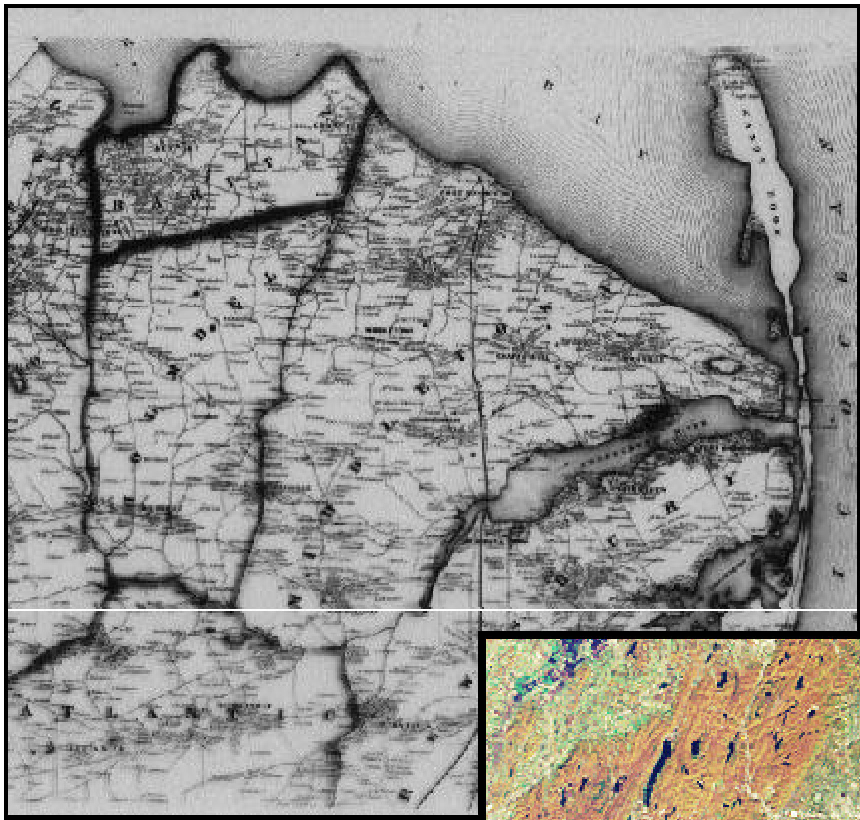
# Renourishment and Offshore Borrowing in the Raritan Bay Ecosystem: A Biological Assessment for Sea Turtles



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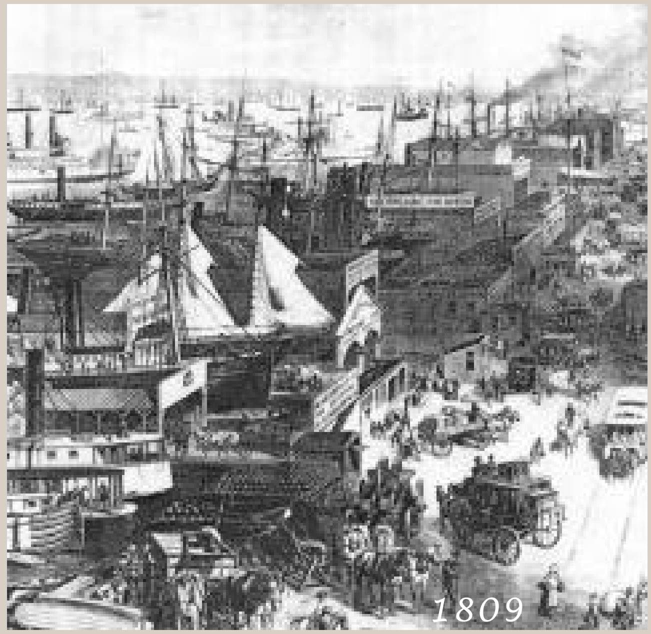




**July 2001**

# Beach Renourishment and Offshore Borrowing in the Raritan Bay Ecosystem: A Biological Assessment for Sea Turtles.

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A) **Introduction**

At the apex of the New York Bight, lies the Lower New York Harbor with its western portion, Raritan Bay. At the harbor's southeastern side lies Sandy Hook Bay, which is enclosed by the long peninsular arm of Sandy Hook. The location and physical aspects of this estuarine system combine to provide what appears to be extremely favorable conditions for supporting fish nurseries, shellfish beds, and submerged aquatic vegetation. In the absence of external influences these protected waters also would seem to offer ideal foraging habitat for seasonal marine migrants including many fish, mammals, and turtles. However, perhaps ironically, the same attractive physical features and plentiful biota also have attracted humans, who have grossly altered the original habitats in structure and quality.

Over the past four hundred years, Lower New York Harbor and Raritan Bay have been transformed from a large productive embayment with scattered communities of indigenous people, to one of the busiest harbors in the world surrounded by a human population of more than 10 million. During this period, the estuarine complex has gone from a productive habitat teeming with natural marine life, to a health hazard with its open sewage and threats of hepatitis and typhoid, and finally to its current more regulated state.

The encroachment of people and houses along the shoreline also introduced a new set of considerations that more relate to the effect of the environmental processes of the bay on the coastal residents. The mixing processes of the waters in the Raritan Bay complex have traditionally created a slowly circulating water mass in a counter-clockwise gyre (Jeffries 1962). Within the general pattern of circulation and tidal flux, there is attendant erosion and deposition at different locations throughout the bay. In the absence of people, these common processes seemingly achieved a balance within the bay system, without much of an overall impact to the estuarine ecosystem. In the current environment, however, there are numerous permanent buildings and houses constructed on what used to be impermanent sites that traditionally were shifting and dynamic series of salt marshes and beaches. The erosion of sand on these populated shorelines can be a serious problem, severely impacting residences and even entire communities.

To alleviate the problems of erosion faced by many coastal communities, the Raritan Bay shoreline renourishment project has been proposed. This project will entail excavation of sand from nearby shallow water sites where sand has been deposited, and redistribution of the sand along the severely eroded shoreline. However, in accordance with NEPA requirements, any such activity proposed by a federal agency must be preceded by an evaluation of the potential effects of its activities on the environment. More specifically, the analysis must address the possible impacts to local biota, and especially threatened and endangered species that may occur in the area.

A group of endangered and threatened species in this region that warrant special attention are the sea turtles. Each year, during the warmer months, four species of marine turtles inhabit the New York Bight. Because of the documented presence of sea turtles in the region of the proposed project, and because all four of these species are federally listed as Threatened or Endangered, the possible impacts to this group were appraised separately from the analyses of other environmental impacts of excavation and beach renourishment. The following is a summary of the findings of this evaluation. As such, this report represents the Army Corps of Engineers New York District's Biological Assessment for sea turtles with respect to the potential impacts of the proposed Raritan Bay shoreline renourishment project.

B) **Project Area and Site Description**

The proposed project areas are within the Lower New York Harbor and Raritan Bay Complex, located at the apex of the New York Bight (Fig. 1). The proposed sites of activity are potential excavation areas in shallow water areas of southern Raritan Bay and east of Sandy Hook, in open ocean waters. This is a region of very high human density and much shipping and boating traffic all year. In fact, New York harbor and its approach channels throughout the Lower Bay comprise one of the most active harbors in the world. There also is considerable military traffic moving in and out of the Sandy Hook area, and utilizing the Naval Pier facilities. The military facilities have only been active for about 50 years, but human activity in the Raritan Bay area dates back thousands of years. During the past few hundred of these years, the bay has undergone some radical changes that have greatly affected ecosystem quality and structure.

During the late 1600's, the first European settlements surrounding Raritan Bay were already well-established. The main settlements at Tottenville, Perth Amboy, and Keyport all were centered around the sites of huge oyster beds that sprawled for kilometers near the mouth of the Raritan River and in Keyport Harbor. The placement of these communities near these tremendously productive habitats was no mere coincidence. Rather, these sites had been occupied for thousands of years by the indigenous tribes of the Lenapes, who also took advantage of the constant food supply prior to their displacement by the Europeans.

Upon arrival from Europe, the 17$^{th}$ century colonists apparently were impressed with the "fish in abundance in every little brook"; the huge supply of oysters that were "exceedingly good for roasting and stewing"; the great schools of herring, shad, and bunkers, along with striped bass and sturgeon; and the ready-made piles of oyster shells in the middens of the former residents, to be used in building and for liming fields (MacKenzie 1992). But, during the next century, there already were bitter disputes between New York and New Jersey oystermen over the few remaining oysters.

By the early 1800's, the great oyster beds were all but barren, and the plentiful shad populations had crashed; the direct result of overfishing, siltation from agriculture and urban runoff, and general habitat degradation due to overpopulation (McCormick et al. 1984). In fact, with the population exceeding 5 million people in 1905, the conditions within the New York and New Jersey Harbor Complex became alarmingly worrisome to health and sewerage authorities (Metropolitan Sewerage Commission 1910). Nearly two thirds of a billion gallons a day of mostly untreated sewage into the New York Harbor, along with more than 1100 cart loads of garbage dumped daily in nearshore waters, had severely impacted water and ecosystem quality. Solid garbage was recorded piling up from Westhampton Beach to Atlantic City, and throughout Raritan Bay and Sandy Hook Bay. Within the entire harbor complex bacterial counts were from 2 to 3 orders of magnitude higher than coastal waters, which contributed to several thousand cases of typhoid, cholera, and hepatitis each year.

As a result of continued development, agricultural practices, and shoreline hardening, siltation and sediment load also increased to very high levels. With a plume of polluted sediment documented extending across the length of the Lower Bay (Metropolitan Sewerage Commission 1910), the benthic communities underwent marked changes in structure and species composition. These conditions accelerated, and persisted through the middle of the 20th century in the face of continued population increases and continual alterations within and around the Lower Bay. Beginning in the 1930's, extensive plans also were drawn up for the construction of a network of channels throughout the Lower Bay to provide deepwater access into New York and New Jersey Harbors, Sandy Hook Bay, Raritan Bay, Arthur Kill, and Raritan River(Port of New York Authority 1931). These channels, which are even more extensive today, undoubtedly further altered the character of the bay.

The shoreline also noticeably changed during this period. The first major piers were constructed near Leonardo, at the western end of Sandy Hook Bay, including the Amusement Park Pier, Standard Oil Pier, and during World War II, the extensive Navy Pier that runs for more than 3 _ kilometers straight out into the bay. Also leading up to that period, the extensive marshes along the New Jersey shoreline between Laurence Harbor and Sandy Hook were ditched and contained. This led to the mushrooming of coastal communities such as Keyport and Port Monmouth, along with the development of new towns all along the shoreline including Union Beach, Kearnsburg, and Highlands. Currently, tens of thousands of people inhabit this stretch of shoreline that was once a dynamic system of salt marshes.

It is difficult to evaluate the predicted impacts of the current proposed excavation of sand at shallow water borrow sites, especially when placed within the context of the intense fishing, construction, urban development, and broad-scale ecosystem changes within the Lower New York Harbor and Raritan Bay Complex. After centuries of such disturbance, the localized activities of the proposed project appear relatively minor in scope. Furthermore, with such intense restructuring of the bay ecosystem, the characterization of this once highly suitable habitat for sea turtles, is no longer that straightforward. Nevertheless, it would be prudent to examine the proposed activities and evaluate the potential impacts at specific sites, especially with respect to sea turtle presence and critical habitat that may exist within the area.

C) **Proposed Project Summary.**

The project will alleviate the erosion problems that currently are severe along the inhabited shoreline of New Jersey bordering the southern portions of Raritan Bay. The proposed methodology will be to replenish beaches along this stretch using materials that are excavated from nearby sites, offshore, where sand deposition occurs. The nourishment of beaches also will provide protection from storm-related events.

This technique of shoreline protection, in many ways is much preferable to common alternative methods such as fortifications and bulkheads. The use of revetments to retain soils and to prevent erosion unquestionably contributes to hardening of the shoreline, which already is a pervasive problem, especially in populous areas. However, the same benefits do not necessarily apply to the mining of sand from underwater sites used to buffer the beaches. There are many potential impacts to borrow sites, some of which could negatively affect the bay ecosystem.

In the proposed project plan, sand will be mined from designated underwater sites using dredges in relatively shallow water. There are four proposed borrow sites; three are within Raritan Bay, and a fourth is in ocean waters east of Sandy Hook (Fig. 2). Currently the Army Corps is examining the characteristics of each of these four areas:

Raritan Bay Sites

**Keyport** - shallow water site, off shore of Keyport, NJ, extending from the inner portions of Keyport harbor toward the center of the Bay. Water depths range between 3 and 9 ft.

**Union Beach** - slightly deeper water, slightly farther off shore of Union Beach, NJ, adjacent to the outer edge of the Keyport site. Water depths range between 5 and 13ft.

**Point Comfort** - slightly deeper water, off shore of Point Comfort, NJ, approximately the same distance into the bay as the Union Beach site. Water depths also range between 5 and 13 ft.

Ocean Site

**Sandy Hook** - slightly deeper water, in Atlantic waters off shore, between Sandy Hook NJ and the east section of Sandy Hook Channel. The site extends along False Hook, a sandy shoal area on the eastern fringe of False Hook Channel. Water depths also range mainly between 5 and 16 ft, with some portions to as deep as 30 ft. along the edge of Sandy Hook Channel.

One or all of these sites would provide appropriate sand and fill materials for the beach nourishment project. Currently, alternatives such as dredging deeply from one site, or lightly from several sites, are being examined.

D) **Project Purpose**

The purpose of the dredging project is to borrow sand from nearby areas along the bottom of Raritan Bay or off of Sandy Hook, to use as fill material for nourishing beaches along the southern shoreline of Raritan Bay. The nourishment of beaches is intended to replace sand along areas that already are severely eroded, and to provide a buffer to prevent further damage during extreme high water or storm events. Shoreline protection will contribute to the stabilization of many bayside communities that currently are threatened with property damage or loss. The addition of beachfront also will provide a natural barrier in high-erosion areas which will reduce the amount of seaside rubble and unfiltered urban pollutants washing into the bay. Beach nourishment is a preferred technique of shoreline protection with regard to ecosystem processes, as compared to fortifications which harden the shoreline.

E) **Environmental Considerations**

A chief concern to resource management agencies is the potential effect of sand mining activities on endangered and threatened species and to their critically important habitat. In accordance with Section 7 of the Endangered Species Act, the proposed sand-borrowing activities for the Raritan Bay beach nourishment project must be evaluated for the potential effects on threatened and endangered sea turtles that may be present within the region. The evaluation may be used as a Biological Assessment to determine if formal consultation is required between the U.S. Army Corps of Engineers and the National Marine Fisheries Service (50 CFR, Part 402.12).

F) **Sea Turtles in the Region**

1) Sea Turtles occur in the New York Bight on an annual seasonal basis.

Within the past three decades it has been documented that leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), green (*Chelonia mydas*), and Kemp's ridley (*Lepidochelys kempii*) turtles regularly occur in northeastern U.S. waters during the warmer months (Bleakney 1965, Brongersma 1972, Lazell 1980, Shoop 1980, Morreale and Standora 1994). The acceptance of northeastern waters as important habitat for sea turtles, however, was not immediate. It was argued that the Northeast was clearly a disadvantageous environment for Kemp's ridley turtles (Hendrickson 1980) and, by implication, for other species. This speculation was perhaps more compelling given that many of the turtles in both recent and historical accounts had been found dead or moribund, from hypothermia in early weeks of winter. (Murphy 1916, Latham 1969, Meylan and Sadove 1986, Burke et al. 1991, Morreale et al. 1992). Researchers with more moderate opinions surmised that young sea turtles are swept occasionally into inshore waters of the Northeast by anomalous currents, eddies, and meanders of the Gulf Stream, whereupon they may sometimes find their way back to southern waters (Carr 1980, 1986, Meylan 1986, Ogren 1989, Collard and Ogren 1990).

Among the continuum of hypotheses, the most convincing current thought is that New England and New York waters are a critical habitat to loggerhead, Kemp's ridley, and leatherback turtles during warmer months each year (Lazell 1980, Shoop and Kenney 1992, Morreale and Burke 1997). Extensive long-term studies in New York have substantiated this through detailed examination of demographics, feeding ecology, and behavior of the sea turtles that appear in northern coastal waters (Morreale and Standora 1998). With the exception of a few leatherbacks, the turtles in nearshore waters are small juveniles. The loggerhead is the most abundant, followed by the Kemp's ridley. These two species, along with a relatively few green turtles, move into harbors and estuarine waters, while the leatherback turtles remain along the coast and rarely are seen in embayments.

The young hard-shelled turtles appear each year in early summer and remain for up to several months. Loggerheads and Kemp's ridleys feed heavily on a diet composed mainly of crabs and, to a lesser extent, mollusks (Burke 1990, Morreale and Standora 1992*a*, 1992*b*, Burke et al. 1993*a*, 1993*b*, 1994), while green turtles feed mainly on algae (Burke et al. 1992). The leatherback turtles in the region appear to be mostly adults or, at least, very large individuals that appear to feed primarily on the soft-bodied coelenterates and cnidarians. They also occur in northeastern waters during the warmer months, and although they seem to be numerous in coastal waters of the continental shelf, they rarely venture into inshore areas. For the young hard-shelled turtles, the opposite seems to be true. They seem to remain very briefly in open coastal waters, appearing to use them only to move to and from the bays where they spend the summer months. The abundant resources in the nearshore environments of the Northeast results in extremely high measured growth of the juveniles before they slow down their activity in the fall (Morreale and Standora 1994). As temperatures decline rapidly, the juvenile turtles change their behavior and begin to move back toward open ocean waters.

2) Sea turtles predictably leave northeastern waters by mid-October.

The overall pattern that has emerged as a result of many different and complementary studies in many regions is a predictable routine of extensive seasonal migration of sea turtles along the Eastern Seaboard. There are three main types of studies from which this pattern has been made evident: observation studies; mark-recapture records; and telemetry studies.

Synthesis of many observation studies that included shipboard surveys and captures by fishermen suggests that there is seasonal travel along the Atlantic coast to and from Pamlico Sound (Epperly et al. 1995*a, b*), Chesapeake Bay (Lutcavage and Musick 1985, Keinath et al. 1987, Byles 1988), New York (Morreale and Standora 1989, 1990, 1991, 1992*b*, 1994, Morreale and Burke 1997), and New England (Lazell 1980, Shoop 1980). Further observations by aerial surveys have provided complementary and strongly supportive data that further indicate seasonal movements of sea turtles along the east coast (Shoop et al. 1981, Keinath et al. 1987, Byles 1988, Shoop and Kenny 1992, Hopkins-Murphy and Murphy 1994, Musick et al. 1994, Epperly et al. 1995*b, c*).

Recapture data, providing start and end points of travel of individual turtles, also collectively indicate considerable movement of sea turtles along the Atlantic coast. All told, there have been several published reports of tagged turtles traveling between Florida and the mid-Atlantic states (Meylan et al. 1983, Lutcavage and Musick 1985, Henwood 1987, Henwood and Ogren 1987, Byles 1988, Schmid 1995, Epperly et al. 1995*a*), a loggerhead from Rhode Island to Georgia (Shoop and Ruckdeschel 1989) and over a dozen individuals of three species that have migrated from New York to southern waters (Fig. 3; Morreale and Standora 1989, 1994, Morreale and Burke, 1997). Although these data are not well-suited for determining precise timing of movements, there also is some indication of a strong seasonal component to these movements.

The combined information from observation and mark-recapture studies clearly depicts a general pattern of seasonal migration from northern to southern U.S. waters. However, detailed examination of turtle migration routes and precise seasonal movements have only been accumulated more recently using satellite telemetry. Indeed, these studies clearly demonstrate seasonal movements of Kemp's ridley and loggerhead turtles between Florida and North Carolina (Renaud 1995, Gitschlag 1996), from Chesapeake Bay to North Carolina and into Gulf Stream waters (Byles 1988, Keinath et al. 1989, Keinath 1993), and even from New York to southern waters (Morreale and Standora 1991, 1992*b*, 1994, Morreale 1999). These detailed data on sea turtle migration, nicely supplement the patterns of seasonal migrations observed using previous study methods.

The most detailed studies to date that focused on the precise seasonal migratory patterns of sea turtles to and from the northeastern waters, depicted a strikingly predictable pattern of regular migration, not only spatially, but also temporally (Morreale and Standora 1998, Morreale 1999). Data from these long-term telemetry studies that provided detailed satellite tracks of sea turtles, indicated that sea turtles migrating from New York waters travel mainly within a corridor running southward over 800 km along the Northeast coastline, with a maximum width of less than 60 km. All told, satellite transmitters were placed on 15 juvenile turtles leaving New York waters in the fall: 12 loggerhead turtles in 1992, 1995, and 1996; and three Kemp's ridleys in 1990 and 1991 (Fig. 4). The conspicuous orientation southward of all turtles leaving northeastern waters highly contrasted with any expectations of random dispersal away from New York. Later in the winter, some turtles deviated from a southward heading, but upon entering the open ocean, all individuals immediately migrated along the southward-headed corridor.

This tight grouping of turtles was observed not only spatially, as individuals migrated along the same paths, but also temporally, as they traveled within the same time frame each fall. Although the starting dates of the tracking studies were spread out between late summer and early fall, the turtles departed New York waters within a predictably short time frame each fall. The predictability of the dates at which turtles emigrated is undoubtedly related to the predictable change in weather each fall. The impetus to migrate is likely to be simply mediated by abrupt temperature declines each year around late September (Morreale and Standora 1994). Because 15 of the 15 turtles that were monitored over the different years responded similarly by migrating southward at this time, their behavior probably represents the vast majority of turtles in the Northeast region (Morreale 1999).

Once sea turtles leave New York inshore waters, the similarity of behavior becomes even more striking as they follow along a narrow migratory path heading southward. It is obvious, both intuitively and statistically, that each fall sea turtles migrate more than 1000 km southward, from the Northeast to southern waters, along a well-defined oceanic corridor (Morreale 1999). The spatial and temporal extent of this migratory corridor appears to be quite constricted. It is conservatively estimated to be within a band narrower than 60 km wide along the continental shelf. The migratory corridor also is estimated to exist only within a narrow time frame, over the few weeks from October through December (Fig. 5). Thus the general trend for the southward migrating turtles is to leave the New York Bight in October, to pass the Virginia border by the first week of November, and to continue moving southward after that. At the terminus of the corridor, off the coast of North Carolina, turtles slow down their southward movement and apparently become sedentary south of Cape Hatteras by December.

The careful synthesis of the observed behaviors from these observation, mark-recapture, and telemetry studies has revealed some clear behavioral patterns among northeastern sea turtles. Namely: large numbers of turtles occur on an annual seasonal basis in northern temperate waters; this large annual contingent of sea turtles predictably migrates into and out of northeastern inshore waters on an annual seasonal basis; during the spring and fall sea turtles are migrating over great distances; and the turtles of the Northeast shuttle between northern and southern waters (Shoop and Kenney 1992, Morreale and Standora 1994, Morreale and Burke 1997, Morreale 1999). Furthermore, the patterns of behavior and movement are highly stereotyped and predictable from year to year. Thus, it is possible to predict with high confidence the dates when sea turtles will emigrate from New York inshore waters and move southward.

3) The present day usage is similar to recorded historical patterns in terms of timing and distribution.

Sea turtles have been reported in northeastern waters since before the mid-19th century (DeKay 1842). Furthermore, the spatial distribution and the timing of occurrence in New York waters appeared to be very similar to current distribution and seasonal activity patterns (Morreale et al. 1989). The species composition also appeared to be similar to present species accounts. Historically it was reported that many Kemp's ridleys and loggerheads occurred in New York waters in summer and fall, and they frequently were found in the harbors along Long Island Sound, the eastern and southern bays (Engelhardt 1913, Murphy 1916, Latham 1969), and in Lower New York Bay, where some collections were even made by the New York Aquarium for study purposes (DeSola 1931). In all of these areas, sea turtle presence also has been reported at least once in recent years.

## G) **Sea Turtles in the Lower New York Harbor and Raritan Bay Complex**

With all of the alterations to the aquatic and shoreline environment, it has become difficult to characterize the ecosystem processes within the Raritan Bay system. This is especially true when assessing the present-day quality and importance of the bay for sea turtles. The Bay began as a seemingly ideal habitat for benthic invertebrates, fish, and probably sea turtles during warmer months. During the 1800's the bay ecosystem suffered greatly, until the beginning of the next century when it became a stressed and often fetid discharge area for open and untreated sewage. Over the next several decades, much effort was devoted to the primary treatment of human wastewater before it was flushed into the Lower Bay system. However, even as late as the mid-1970's the treatment was deemed very inadequate (McCormick et al. 1984). By this time, the sewage discharge into the New York and New Jersey Harbor Complex ranged from 2 to 4 billion gallons per day; during storm events, most of this was untreated. Raritan Bay had become notable for it's high levels of pollution (U.S. Dept. of Health Education and Welfare 1961, Jeffries 1962, McCormick et al. 1984) and resulting low levels of benthic macrofauna (Simeone 1977). Many damaging contaminants continued to pervade the sediments. Also prevalent in clams, oysters, and crabs, were phenols, PCB's, and non-volatile hydrocarbons (McCormick et al. 1984).

The treatment of wastewater continued to improve after the 1970's, with nearly a 30% decrease in BOD load reported by the next decade (Mueller et al. 1982). However, nitrogen loads remained steadily high, and long-lasting contaminants persisted. Some researchers believe that the Raritan Bay ecosystem has exhibited signs of having somewhat rebounded, or at least stabilized, since the 1960's (Stainken et al. 1984, Steimle and Caracciolo-Ward 1989). However, the bay likely never will revert to its former state with respect to physical or biological structure.

Perhaps one of the most significant changes to the Raritan Bay ecosystem with great relevance to sea turtles, was the sudden die-off of eelgrass during the mid-1930's. Until this time extensive beds which covered the perimeter of the bay provided structure and essential habitat for fish, shellfish, and crustaceans (MacKenzie 1992). For a variety of proposed reasons, including high siltation, pollution and physical disturbance, eelgrass has not been re-established to any degree in Raritan Bay since it's initial disappearance. The resultant loss of prime habitat for many benthic invertebrates, easily could have important implications for the habitat suitability and the abundance of summer foraging sea turtles. Many of the turtles' common prey items including spider crabs, rock crabs, blue crabs, and green crabs, all are much more abundant where there are active eelgrass communities (Wilson et al. 1987, Heck et al. 1989).

The transformation of the bay as a result of past and current high levels of use, contributes to the difficulty in determining whether the Raritan and Lower New York Bay system presently supports a seasonal population of sea turtles, or is even appropriate habitat for turtles. Until the 1800's, the bay seems to have had the physical and biological characteristics that would make it very suitable for foraging sea turtles. Even as late as 1930's, one of the few written reports of sea turtles in the Lower Bay, alludes to great numbers of turtles there (DeSola 1931). Apparently in collecting trips throughout the 1920's researchers from the New York Aquarium frequently would encounter loggerhead turtles " that were abundant....." and Kemp's ridleys that "were common only second to loggerheads....". But soon after that period, the eelgrass was wiped out by wasting disease, and the bay habitat went into steep decline. So, what once was a great habitat, became unsuitable for several decades, until many of the abuses became more regulated. But the effects of past usage are more than transient, and the bay has not rebounded back to its initial state by any means. This pattern of degradation may be reflected in the usage of the bay by sea turtles, which once apparently were abundant, but since have been rarely recorded.

From direct evidence there is very little means of assessing whether sea turtles occur in New York Harbor and Raritan Bay in recent times. No active studies of sea turtles are being conducted in those waters, and the fishing industry of the region is not of the sort that generally captures and reports sea turtles. Some dead individuals wash up on shore along Staten Island, Coney Island, and Rockaway each summer. However, these carcasses often are of large turtles, much larger than the size of the juveniles that normally would be expected in nearshore waters. It has traditionally been assumed that these large dead turtles are floating in from distant areas, transported by prevailing winds and surface currents.

In the primary literature over the past several decades, there is only one report of an encounter with a healthy sea turtle (MacKenzie 1992). This was a loggerhead turtle captured near Belford, NJ in a pound net on 12 August 1986. The lack of turtle reports certainly could be influenced by the lack of turtle research. However, there are other sources of information which would be expected to report the occurrence of sea turtles in New York Harbor and Raritan Bay. These include reports from biological studies, inventories, and surveys that have been conducted in all seasons, and over many different years. In fact, the New York and New Jersey Harbor Complex has been the site of numerous sampling and monitoring studies (for a recent review, see USACE An Annotated Bibliography of NY/NJ Harbor: Emphasis on Biological Studies 1996, and USACE Existing Biological data report 1998). None of the listed references since 1980 provides a single account of active and healthy sea turtles in the New York Harbor Complex, and there is only a mention of sea turtles occurring in New Jersey waters, but this reference was actually for Delaware Bay (Schoelkopf and Stetzar 1995).

The more likely studies to provide data on sea turtles that may have been captured during the course of study, are those that examined the benthic biota, especially by trawling. Some key surveys of this type during the 1980's were conducted using large trawl nets in the deeper water sites of the New York Harbor complex, including the Newark Bay and the Lower Bay, over all seasons in different years (Woodhead and McCafferty 1986, Woodhead et al. 1988). In these studies within the New York and New Jersey Harbor Complex, there were numerous captures of vertebrates that dwell on the bottom, such as sea robins, fluke, flounder, and hogchokers. In addition, the inventories yielded many species of benthic invertebrates such as spider crabs, rock crabs, lady crabs, sea stars, and horseshoe crabs. In all of the sampling in the benthic zone, where sea turtles would be most often encountered, no turtles were ever captured. Furthermore, no sightings of turtles were ever made, including during the hundreds of shipboard hours spent sampling during the warmer months (P.M.J. Woodhead, personal communication).

Continuing through the 1990's, despite intensive biological surveys, there have been no additional records of sea turtles captured or spotted at the surface in Lower New York Bay and Raritan Bay. In fact, after combing through hundreds of available records, it is still difficult to tell whether sea turtles currently occur in Raritan Bay. It is possible that turtle presence has paralleled the conditions of the bay, being once abundant, then after decades of environmental insults they seem to have disappeared, and have not returned. The same sense of long-term decline was conveyed in the written report of the single loggerhead turtle captured in Raritan Bay in recent years. MacKenzie (1992) wrote: “For many years, pound netters retained and sold these turtles, but in recent years they have become so scarce they are classified as an endangered species.”

In summary, although sea turtles occur in nearby waters throughout the warmer months each year, there is surprisingly little documented evidence of their presence within the Lower New York Harbor and Raritan Bay. The lack of turtles reported in the area is not due to a lack of sampling and monitoring studies within the New York and New Jersey harbors. Rather, there have been numerous such scientific studies in the region in recent years, none of which have reported sea turtle activity. However, there has been little attention and few resources focused directly on determining the frequency and extent of sea turtle presence in the Lower New York Harbor and Raritan Bay complex. Without such careful studies, there can be no definitive evaluation of the region’s importance as sea turtle habitat.

Thus, a judicious approach to determining the impacts of the proposed dredging activities to turtles should begin with the cautious assumption that sea turtles may occur in the area. Within this framework, the specific areas of the harbor complex should be analyzed with respect to their physical and ecological characteristics, and the likelihood of the usage of the individual habitats by sea turtles. Possible impacts to turtles and potential turtle habitats can then be derived from the assigned likelihood of sea turtle occurrence in each area within the harbor and throughout the year. Once the likelihood of occurrence and the potential effects are estimated, alternative strategies can be explored to minimize any possible impacts from the proposed activities.

## H) **Likelihood of Possible Impacts to Turtles**

The likelihood of any impacts of sand mining operations on turtles will certainly be related to the likelihood of turtle occurrence within the area, especially at the time of dredging.

Although there is little documented evidence of sea turtles inhabiting Lower New York Harbor and Raritan Bay system in recent decades, a cautious approach is warranted. This strategy also is in concurrence with the guidelines of Section 7 of the Endangered Species Act and the development of a Biological Assessment to determine if formal consultation is desired (50 CFR, Part 402.12).

In keeping with the premise that sea turtles may inhabit the New York and New Jersey Harbor Complex, there would be three primary assumptions: 1) sea turtles occur in the harbor complex on the same seasonal schedule as they do in the rest of New York and northeastern U.S. waters; 2) the ecological requirements for sea turtles in the harbor complex are similar to those of other sea turtles in the region; and 3) habitat preferences of sea turtles within the harbor complex are similar to those observed for turtles in nearby waters. Using these three assumptions as guidelines, a measure can be provided to estimate the potential current suitability of the harbor complex in general, and the proposed sand mining habitats in particular, with respect to sea turtles. The ultimate objective of such a habitat suitability index, is to assign some likelihood of occurrence of sea turtles in specific habitats in the New York Harbor and Raritan Bay area, and conversely, to designate times and areas in which dredging operations are less likely to affect turtles.

1) Activity Season

As a consequence of the regular and highly similar behavior observed among turtles of different species and from different years, the temporal and spatial positions of sea turtles in the entire Northeast Region can be reasonably predicted (Morreale 1999). Using a mathematical model that was designed to predict seasonal movements of sea turtles along the Northeastern coastal waters (Fig. 6 and Fig. 7), it is possible to designate a period during which turtles would not be expected to occur within the New York Bight and within Raritan Bay. By using a generalized model, we can predict with confidence the times when interactions with turtles would be unlikely, despite the lack of sea turtle observation data in the bay complex. The model that was first developed using satellite telemetry tracks of juvenile loggerhead turtles, was tested using several hundred observations of four species of sea turtles during CETAP studies in 1978-1982 (for details, see Shoop and Kenney 1992). Using pre-determined confidence limits of 95%, the mathematical model encompassed more than 94 % of all turtle positions in the CETAP data set. Thus, the model was a successful predictor of seasonal positions of turtles in coastal waters within the region (Morreale 1999).

The underlying biology of the turtles, and their predictable migration response to declining temperatures, contributes to the model accuracy. In this way, the spatial-temporal model is very effective at predicting when turtles would be clear of the northern coastal waters in the fall. To calculate the expected seasonal activity of sea turtles in Lower New York Harbor and Raritan Bay, the predictive model was applied. Along with the model's 95% confidence limits, an additional buffer of 50 km was added to conservatively predict when turtles would migrate out of New York and Raritan Bay waters (Fig. 8). Using these conservative guidelines, the model predicts that by early October, some turtles are still lagging behind in northeastern waters. By the end of October, however, nearly the entire contingent of sea turtles has left northern waters. More precisely, 26 October was the calculated date after which nearly all sea turtles will have migrated southward to at least as far away as 50 km south of Sandy Hook (below a latitude of $40^{o}$ N). With the possible exception of cold-stunned turtles, which do not wash ashore in all years (Burke et al. 1991), sea turtles do not begin to appear again in the region until the following spring.

The yearly activity cycle for juvenile Kemp's ridleys and loggerheads along the U.S. east coast begins in early spring. In early March, many individuals of both species reside in southern waters. By April, the numbers of juveniles in Atlantic waters of Florida decrease (Henwood 1987, Henwood and Ogren 1987, Schmid 1995) and young turtles begin to show signs of activity farther north, from Georgia to North Carolina (Epperly et al.1990, Musick et al. 1994, Epperly et al. 1995*a*, Maley et al. 1994). In May, as water temperatures continue to rise farther northward, Kemp's ridleys and loggerheads begin to appear in Virginia (Lutcavage and Musick 1985, Keinath et al. 1987, Keinath et al. 1994), and by June, juveniles begin to arrive in New York (Morreale and Standora 1994, Morreale and Burke 1997) and New England (Bleakney 1965, Shoop and Kenney 1992). In eastern Long Island waters, young sea turtles do not appear until June, but it is reasonable to expect that they could arrive in the Lower New York Harbor and Raritan Bay area as early as May. Thus, there would be a window of time between 26 October and 1 May during which it would be highly unlikely to encounter live sea turtles anywhere within the New York Harbor and Raritan Bay.

2) <u>Depth</u>

During the warmer months in the Northeast juvenile sea turtles spend much of their time in apparent foraging behavior along the bottom in shallower embayments (Morreale and Standora 1990; 1991; 1998). Over several years of tracking studies of individuals during the active season, turtles mainly occurred in areas where the water depth was between 15 and 49 ft. This was interpreted not to be an upper physiological depth limit for the turtles, since these same turtles can dive deeper than 330 ft while migrating (Morreale 1999). Rather, this depth range is probably a natural limiting depth where light and food are most suitable for foraging turtles (Morreale and Standora 1990). There are some records of individuals that spent some time at the shallowest edge of this depth range, and occasionally in shallower water (Morreale and Standora 1991), but nearly all of the turtle foraging and resting occurred in water deeper than 15 ft.

Using these apparent depth preferences, the digitized bathymetric data for New York and New Jersey Harbor Complex (Army Corps of Engineers GIS database) were reclassified into qualitative categories with respect to suitability for foraging turtles (Fig. 9). Given these new criteria, it was estimated that about one third of the Lower New York Harbor and Raritan Bay system included areas of highly suitable water depths between 15 and 49 ft. This applies to the channels extending from Sandy Hook Channel East, and westward through the Lower and Raritan Bays, all of which are maintained by Army Corps dredging. None of these channels exceed the depth preference of juvenile turtles, and could even be attractive habitats. Most of the rest of the area was considered to be marginally suitable habitat, with water depths of less than 15 ft.

The different depth ranges among the four proposed sites of dredging probably provide a measure to further ranked the sites in terms of suitability for turtles:

– The **Keyport** borrow site is the shallowest area of the four proposed sand sources. With mean low water depths ranging from 3 to 9 ft, this site is estimated to be the least likely to support a resident group of foraging sea turtles.

– The **Union Beach** and **Point Comfort** borrow sites are very equivalent in terms of depth ranges and their estimated suitability for sea turtles. With depths at mean low water ranging mostly between 5 and 13 ft, these two sites were still considered only as marginally suitable habitat, but slightly more likely to be attractive to sea turtles than the Keyport site.

– The **Sandy Hook** borrow area is more heterogeneous in depth, encompassing parts of False Hook, a shallow sand spit, and extending into two different deeper water channels. The mean low water depths of False Hook range from 6 to 15 ft. These waters comprise the majority of the borrow site. On the northeastern section of the site, the bottom slopes down and joins the edge of the east branch of Sandy Hook Channel. Water depths there, ranging from 20 to 43 ft, all are in the depth range that was considered suitable for resting and foraging turtles. Similarly, the southern portion of the proposed site runs across a natural channel area with depths of 19 to 20 ft. This area also would appear to provide more suitable depths for sea turtles that might be in the area. The combination of slightly deeper water over the False Hook portions and the suitable depths over the channel portions of this site, make the Sandy Hook site the most likely of the four sites to support turtles.

The suitability of the sites for sea turtles with respect to depth preferences may be important in determining their presence during warmer months. However, it is not the sole determining factor. To assess overall suitability, other important environmental factors need to be superimposed.

3) Current

Although a small sea turtle apparently can swim against strong currents, they rarely are observed in habitats with such current in New York waters (Morreale and Standora, 1990, 1991). This may be related simply to energy expenditure necessary to remain stationary in a current. In general, when juvenile turtles were tracked through areas of current of two knots or greater, they tended to pass through quickly in the direction of the current (Morreale and Standora 1989, 1990, 1991). If the current was opposed to the direction of travel, they often moved toward the sides of the channel and waited for the next tidal change to pass on through. For the most part, turtles in the summer foraging mode spent most of their time in slow-moving or still waters, usually in bays and harbors.

This apparent preference for slower moving waters was translated into three suitability categories for sea turtles, with which the New York and New Jersey Harbor Complex were classified as either highly suitable, marginally suitable, or not suitable (Fig. 10). The original values of maximum tidal velocities were placed into three intervals that matched the preference categories respectively: < 1 knot; 1 to 2 knots; and > 2 knots. These current velocities were obtained from a data set in which there were only very slight changes in the values reported over a 30 year period within the harbor complex (U.S. Coast and Geodetic Survey Tidal Current Charts).

In the resulting categorization of the harbor complex based solely on current preferences of sea turtles, most of the Lower New York and Raritan Bays were classified as highly suitable habitat. The Ambrose Channel was deemed unsuitable because of its high peak flow exceeding 2.5 knots, and the areas adjacent to it were marginally suitable. In addition, the East Branch of Sandy Hook Channel and the Terminal Channel that leads to the Navy Pier were classified as marginal habitat because of moderately high tidal flows. All four of the proposed dredging sites had current regimes that were suitable for sea turtles.

4) Benthic Biota

The main dietary items of juvenile loggerhead and Kemp's ridley turtles in New York waters are spider crabs, lady crabs, rock crabs, and to a lesser extent blue crabs and mollusks (Burke 1990, Morreale and Standora 1992*a*, 1992*b*, Burke et al. 1993*a*, 1993*b*, 1994). Relative densities of crabs within the NY Harbor and Raritan Bay were summarized from sampling data gathered in a study of the Lower Harbor in 1994 (Army Corps of Engineers, New York District). Data on benthic crustaceans from False Hook were collected even more recently (U.S. Army Corps of Engineers, New York District 2000). The original studies provided distribution and abundance data for three species of crabs, which were used to categorize the harbor into two types of regions: higher and lower crab densities (Fig. 11). The relative densities of crabs were calculated to be high within Raritan Bay and up through the middle of the Lower New York Harbor, with a reduction in numbers of rock crabs away from the main channels, and an increase in lady crabs in the southern Lower Bay and throughout most of Raritan Bay. At False Hook the density of crabs was high, and most of these were lady crabs, and spider crabs.

The same type of abundance data were analyzed for mollusks within the entire harbor complex. The mollusks included in the categorization scheme were general groupings of bivalves and gastropods. These were similarly grouped into higher and lower density regions that were intended to be reflective of potential quality of habitat for sea turtles (Fig. 12). Most of Lower New York Harbor and Raritan Bay system was classified as higher density mollusk habitat, with consistently high densities in Raritan Bay. The False Hook benthic community also had a high density of mollusks, dominated by the blue mussel.

The abundance of food items is not necessarily a direct indication of the presence of sea turtles. In the several seasons of telemetry studies in New York waters, sea turtles were most often found to pass through many different habitats, where food was abundant, before taking up residence in other areas of abundant benthic invertebrates (Morreale and Standora 1991, 1992*a*). The clarity of water and light penetration may have a further influence on the turtles' choice of food-rich habitats. Nevertheless, because food abundance would be ultimately important, it was considered a potential indicator of the quality of the habitat and its suitability for sea turtles.

With respect to food abundance, the Keyport site would be the least suitable of the four proposed borrow areas for sea turtles. Benthic samples near this site, indicated that the shallower waters around Keyport host a benthic community that is dominated by polychaete and oligochaete annelids, along with amphipods and isopods (U.S. Army Corps of Engineers, Waterways Experiment Station 2000), all common indicators of tidal and muddy flats. These tidal and subtidal communities were not found to support sea turtles in nearby Long Island waters (Morreale and Standora 1994). The Point Comfort site has components with high and medium densities of mollusks, but on the whole appears to be roughly equally suitable to the Union Beach and Sandy Hook sites. All three of these sites were characterized as suitable habitat for sea turtles' common benthic food items.

5) Bottom Substrate

Bottom substrate is probably less likely to be a primary factor in determining the distribution of sea turtles than are season, current, and food abundance. However, it was noted over several seasons of study in New York that young foraging sea turtles were most often associated with areas containing sandy substrates (Morreale and Standora 1989, 1990, 1991). The association with this habitat may reflect the turtles' preference for other factors that relate to bottom type, such as currents, food, cover, or light availability. For instance, while the common spider crab occurs on many substrates, lady crabs and rock crabs are more commonly associated with sandy bottoms (Williams, 1984). As such, the type of substrate may be only a general indicator of habitat suitability for summer foraging sea turtles.

A digitized data base containing numerous classifications of bottom sediment type within the harbor complex (Army Corps of Engineers GIS database) was consolidated into three main substrate categories. A substrate type was assigned to one of the categories based solely on its main soil component: sand, silt, or gravel (Fig. 13). The primary substrate category was sand, which comprised most of the New York Harbor complex. This was deemed to be the habitat type of highest suitability for sea turtles. Toward the outflows of the estuaries, where the water was shallower, there were some silty habitats, especially in the western Raritan Bay. This silt plume seems to completely encompass the Keyport site. In addition to input from the larger estuaries, the shallower waters near Keyport may be influenced by sedimentation from nearby marshes (U.S. Army Corps of Engineers, Waterways Experiment Station 2000). However, because the silt is mixed with a generally sandy substrate, it was considered as marginally suitable habitat for turtles. The substrates at the other two Raritan Bay sites were classified as suitable for turtles. There also were some small pockets composed primarily of gravel, but none were reported in the Raritan Bay or Sandy Hook sites. At the Sandy Hook borrow site, the sediment was very recently characterized as muddy sand, with less than 2% shell hash (U.S. Army Corps of Engineers, New York District 2000), also making it suitable for sea turtles.

6) Calculated Overall Habitat Suitability

Using the habitat classification schemes from the measured environmental variables, GIS models were constructed by intersecting the five different spatial layers. The spatial models were used to determine overall suitability of the different regions of the harbor complex for sea turtles, and specifically focused on the areas near proposed borrow sites. In both the resulting different GIS models, there was a hierarchal structure in which the time of year was an overriding factor in determining habitat suitability. That is, habitat could only be designated as suitable for sea turtles between the dates of 1 May and 26 October. At all other times of year, the habitat was considered unsuitable, and therefore highly unlikely to support turtles.

Within the seasonal activity window, both models then dealt with the other five spatial variables differently. In the first model there was equal importance given to the environmental variables of depth, current velocities, crab density, mollusk density, and substrate quality (Fig. 14). In this stringent spatial model, a specific habitat was only considered suitable for foraging sea turtles if it represented the intersection of high-quality habitat for all five of the environmental variables. The resulting habitats that were calculated to be of high quality were confined mainly to the central portions of Raritan Bay, and some portions of the Sandy Hook site. Using this model less than one quarter of the entire Lower Bay and Raritan Bay complex, an area of approximately 5500 hectares, would be designated as suitable habitat for foraging sea turtles.

In the second model, the calculated suitable habitat represented areas in which the key environmental variables were either of high quality or of marginal quality (Fig. 15). Using these less restrictive criteria, the resulting area that was deemed to be suitable for sea turtles increased to 59% of the entire Lower Bay complex. The calculated area of more than 14,000 hectares represented mostly an expansion of the areas that were calculated as suitable in the previous model. Thus, in this liberal model, most of the Lower Bay and Raritan Bay were highlighted, along with most of the proposed Sandy Hook borrow site.

The nature of the methods used in these spatial models probably makes them rough estimates of what would be suitable habitat if turtles were present. Turtles move around and are not as strictly bound by environmental quality as the first model implies. However, they have certain requirements that must be fulfilled if they are to remain active and healthy in a foraging area. Therefore, it may not be acceptable for a turtle to live in a habitat that only marginally meets these requirements, as the second model permits. Furthermore, neither model really assigns differential value to any of the five environmental variables that are all subservient to the season of the year. If turtles were most influenced by food availability, then a marginal crab density might render the area totally unsuitable for summer foraging. Or if the available light were too low to feed by sight, then even if habitat were good by all other accounts, it might be unsuitable for turtles.

The spatial models are intended to sort out and highlight the general areas that are more likely to support sea turtle populations during the warmer months of the year. As such, they may be used as a guideline to direct activities, such as sand mining, that may disturb sea turtles within the area. Although there are very few reported observations of sea turtles in Raritan Bay, the habitat suitability models would be a very good place to start when designing future studies aimed at censussing and studying the ecology of sea turtles in the area. The models at least provide the basis for a testable set of habitat criteria. More importantly, these spatial models help identify the more likely turtle habitats, which could greatly reduce the effort involved in monitoring the tens of thousands of hectares in the entire Lower Bay and Raritan Bay complex.

## I) **Possible Impacts to Turtle Habitat**

The primary factor influencing sea turtle presence is seasonal temperature pattern, which clearly would not be affected by any dredging or sand mining operations. Within the seasonal window of regional sea turtle activity, the predicted impacts of dredging would depend first on whether or not turtles already occur at that specific site, and whether they are present in the general area. The best way to approach this question, without direct studies focused on sea turtles, is to use the above model for determining the likelihood of sea turtle presence based on habitat suitability.

The Keyport borrow site is most likely too shallow for sea turtles in its present state. Likewise the Union Beach and Point Comfort sites are somewhat shallower than foraging turtles appear to prefer. If presence were strongly influenced by this single factor, sea turtles would not be expected to linger in these areas, and therefore would unlikely be encountered during dredging operations. Some portions of the Sandy Hook site on False Hook, are of comparable shallow depths, but the remainder of this site is well within the preference range of turtles in the region. Thus, the likelihood of their occurrence at Sandy Hook would be greater. However, the other habitat characteristics such as the current regime, food abundance, and substrate quality need to be examined. For the Keyport site, the suitability with respect to some of these measures is questionable. Thus, overall, Keyport appears unlikely to be an attractive site for sea turtles. The other three sites, however, all appear to provide enough adequate resources to make them more likely places to encounter turtles. Based on all of these requisites, the main area of concern would appear to be Sandy Hook, followed by Point Comfort. The Union Beach site would appear less likely to be of concern than these two sites.

If sea turtles are not physically harmed by the dredging gear, the main impact to them would most likely be measured by the effects of dredging activities on their food sources: crabs and some mollusks. In this case, there probably would be no immediate proximal effect to the turtles, but only indirect effects caused by the alteration of the existing biotic assemblage. Turtles are not very easily affected by changes in water quality, increased suspended sediments, or even by moderate alterations of flow regimes. However, if these changes have the effect of subtly making the habitat less suitable for turtles, in the long run sea turtles would tend to leave or avoid these less desirable areas, especially if they became food limited.

Ironically, the dredging activity will result in changes to some of the key habitat characteristics in the borrow areas. The sand mining activities, by there very nature, will affect the depth to varying degrees, depending on the approach taken by the Army Corps; namely, whether a lot of sand is removed from a single area, or smaller amounts are removed from multiple areas.

Additional predictive models of altered flow and sedimentation patterns would greatly aid the evaluation of potential impacts on the habitat quality and future attractiveness for sea turtles. Upon superficial examination, it would appear that substantial removal of sand and silt at specific sites would make them deeper, and possibly more suitable for turtles.

J) **Possible Alternative Approaches**

The main choices involve focusing on one of the sites to be used exclusively as the borrow pit, or to choose multiple sites among which to distribute mining activities. The different alternatives would each seem to have merit with regard to impacts on sea turtle habitat. In one scenario, dredging activities could be confined to a relatively small portion of the entire Bay, and could focus on the least likely of the four sites to support sea turtles. Alternatively, dredging could be less intensely directed at any one site, but instead, spread among the three less likely sites. The area of impact would be greater, but the subsequent changes to each of the sites should be less. Regardless of the alternative selected, an attempt should be made not to create an attractive habitat for turtles, then continue dredging the same area without further consideration.

K) **Recommendations**

The planning, design, and implementation of the Raritan Bay shoreline nourishment project should take into account the likelihood of the presence of sea turtles in each of the specific proposed areas where sand is to be dredged. The overall likelihood of negative encounters with sea turtles during dredging operations probably will be influenced greatly by seasonal and spatial patterns of turtle activity, in connection with choice of dredging gear type. An important objective in the planning should be to conduct dredging operations in a way to minimize potential interactions with sea turtles.

The following hierarchy incorporates both the expected temporal and expected spatial patterns of usage of the New York and New Jersey Harbor Complex by sea turtles. As such, these can be used as guidelines for determining the activity schedule and best locations for sand mining activities within the Lower Bay and Raritan Bay estuary complex.

1) <u>Temporal Usage by Sea Turtles</u>

The least likely time of year to encounter live sea turtles in the New York and New Jersey Harbor Complex is during the several months between 26 October and 1 May. This period of more than six months should be considered the Safe Operational Window, during which time all borrow sites can be dredged with very minimal potential of interacting with sea turtles.

*Recommendation 1*: During the Safe Operational Window, concentrate dredging activities at the borrow sites where the possibility of encountering sea turtles during the activity season is greater. Because the Sandy Hook site seems to be the most suitable, and therefore most likely site to support turtles, operations there should be avoided, or should occur only during the months when sea turtles are not in the region. Alternatively, the Keyport site is unlikely to support an assemblage of foraging turtles at any time, so would be a better candidate site for dredging during the season of regional sea turtle activity.

2) <u>Spatial Usage by Sea Turtles</u>

Within the Lower New York Bay Raritan Bay Estuary Complex, there are specific habitats where sea turtles are less likely to be encountered, even during the activity season between the dates of 1 May and 26 October. Based on GIS analysis of the key habitat features of depth, current, benthic biota, and substrate, the proposed borrow sites can be classified in order of likelihood of encountering sea turtles as follows:

<u>Least Likely</u>

**Keyport Borrow Site**

<u>Marginally Likely</u>

**Union Beach Borrow Site**

**Point Comfort Borrow Site**

<u>Most Likely</u>

**Sandy Hook Borrow Site**

*Recommendation 2*: Concentrate dredging operations in areas designated as "Least Likely" within the regional season of activity of sea turtles, between the dates of 1 May and 26 October. If dredging operations are scheduled during the warmer months in borrow sites where and when sea turtles are more likely to be present, extra precautions should be taken to prevent incidental take of sea turtles in dredges. These can take the form of gear type changes or gear modifications. Or removal and exclusion of turtles prior to daily activities. Also, extra monitoring efforts should be planned at these sites.

3) <u>Gear Type Choices, Modifications, and Preventive Measures</u>.

If turtles are present, the type of dredging gear selected to be used at the site strongly influences the number of turtles killed. Currently most turtle deaths in dredging operations appear to be linked to the use of Hopper Dredges. Turtles resting on the bottom become impinged on the underside of the dragheads and often get extruded through the screens. There have been some indications that in cases where sea turtles are present, using different dredging gear can reduce the number of interactions between dredges and turtles.

*Recommendation 3*: During the expected season of sea turtle activity in the region, there should be trained observers on all dredging vessels within the entire Lower New York Bay and Raritan Bay Complex. Observers should not be there for the sole purpose of reporting body counts. Instead, observers should be on board to assess for potential sea turtle presence in the immediate area, and should be used to enable an immediate response to avoid interactions.

*Recommendation 4*: Where sea turtles are present, alternative gear types that have been demonstrated to lower the probability of mortality should be used. This almost always entails using some form of dredge other than a Hopper Dredge.
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*Recommendation 5*: If hopper dredges must be used during a time and within an area where turtles may be expected, gear modifications that have been shown to be effective in reducing the take of sea turtles should be employed. There are some examples of these, such as the rigid reflectors that have been designed for dragheads on Hopper Dredges. Another possible means of reducing interactions with dredges may be the removal of sea turtles by trawler from the immediate vicinity prior to dredging on a daily basis.

*Recommendation 6*: A concerted effort should be made to investigate the timing occurrence, distribution, and the ecology of sea turtles in the New York Bight. This is the site of intense human activity, much of which relates to the future need for further similar dredging and beach nourishment activities by the Army Corps. Studies aimed specifically at understanding sea turtle ecology in the area will greatly streamline the planning of future operations, mainly by enabling us to more precisely predict where, when, and if sea turtles are inhabiting these waters.

4) Monitoring and Testing Alternative Dredging Strategies.

Dredging activity will result in changes in bathymetry, benthic environment, and community structure at the borrow sites. These changes could greatly influence sea turtle presence by removing critical habitat or, conversely, by creating new attractive habitat. The degree to which sand mining will impact turtles will partly depend on whether much sand is removed from any single area. An alternative strategy would entail removal of smaller quantities of sand from multiple areas. There appear to be relative merits of each of these strategies, or even a combination of the two, when estimating potential impacts to sea turtles.
*Recommendation 7*: Dredging operations that minimize the overall impact to the habitat, with respect to the key requirements for sea turtles, should be favored. By monitoring changes in site characteristics during the course of operations, appropriate decisions can be made regarding future dredging strategies. If the habitat at the borrow site is exhibiting signs of being severely degraded, alternative sites should be considered. Planning should remain as flexible and adaptive as possible.

*Recommendation 8*: Changes in depth, substrate, and food abundance at the borrow sites should be monitored through time. Regardless of the alternative selected, an attempt should be made not to create an attractive habitat for turtles, then continue dredging the same area without further consideration. If borrow site habitats become suitable for sea turtles, new dredging strategies should be developed.

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Fig. 1. The proposed project areas are within the Lower New York Harbor and Raritan Bay Complex, located at the apex of the New York Bight. Proposed sites of excavation are in nearshore areas along southern Raritan Bay and east of Sandy Hook. With nearby cities of New York, Newark, Bayonne, and Jersey City, this is a region of very high human density and much boating, commercial shipping, and military traffic all year.

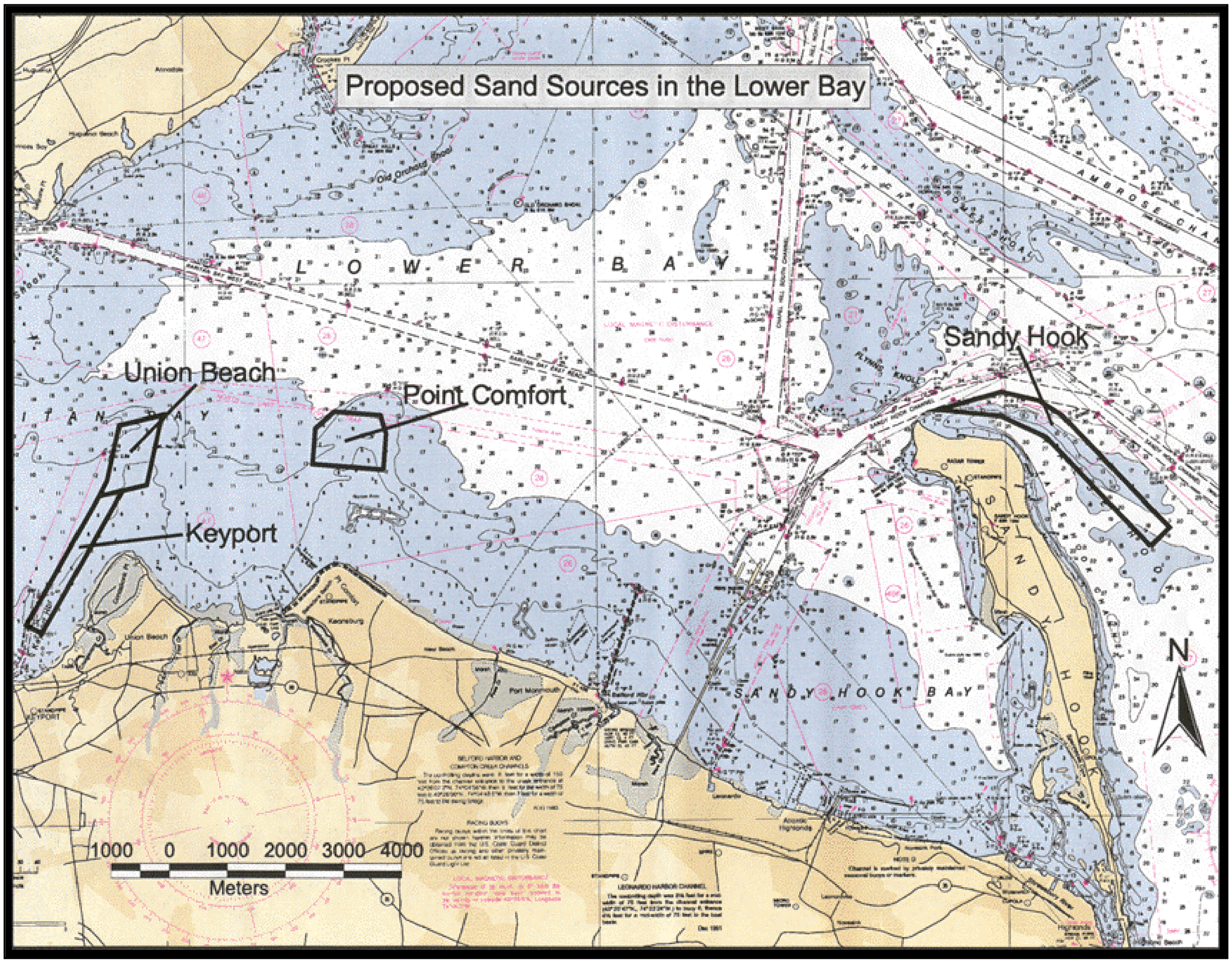


Fig. 2. The four proposed nearshore sites designated as possible areas from which sand will be mined. Three of the proposed borrow sites are within Raritan Bay, and a fourth is in ocean waters east of Sandy Hook.

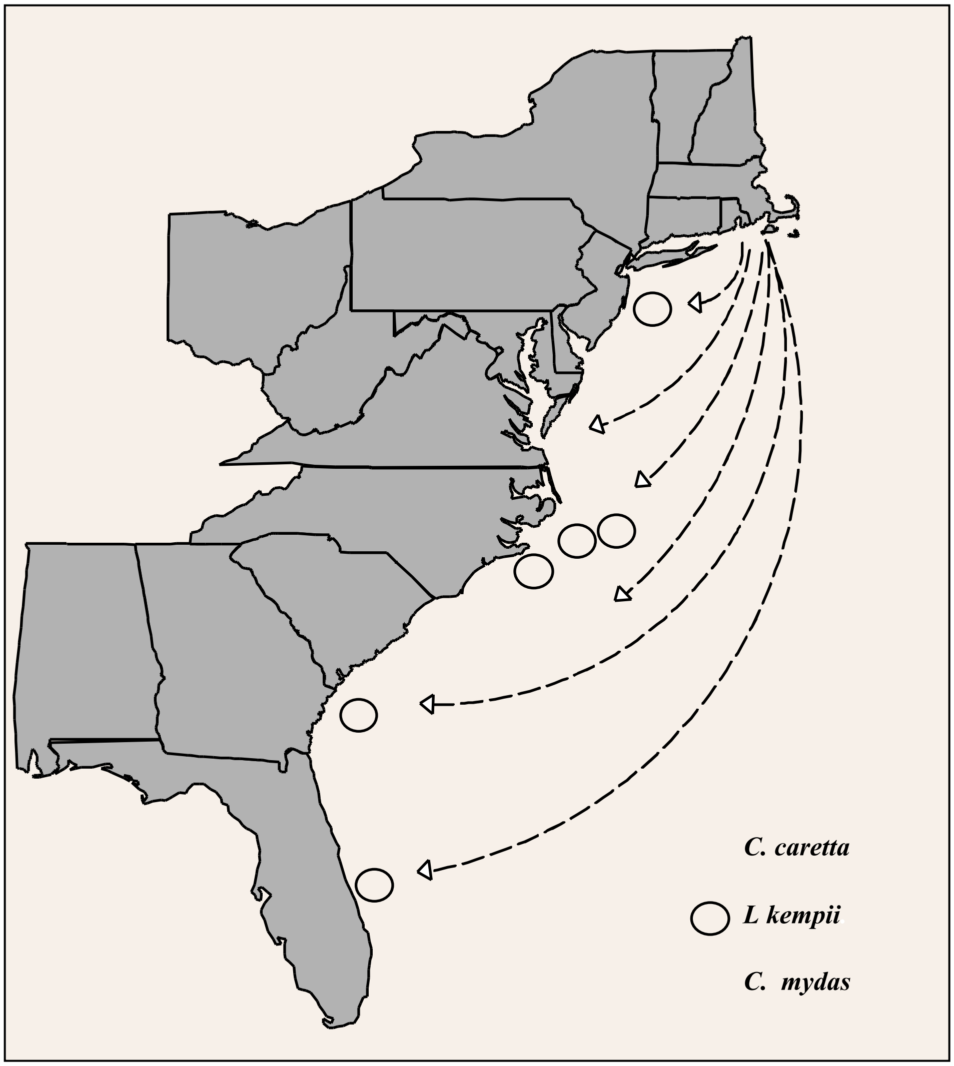


Fig. 3. Long-distance recoveries of 11 juvenile sea turtles of three different species originally tagged in New York waters. Dashed lines indicate unknown migration routes from New York to the other regions along the Atlantic coast.

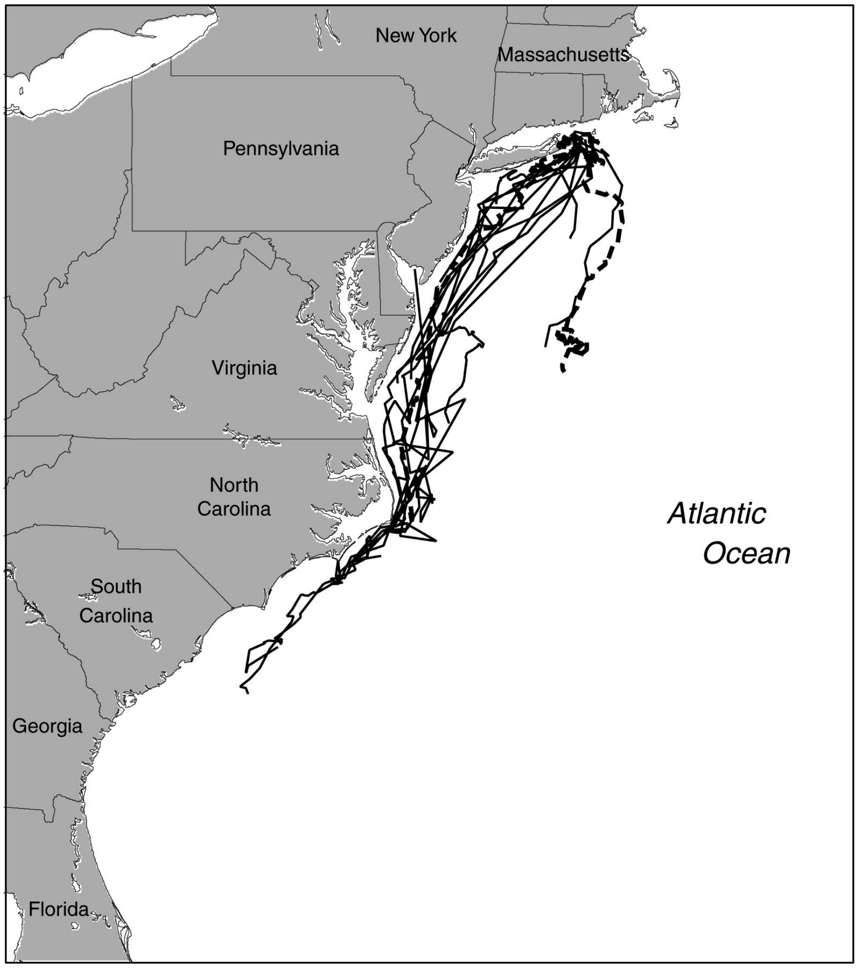


Fig. 4. Fall migrations of 15 juvenile turtles monitored by satellite after leaving from New York waters in studies over five different seasons. The migratory paths of the three *Lepidochelys kempii* individuals (dashed lines) are almost indistinguishable from those of the *Caretta caretta* (solid lines). All of the turtles monitored swam directly southward within continental shelf waters. Most of the turtles traveled along a very narrow coastal corridor that conveyed them to North Carolina by early winter. Late winter travel is not included in this figure.

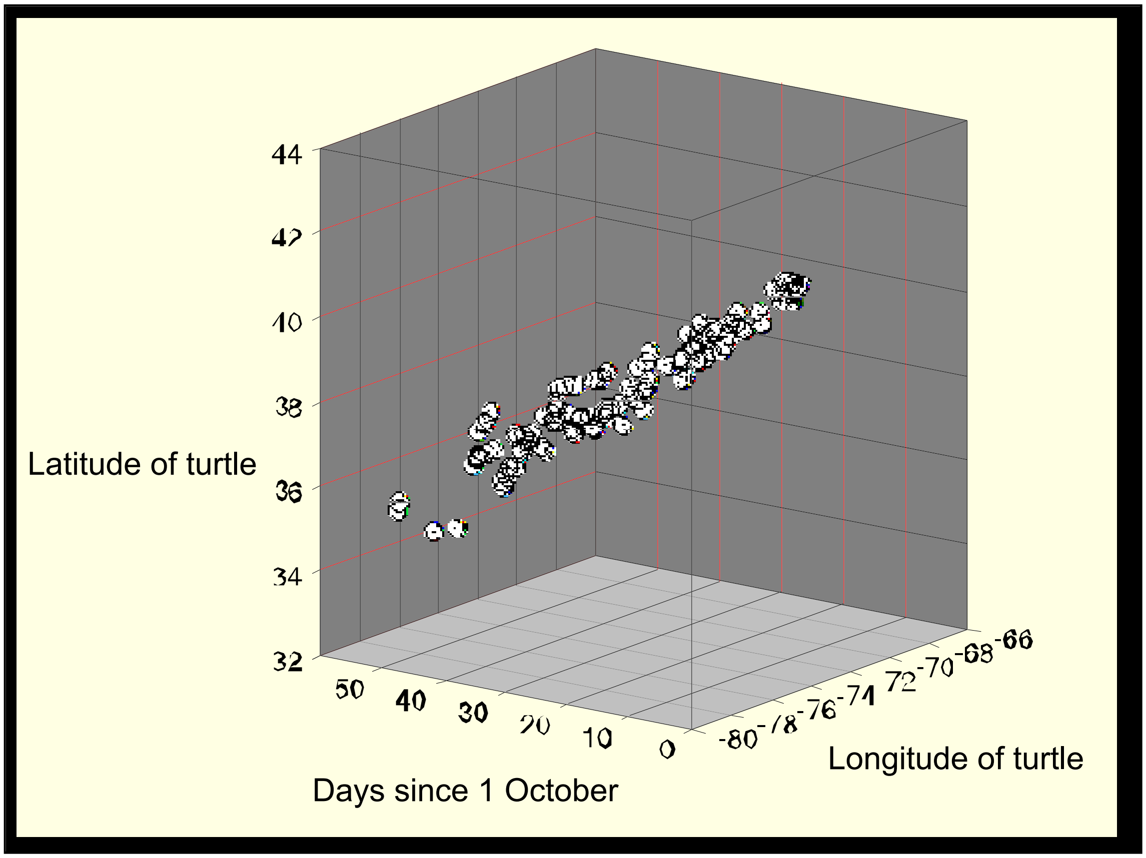


Fig. 5. The movements of eight loggerhead turtles in the fall of two consecutive years depicted as three-dimensional coordinates. The movements of migrating turtles are tightly grouped, both spatially and temporally, as they swim southward migrated from New York to North Carolina waters.

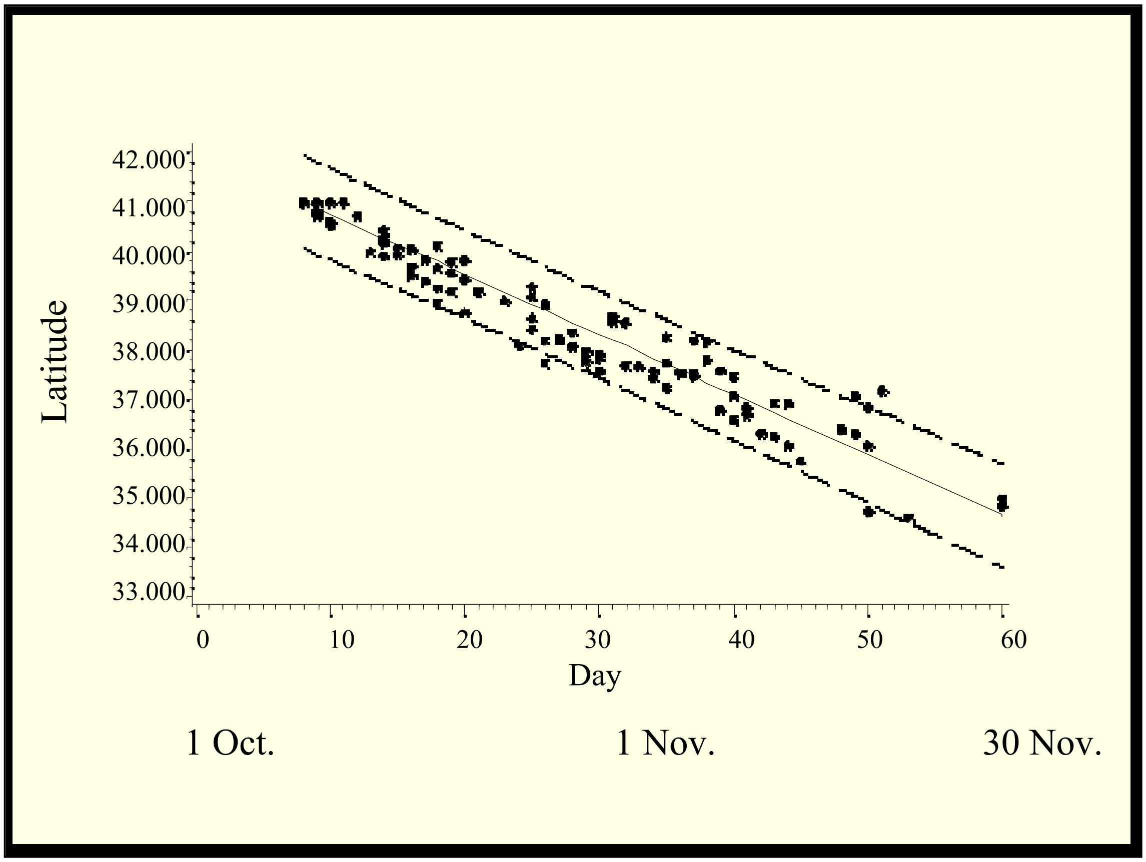


Fig. 6. The close relationship between the latitude of migrating turtles and the date during the fall season as a result of applying a mixed model on known turtle movements. In conjunction with the model for longitude, the linear relationship depicted here is easily used to generate a predictive model of turtle locations along the U.S. Eastern Seaboard.

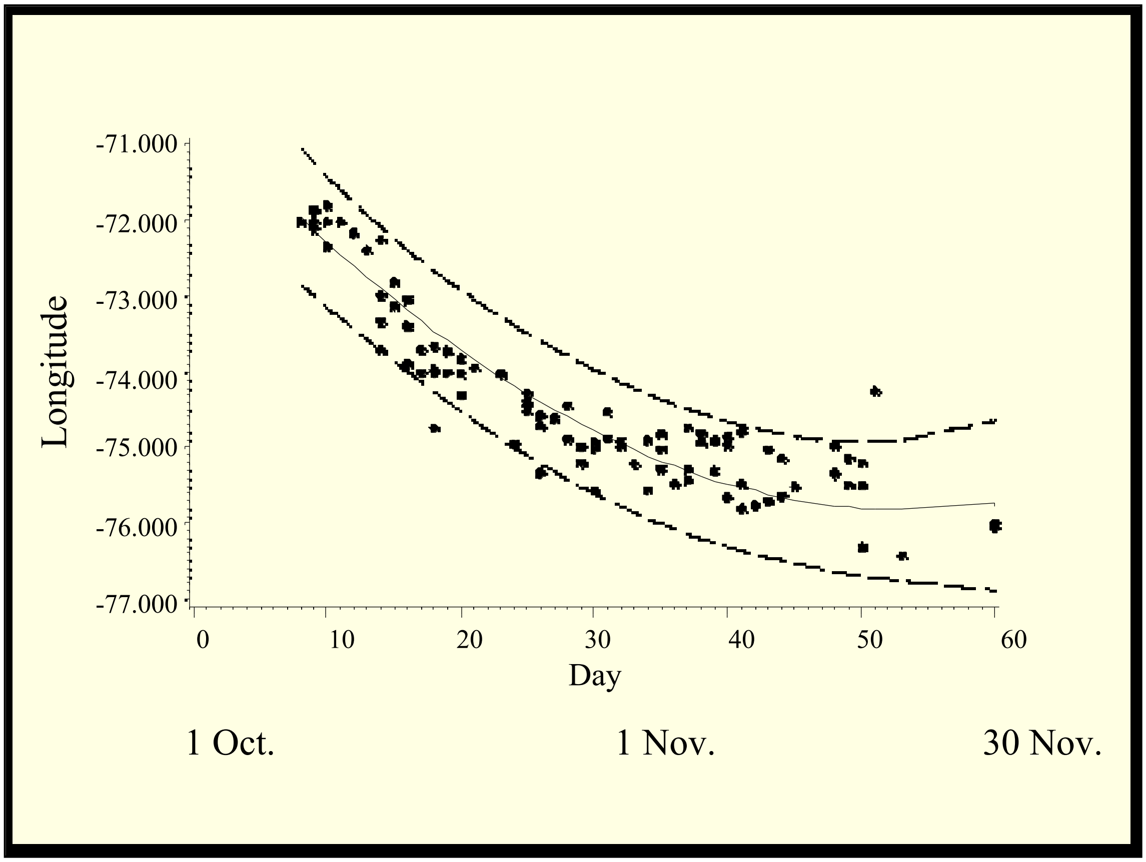


Fig. 7. The close relationship between the longitude of migrating turtles and the date during the fall season as a result of applying a mixed model on known turtle movements. In conjunction with the model for latitude, the quadratic relationship is easily used to generate a predictive model of turtle locations along the U.S. Eastern Seaboard.

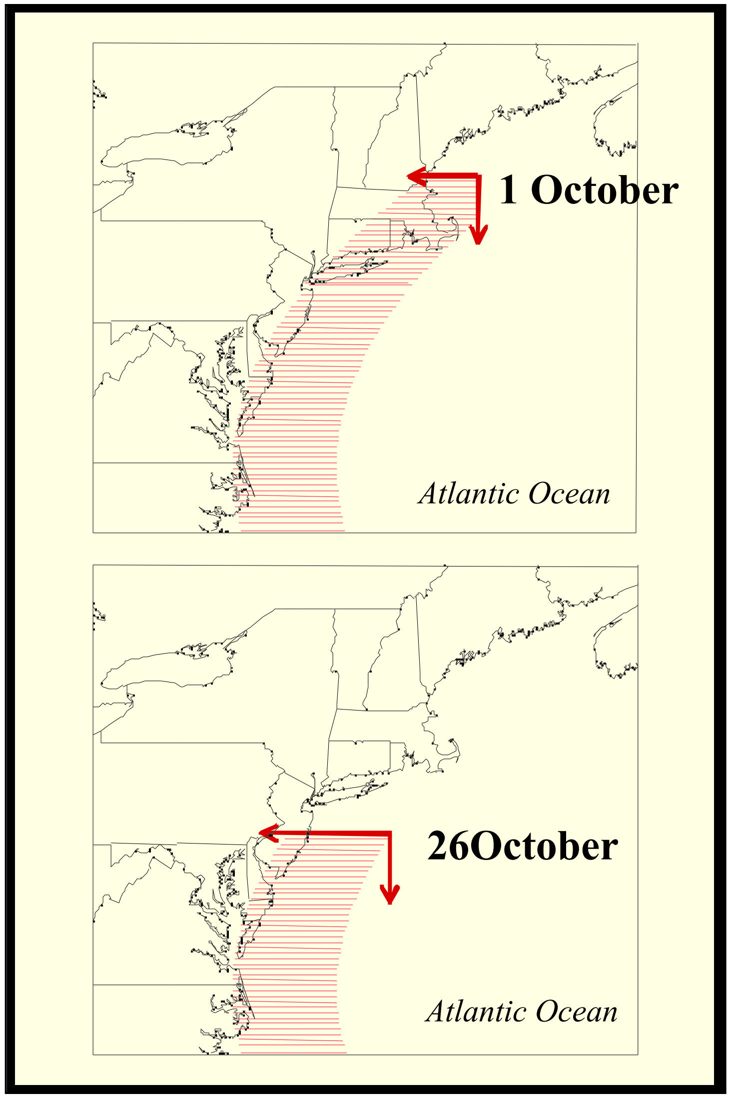


Fig. 8. The predictive model of seasonal sea turtle movements along the continental shelf of the northeastern U.S. During the warmer months, turtles extend far into northern waters. Areas highlighted in red represent waters where turtles are predicted to occur within 95% confidence limits. On 1 October, the region of predicted turtle activity extends into New England waters. By 26 October, the northern contingent of sea turtles has moved southward of 40 North Latitude.

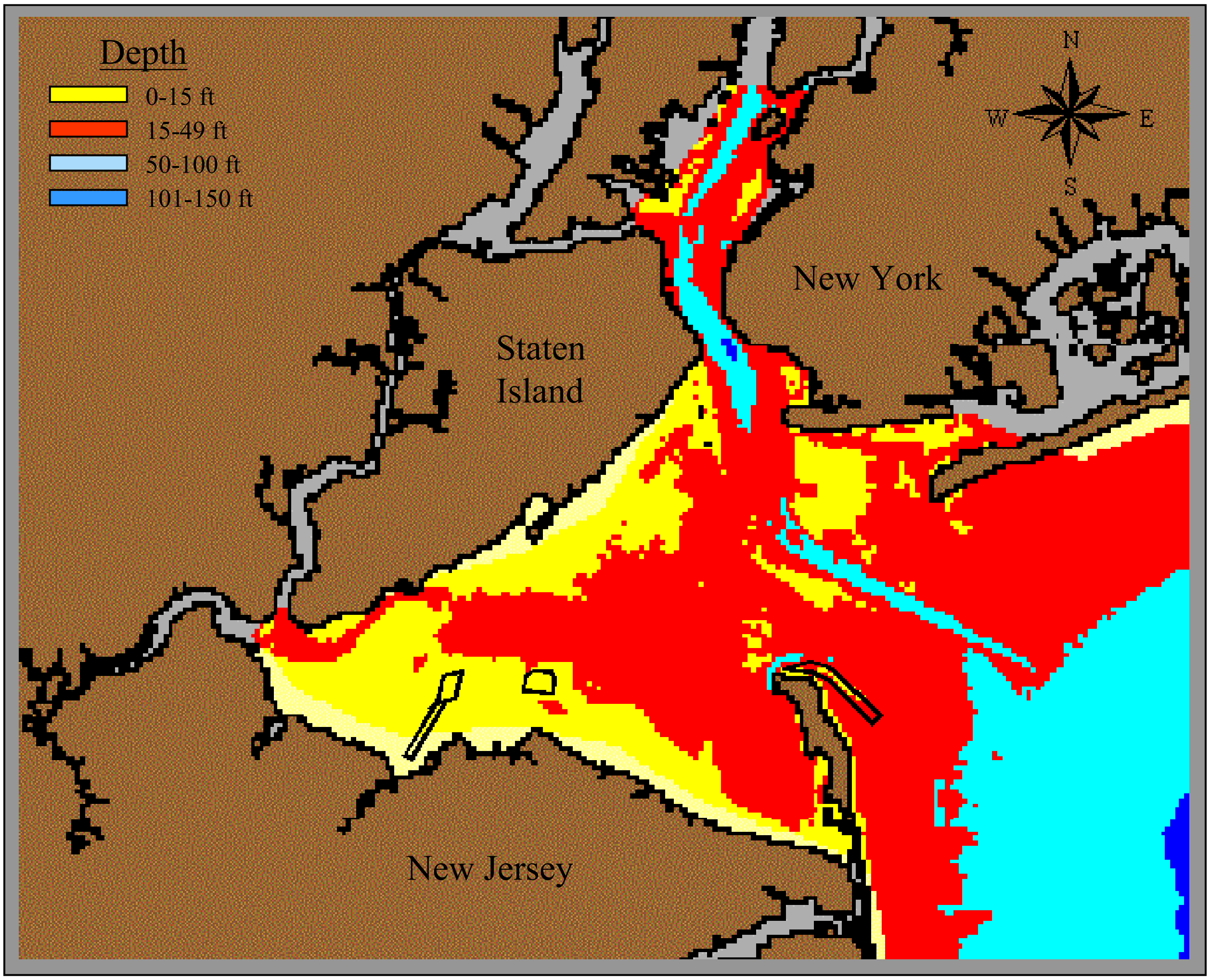


Fig. 9. A qualitative assessment of suitability of the depths within the Raritan Bay and New York Harbor ecosystem with respect to juvenile sea turtles foraging during the warmer season. The regions shaded in red represent the most suitable depths; habitats shown in yellow were considered marginal because they are shallower than preferred depths; and areas in blue were considered unsuitable because they are too deep for young foraging turtles. The four proposed borrow sites are outlined in black. Gray represents no data.

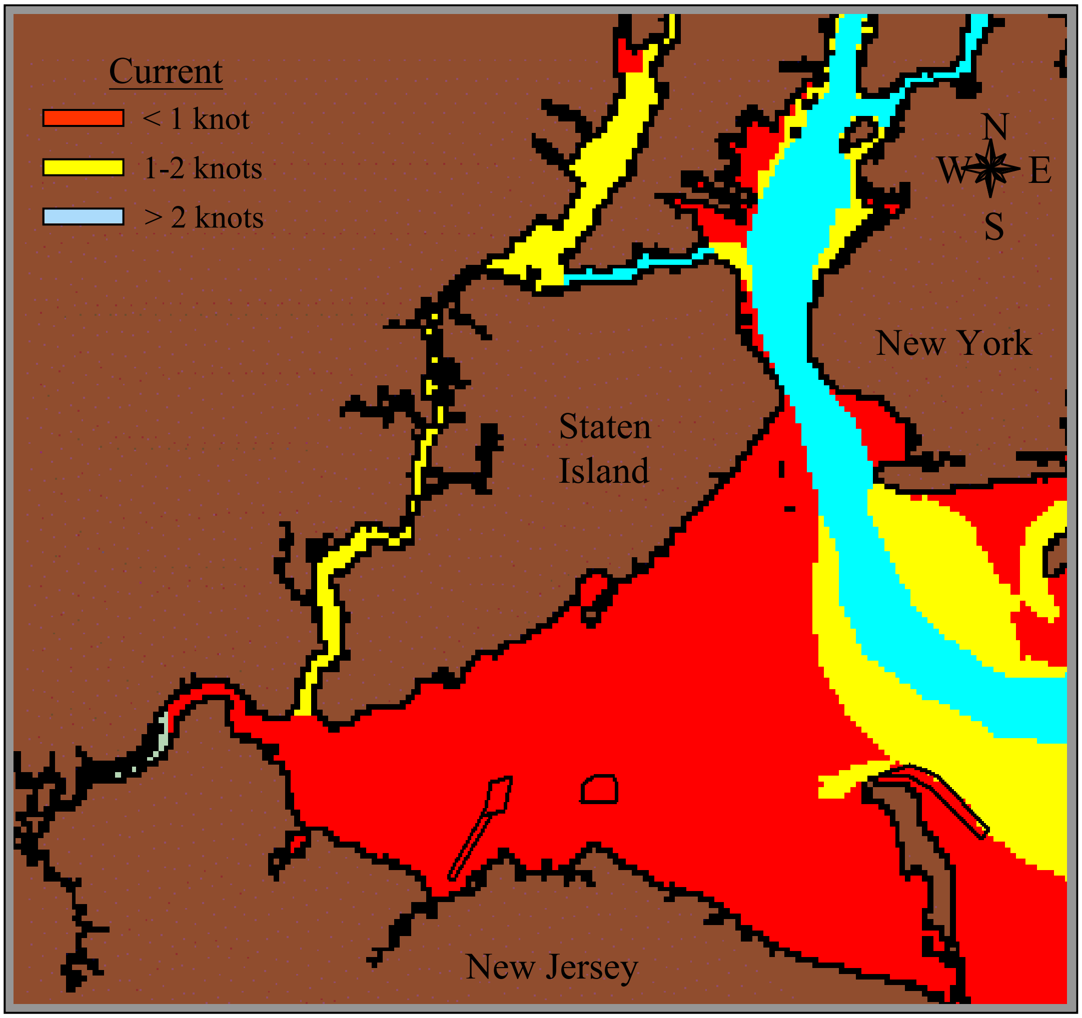


Fig. 10. A qualitative assessment of suitability of the current regimes within the Raritan Bay and New York Harbor ecosystem with respect to juvenile sea turtles foraging during the warmer season. The regions shaded in red represent the most suitable habitats, with current speeds of less than 1 knot at peak tidal exchange. The slower moving channels and the main channel edges with peak current speeds of 1 to 2 knots (yellow) were classified as marginally suitable. The main channels with speeds of greater than 2 knots (blue) were considered unsuitable for turtles. The four proposed borrow sites are outlined in black.

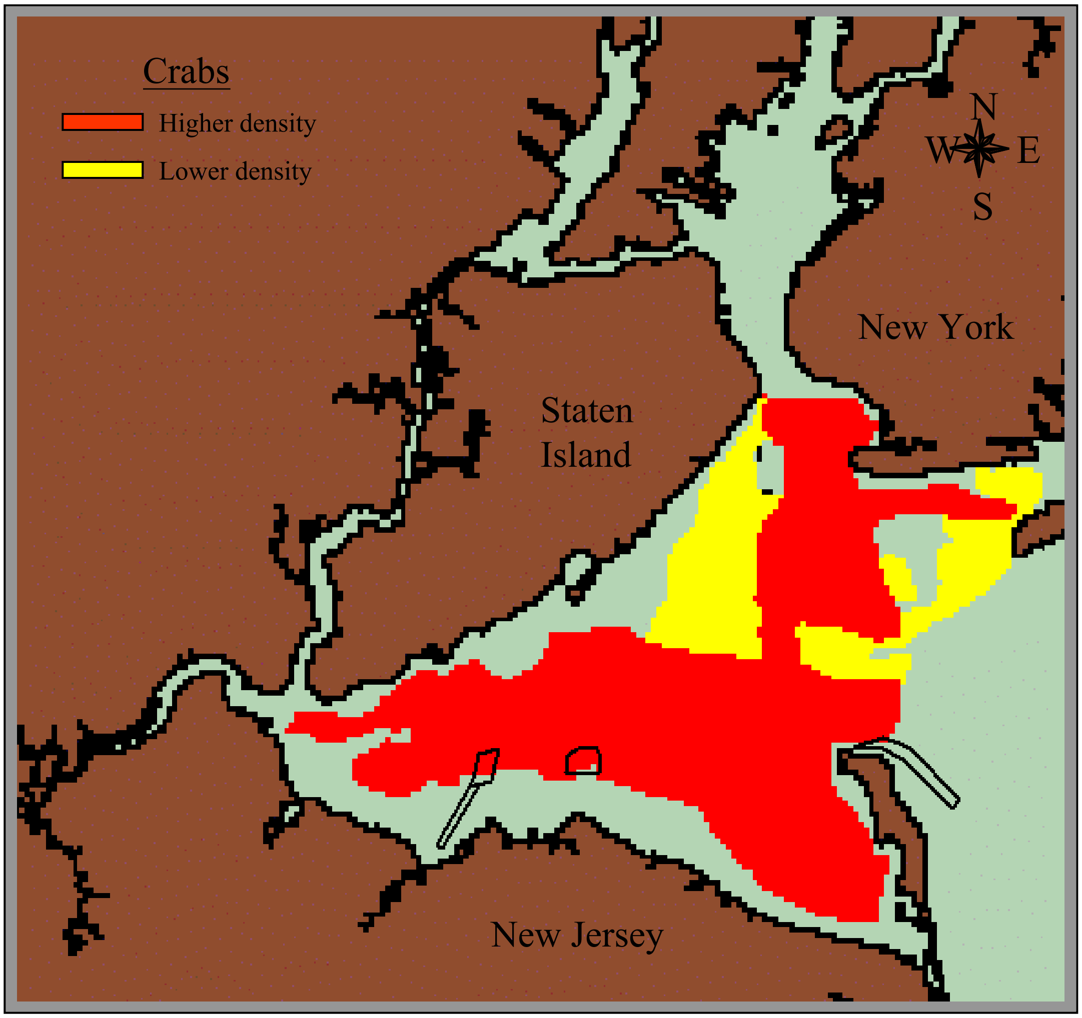


Fig. 11. A qualitative assessment of suitability of the habitats within the Raritan Bay and New York Harbor ecosystem with respect to reported crab densities and foraging sea turtles. The regions shaded in red represent habitats that were considered to be more suitable because of generally higher densities of crabs. The habitats with lower crab densities (depicted in yellow) were considered less suitable. The four proposed borrow sites are outlined in black. Gray represents no data.

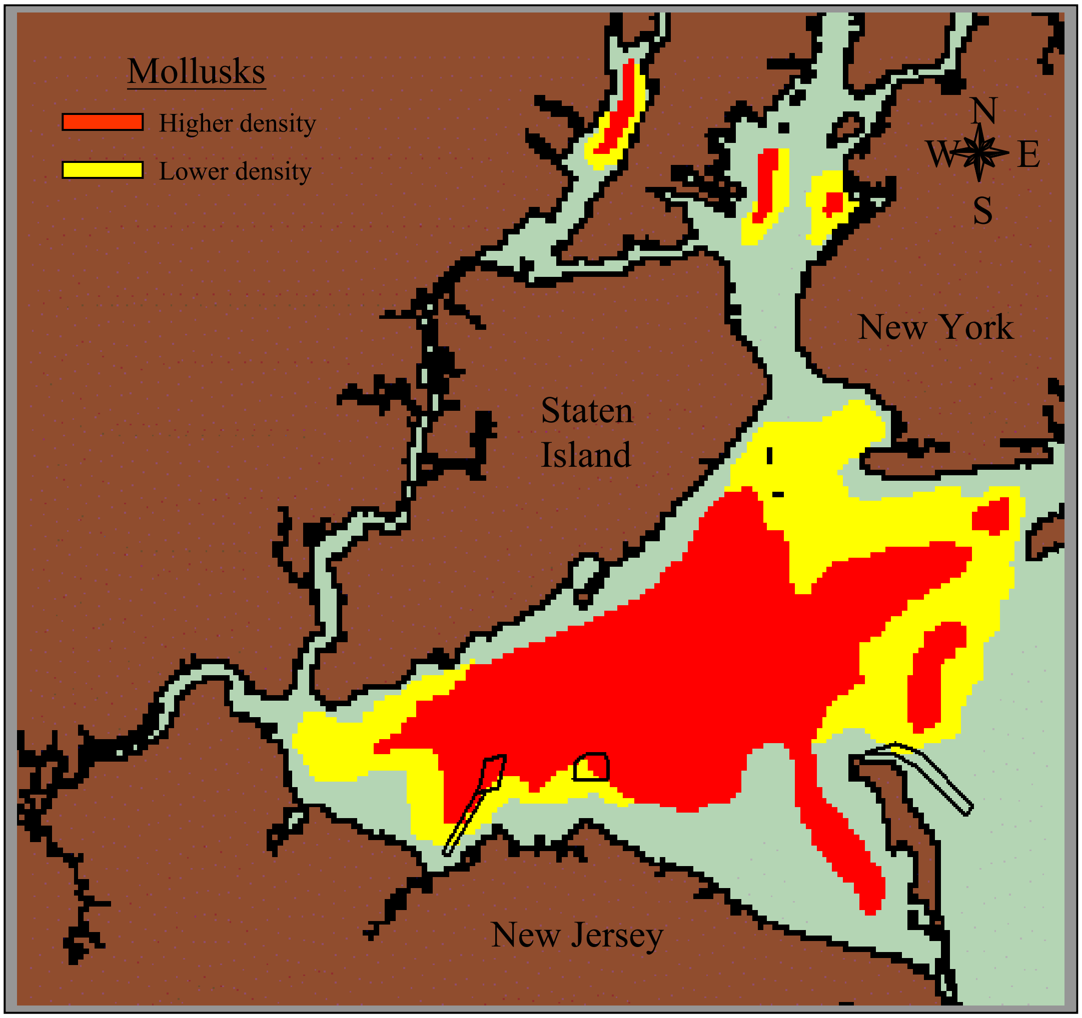


Fig. 12. A qualitative assessment of suitability of the habitats within the Raritan Bay and New York Harbor ecosystem with respect to reported mollusk densities and foraging sea turtles. The regions shaded in red represent habitats that were considered to be more suitable because of generally higher densities of mollusks. The habitats with lower mollusk densities (depicted in yellow) were considered less suitable. The four proposed borrow sites are outlined in black. Gray represents no data.

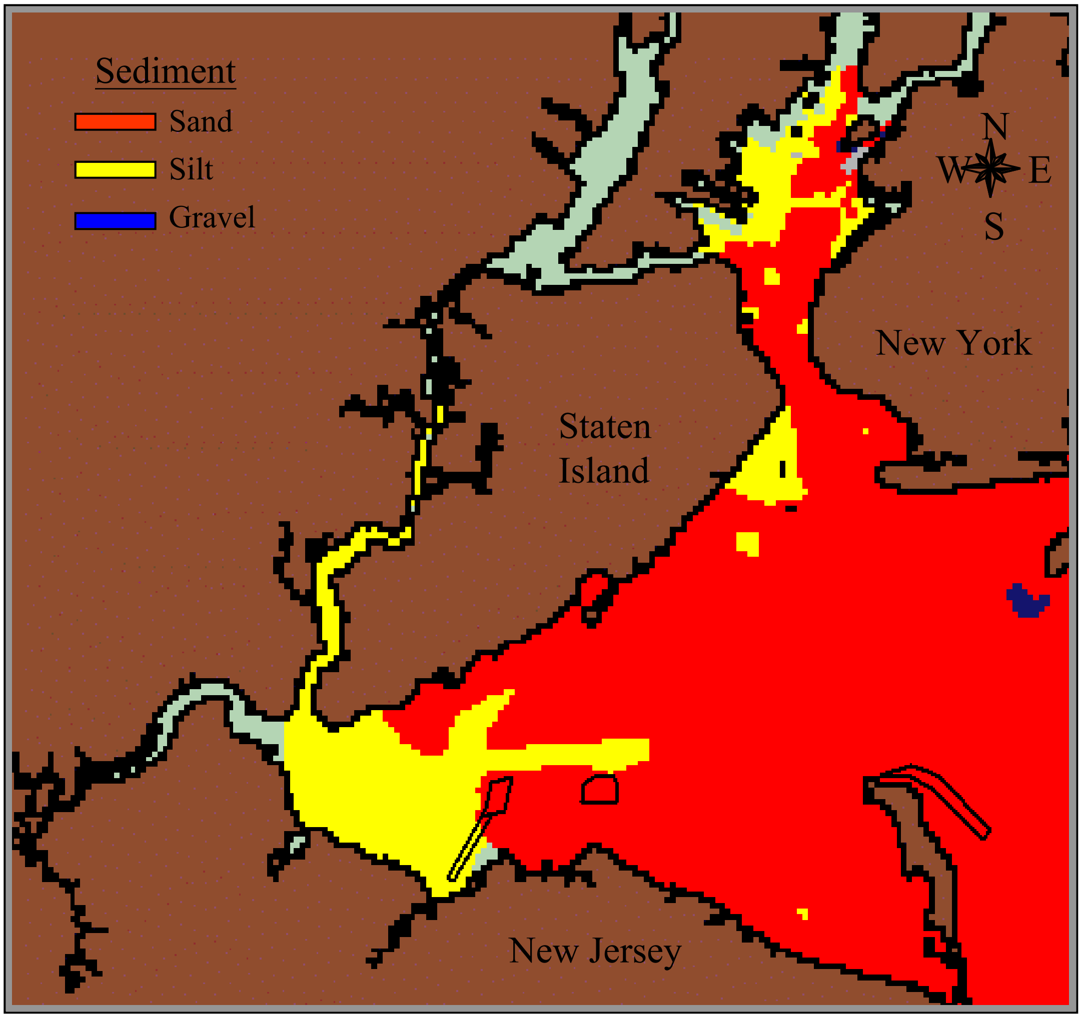


Fig. 13. The habitats within the Raritan Bay and New York Harbor ecosystem were assigned to one of three categories, which corresponded to general substrate characteristics. The primary component of most of the substrate in the harbor complex was sand (red). Sandy habitats were considered to be the most suitable habitat for foraging sea turtles because of their association in previous studies. A few smaller areas were composed of silt (yellow), and gravel (blue) which were considered to be less suitable for turtles. The four proposed borrow sites are outlined in black. Gray represents no data.

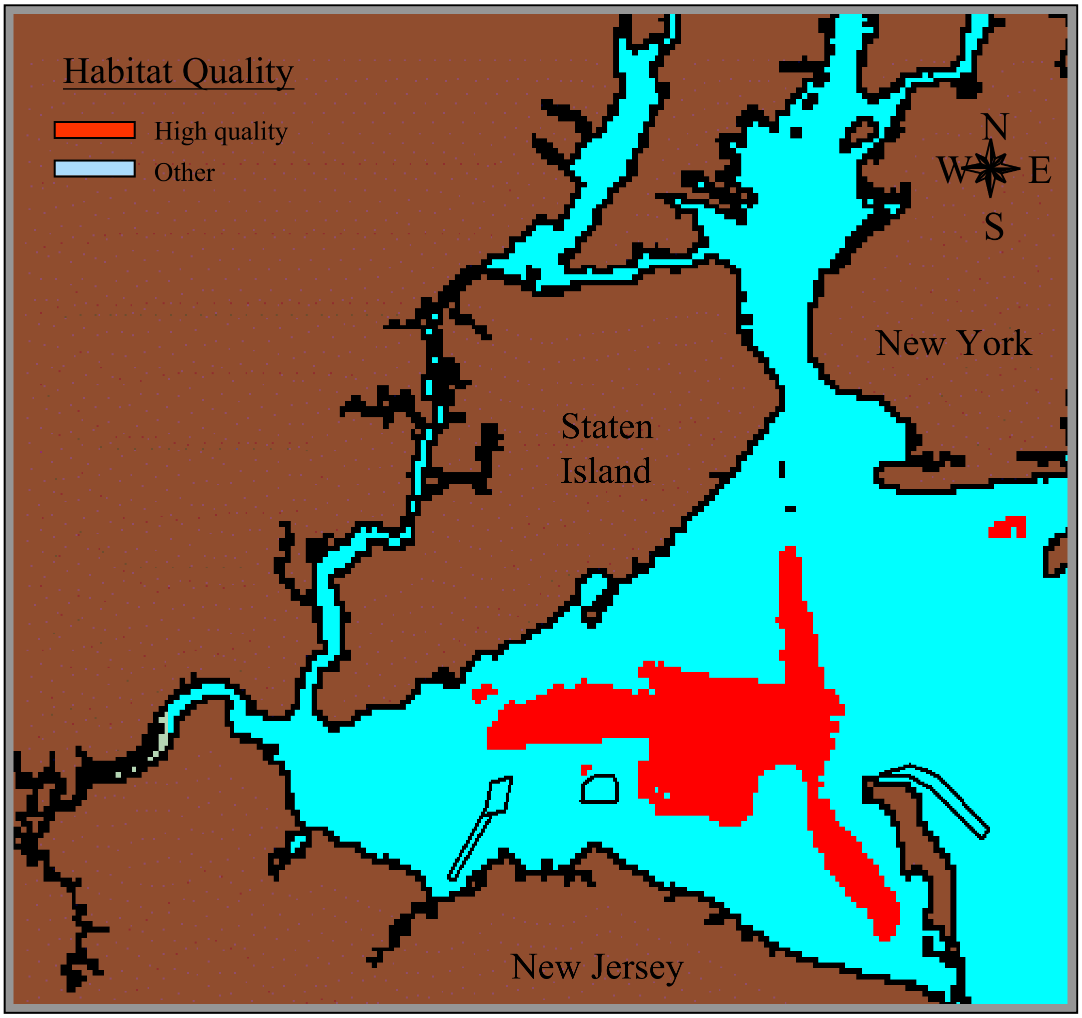


Fig. 14. A spatial model was constructed to depict habitat suitability for sea turtles between 1 May and 26 October within the Raritan Bay and New York Harbor ecosystem. In this rigorous model, habitat was strictly defined as suitable for sea turtles only if it was designated as high quality with respect to all of the five environmental variables. Using these criteria, nearly all of the suitable habitat for turtles was confined to within Raritan Bay, but outside of the proposed borrow sites.

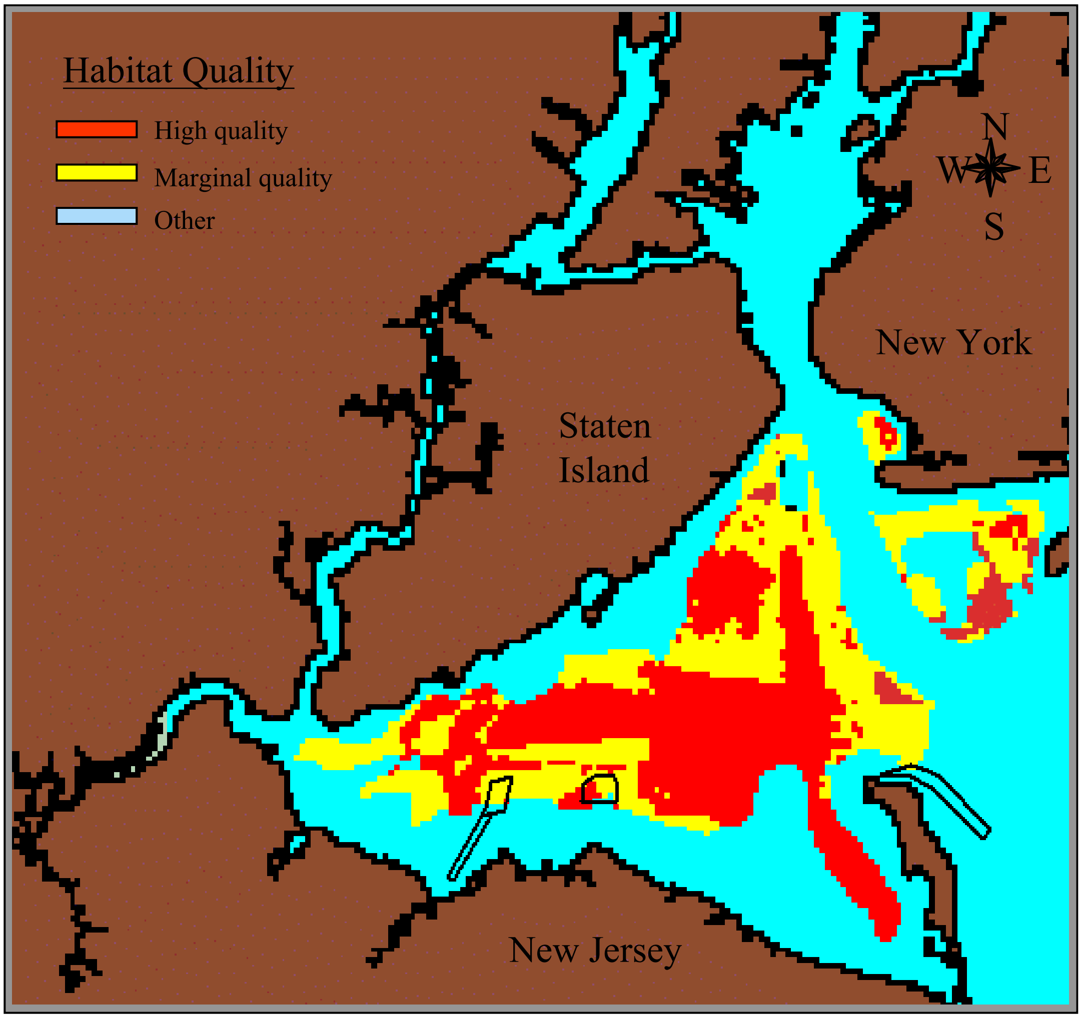


Fig. 15. A less rigorous, and more cautious, spatial model was constructed to provide a broader measure of habitat suitability for sea turtles between 1 May and 26 October within the New York and New Jersey Harbor Complex. The criteria were expanded to include areas that were classified as either of high quality or of marginal quality with respect to the five chosen environmental variables. Habitats in the two suitable categories combined (red and yellow), comprised 35% of the total harbor complex, much of it within Raritan Bay. In two of the proposed borrow sites, Union Beach and Point Comfort, most of the habitat was deemed suitable for turtles; only a small portion of the Sandy Hook site was suitable; and there was no suitable habitat at the Keyport site.