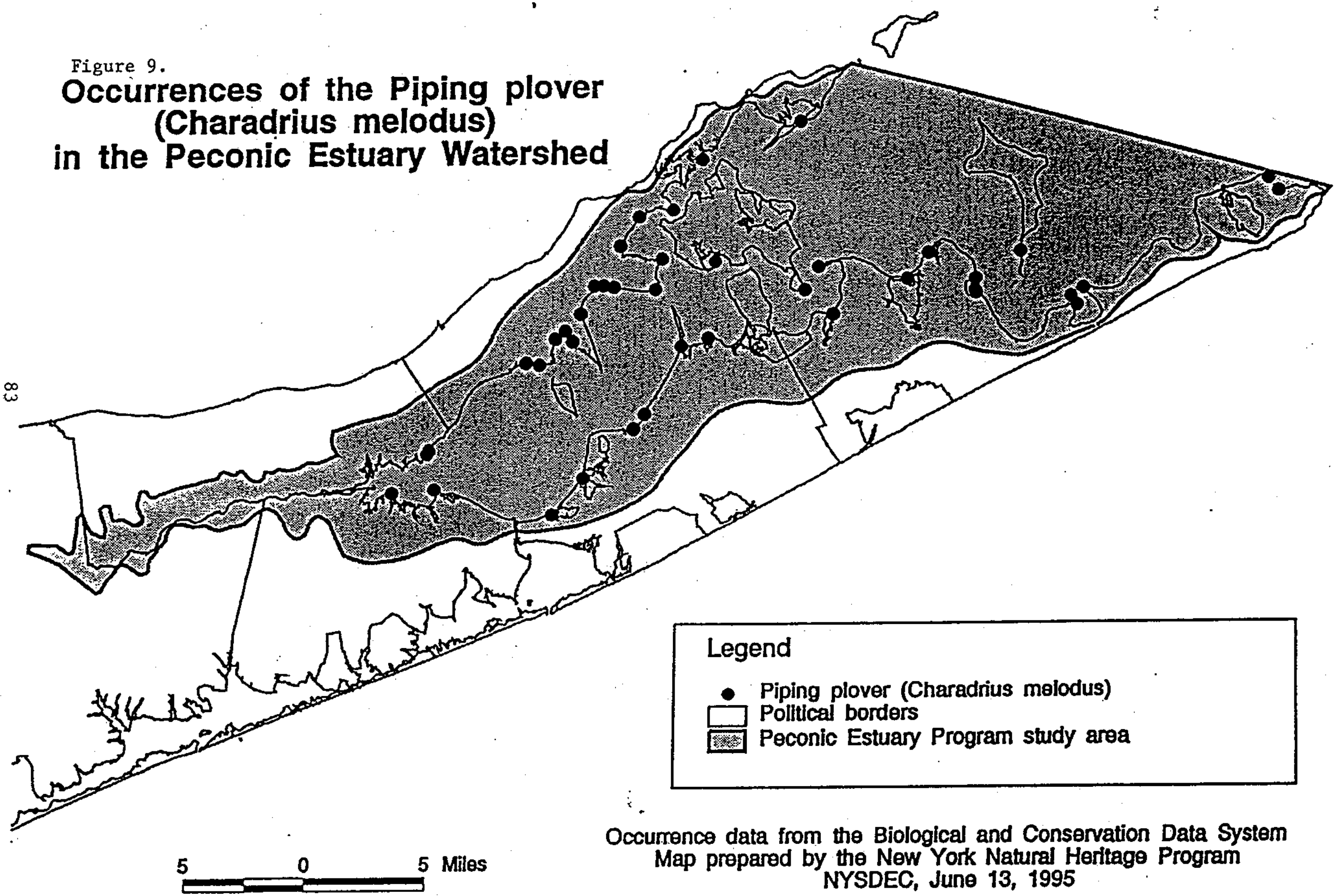
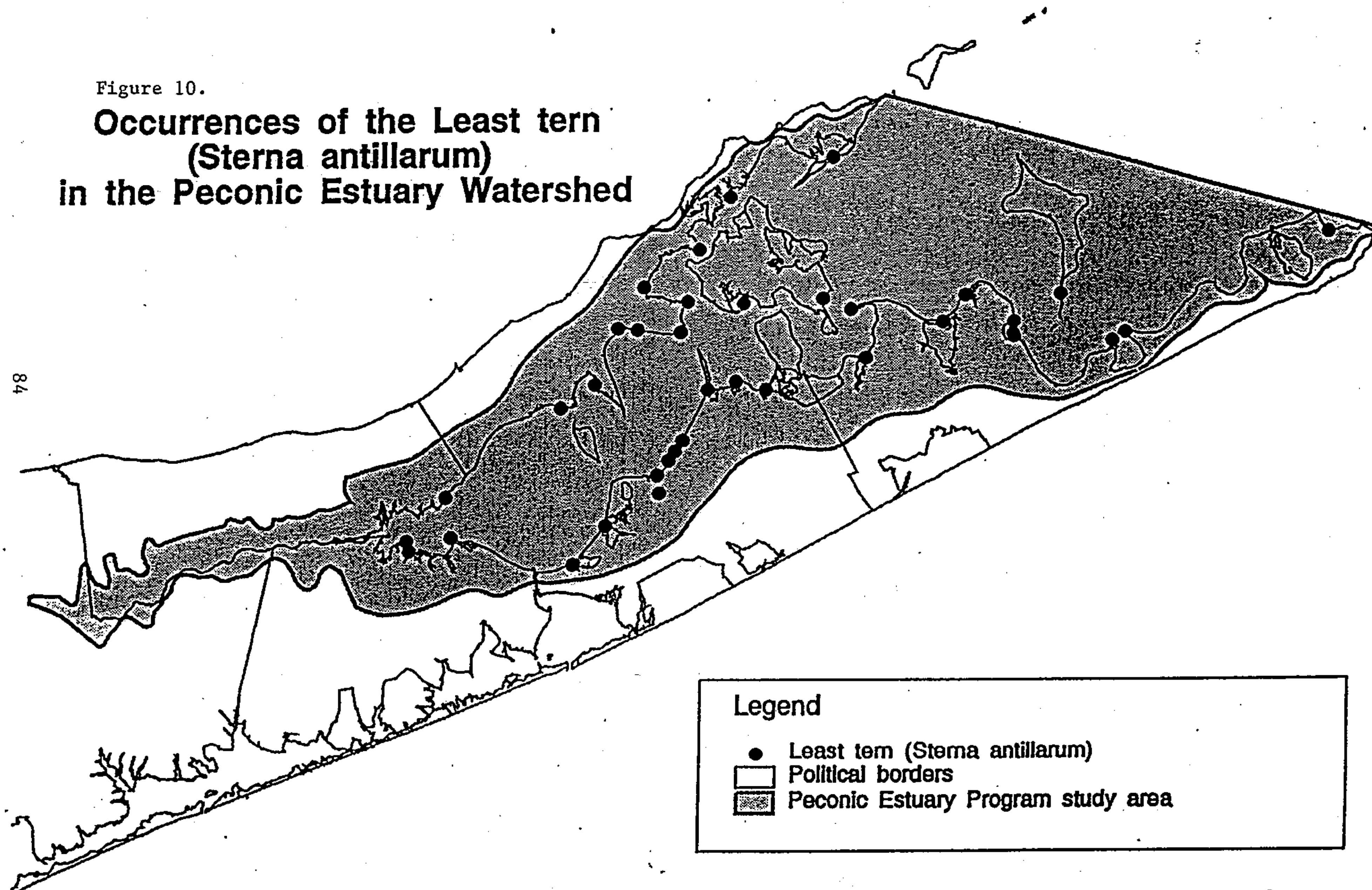


Figure 10.

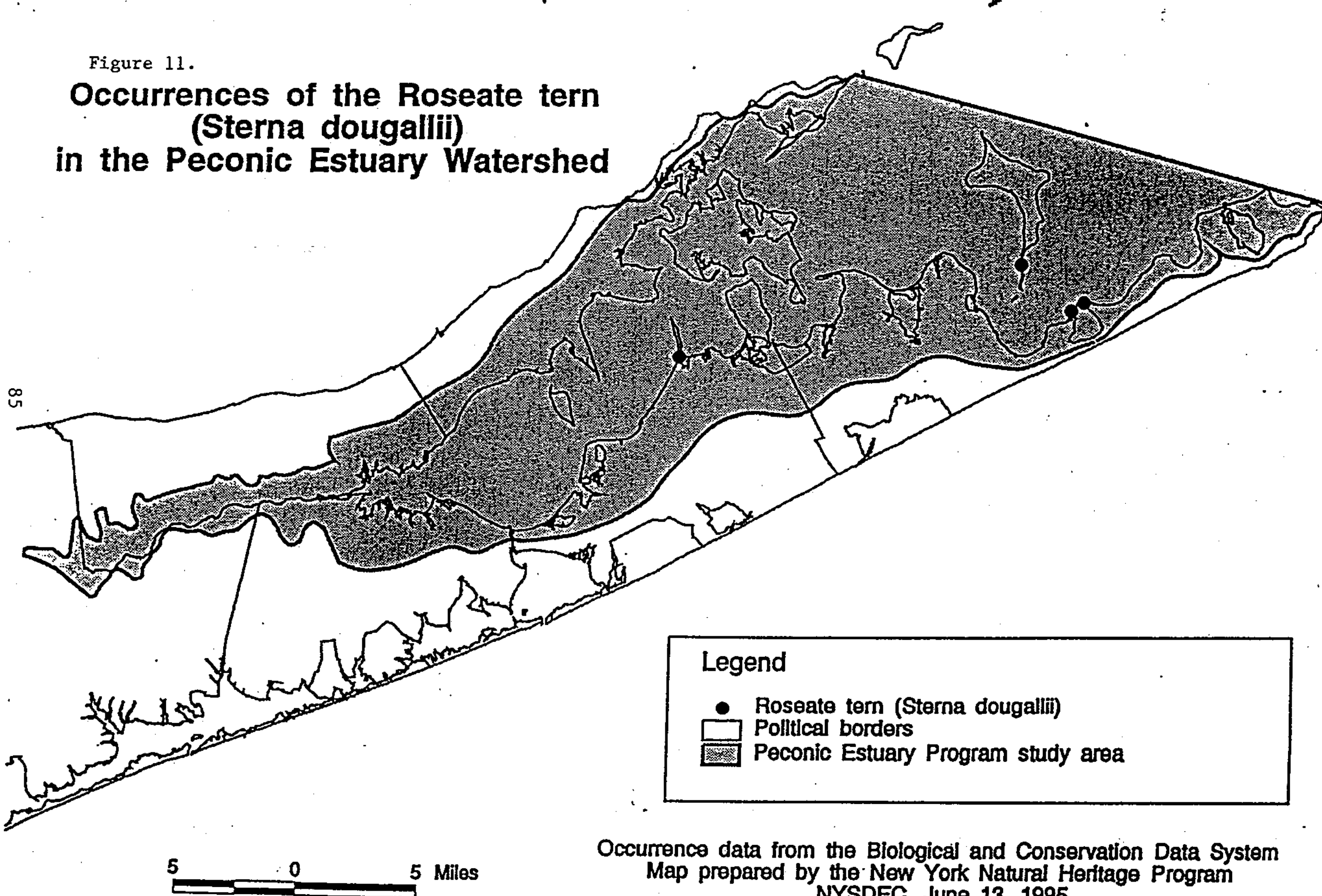
Occurrences of the Least tern (Sterna antillarum) in the Peconic Estuary Watershed



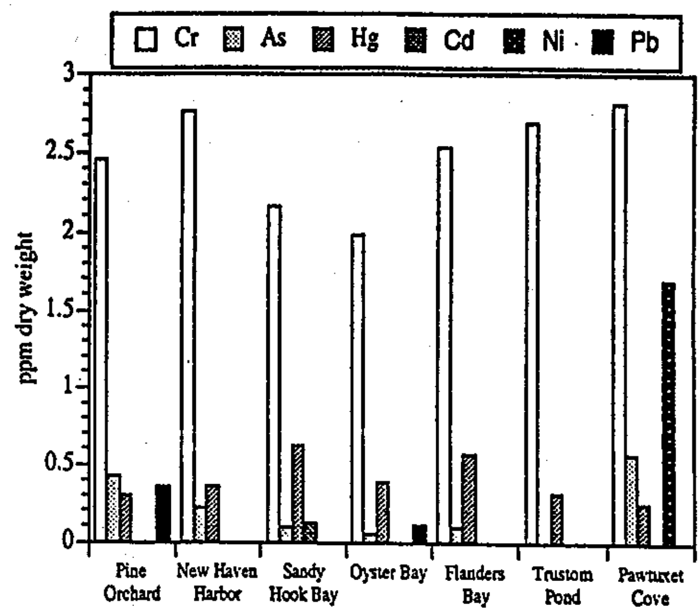
Occurrence data from the Biological and Conservation Data System
Map prepared by the New York Natural Heritage Program
NYSDEC, June 13, 1995

Figure 11.

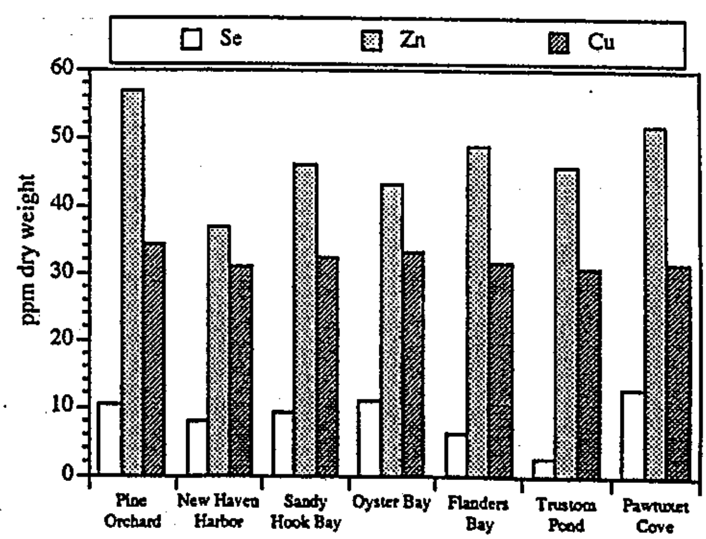
Occurrences of the Roseate tern (Sterna dougallii) in the Peconic Estuary Watershed



Occurrence data from the Biological and Conservation Data System
Map prepared by the New York Natural Heritage Program
NYSDEC, June 13, 1995



Amounts of cromium, arsenic, mercury, cadmium, nickel, and lead in the breast muscle of scaup.



Amounts of selenium, zinc, and copper in the breast muscle of scaup.

Figure 12.
Source: Cohen and Barclay (1997)