Avian Use of the Hampton-Seabrook Estuary: 2006-2007

Shorebirds at the Route 286 pools, Seabrook. Photo by Peter McKinley

Phase 1 of the Hampton-Seabrook Estuary Conservation Project

A report to the New Hampshire Fish and Game Department,
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by

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Executive Summary

At roughly 5000 acres, the Hampton-Seabrook Estuary is the largest contiguous area of salt marsh and tidal flats in New Hampshire. It represents the northern one quarter of an extensive complex of salt marshes stretching south to Cape Ann in Massachusetts, and known as the "Great Marsh" in the latter state. Salt marshes worldwide have been subject to human impacts for centuries, located as they are in narrow strips along densely inhabited temperate coastlines, and they now face additional threats in the form of climate change and invasive species. At the same time these habitat are areas of exceptional biological productivity and host a diverse array of wildlife and plant species specialized for life in the often extreme ranges of moisture, salinity, and temperature that characterize tidal ecosystems.

Although the Hampton-Seabrook Estuary is almost completely surrounded by development, and subject to extensive habitat alteration in the form of ditching and tidal restriction, it retains significant ecological value and supports a high diversity of wildlife species. The goal of this study was to undertake a comprehensive investigation of bird use of the estuary, with particular focus on migrating shorebirds and salt marsh breeding birds. Such data are largely lacking for estuarine systems in New Hampshire, and can ideally be used to prioritize future conservation efforts that benefit both birds and other wildlife. Key findings from the current study are as follows:

- Roughly 3000-3500 shorebirds of over 20 species regularly pass through the estuary during the southbound fall migration. Significantly fewer use the area in spring, and only a few hundred individuals remain here between November and April. This diversity and abundance make the estuary New Hampshire's most significant migratory stopover site for this group of birds.
- Two thirds of these shorebirds are of only two species: Semipalmated Plover and Semipalmated Sandpiper, with over 1000 individuals each. Populations of the former approach 1% of global population estimates, potentially qualifying the site for inclusion in the Western Hemisphere Shorebird Reserve Network.
- Shorebirds preferentially use two areas of the estuary for foraging:
    - Extensive mudflats at the southern end of Hampton Harbor and at the mouths of Mill Creek and Brown's River.
    - Freshwater or brackish pools along the northern edge of the estuary
- The above areas appear to support higher prey densities than other portions of the estuary.
- At rising and high tides, the majority of shorebirds roost either at the aforementioned pools or within the marsh on slightly elevated *Spartina* banks, including in a relatively natural section of marsh below the state line in Salisbury, Massachusetts.
- Saltmarsh Sharp-tailed Sparrows are not evenly distributed across available habitat. The bulk of the estuary's population occurs in the far northeastern corner of the marsh, with lower numbers in the northwest. Both these areas are characterized by the absence or near absence of salt marsh ditching.
- Breeding Willets occur primarily in either the northeast (as above) or along the lower reaches of the tributaries in the southern portion of the estuary.
- The only Common Tern breeding colony in the estuary is also in the northeastern section.

When these data are taken as a whole, four focal areas can be identified within the estuary as priorities for bird conservation:

- The extensive natural salt marsh in the northeast, including Henry's Pool, a significant shorebird foraging site,
- A less extensive and only slightly ditched area of marsh in the northwest below Drakeside Road,
- The freshwater pool at Landing Road, which serves as an important shorebird roosting and foraging site, and
- The complex of mudflats, creeks, and marshy banks at the southern edge of Hampton Harbor. This area supports a large Willet breeding population and serves the foraging and roosting needs of significant numbers of migrant shorebirds.

Conservation strategies that would benefit birds in these areas and across the estuary as a whole include:

- Restoration of currently-ditched portions of salt marsh that have the potential to support increased populations of Saltmarsh Sharp-tailed Sparrows, and possibly serve as shorebird roost sites.
- Preservation of pools used by roosting or foraging shorebirds, including consideration of the role of continued freshwater inputs. Restoration of pools that have apparently lost function should also be considered.
- Protection of both marsh and adjacent upland to maintain habitat connectivity, minimize external impacts, and possibly allow for adaptation to sea level rise.
- Reduction of human disturbance to roosting shorebirds through land protection or education.
- Increased public education and outreach on the ecological significance of the Hampton-Seabrook Estuary, perhaps with a focus on its role in the hemispheric migrations of shorebirds.

The next stage in this project is to develop a strong conservation plan and partnership for the estuary that uses the best available science to guide decisions that ultimately benefit birds, other wildlife, and the habitat as a whole.

Project Overview

The Hampton-Seabrook Estuary is the second largest estuarine system in New Hampshire after Great Bay. While the overall area occupied by the Great Bay Estuary is significantly larger, Hampton-Seabrook contains a significantly large extent of salt marsh habitat (5000 acres vs. 2230 acres, Figure 1), and this acreage is primarily in a single contiguous landscape block. This landscape includes an interacting mosaic of communities characterized by grasses, peat banks, pools, pannes, creeks, mud flats, sand flats, wooded terrestrial buffers, and freshwater streams that distinguish it qualitatively and quantitatively from the landscape of the Great Bay Estuary.

In addition, the Hampton-Seabrook Estuary is functionally the northernmost point of the "Great Marsh" of northeastern Massachusetts, and in fact drains a significant area of the latter in the town of Salisbury. In this sense it shares a variety of ecological processes and conservation values with this important and comparatively well-protected ecosystem over the state line. Like the Great Marsh, the contiguous landscape structure of Hampton-Seabrook and its salt marsh offers ecological and conservation values that are disproportionately greater than an equivalent, but fragmented area of the same landscape composition.

Estuaries are often associated with high levels of primary production through their phytoplankton and macrophyte communities. While the Hampton-Seabrook Estuary provides this ecosystem function, its unique contribution to the region's ecological productivity is associated with its landscape dominated by salt marsh, harbor flats, and creeks. Estuaries dominated by contiguous blocks of salt marsh offer substrate, refuge, and food to breeding adults, and larval and juvenile stages of many off-shore and near-shore marine vertebrates and invertebrates, and breeding and migratory marsh birds, shorebirds, and passerines.

Salt marshes throughout their range face numerous threats, and those in New Hampshire are no exception (see NH Wildlife Action Plan). Among the greatest threats is fragmentation of marshes by roads or other infrastructure, which often results in tidal restriction and eventual invasion of the marsh by non-native plants such as *Phragmites* and purple loosestrife. Although development of salt marsh is prohibited by wetland regulations, extensive development around existing marshes has the potential to degrade the remaining habitat through either alteration of water quality (contaminants, sedimentation) or altered water flows from freshwater inputs to the marsh. Continued development of adjacent upland habitats has the potential to impact the condition of salt marsh that such buffers historically protected. Development of these buffers and other upstream areas also reduces the ability of salt marsh habitat to "migrate" in response to potential sea-level rise associated with global climate change. Finally, the presence of large numbers of people in estuarine systems such as Hampton-Seabrook can also have direct effects on salt marsh wildlife, either through disturbance by recreational activity (e.g., boating, beach use) or artificially high populations of predators such as feral cats, raccoons, and skunks.

Because of the estuary's known value to both migratory shorebirds and salt marsh breeding birds, New Hampshire Audubon recognized the "Hampton-Seabrook Marsh and Dunes" as an Important Bird Area in 2003. Salt marshes are also among the habitats considered as being at highest risk in the New Hampshire Wildlife Action Plan. However, despite this statewide importance and its central location in a landscape of salt-marsh-dominated ecosystems extending

from northeastern Massachusetts to southern Maine, relatively little conservation work has been done in the Hampton-Seabrook Estuary. Efficient conservation efforts depend upon knowledge of an ecosystem's strengths and weaknesses. To this end, New Hampshire Audubon initiated a two year conservation research program in the estuary designed to inform future restoration and conservation efforts.

The long-term goal of this project is to help New Hampshire's largest tract of salt-marsh-dominated estuary remain ecologically viable into the future. Data collected in the first two years will help inform subsequent conservation actions in estuary; including land protection, water quality and buffer strip policies in the watershed, habitat restoration, and invasive species control. Successful and cost-effective conservation and restoration in this complex system will require identification of the most ecologically valuable portions of salt marsh, harbor flats, creek flats, barrier beach, and associated upland buffers. Phase One of the study was designed to systematically gather data on avian use of the varied habitats within the estuary, and in the process identify important ecological features associated with areas of high use.

To this end, we focused efforts on two distinct components of the Hampton-Seabrook avian community: 1) migratory shorebirds and 2) breeding species typically restricted to salt marshes. These two groups capture the full range of habitats within the marsh, from mud flats and mussel beds to high marsh dominated by grasses and interspersed with pools. They also reflect two very different ecological niches. Shorebirds use the area entirely as a stopover site during their long intercontinental migrations between breeding and wintering areas. Their primary need at such sites is a combination of productive foraging habitat and nearby areas where they can rest and build up fat reserves prior to undertaking the next leg of their journey. In contrast, breeding species arrive in spring, establish breeding territories, and spend the next several weeks within these territories building nests, laying and incubating eggs, and caring for young. They are tied to a location and its underlying ecological condition in ways that transient shorebirds are not. As a result, the two groups of birds are subject to slightly different conditions and threats, and investigation of both is important to gain a full understanding of the value of a given estuarine system from the avian perspective. The migrant shorebird and breeding bird sections of this study have been separated into two distinct sections, each following the format of a scientific paper. Following these parallel sub-reports, all parts of the study are summarized in a single Conclusions and Recommendations section.

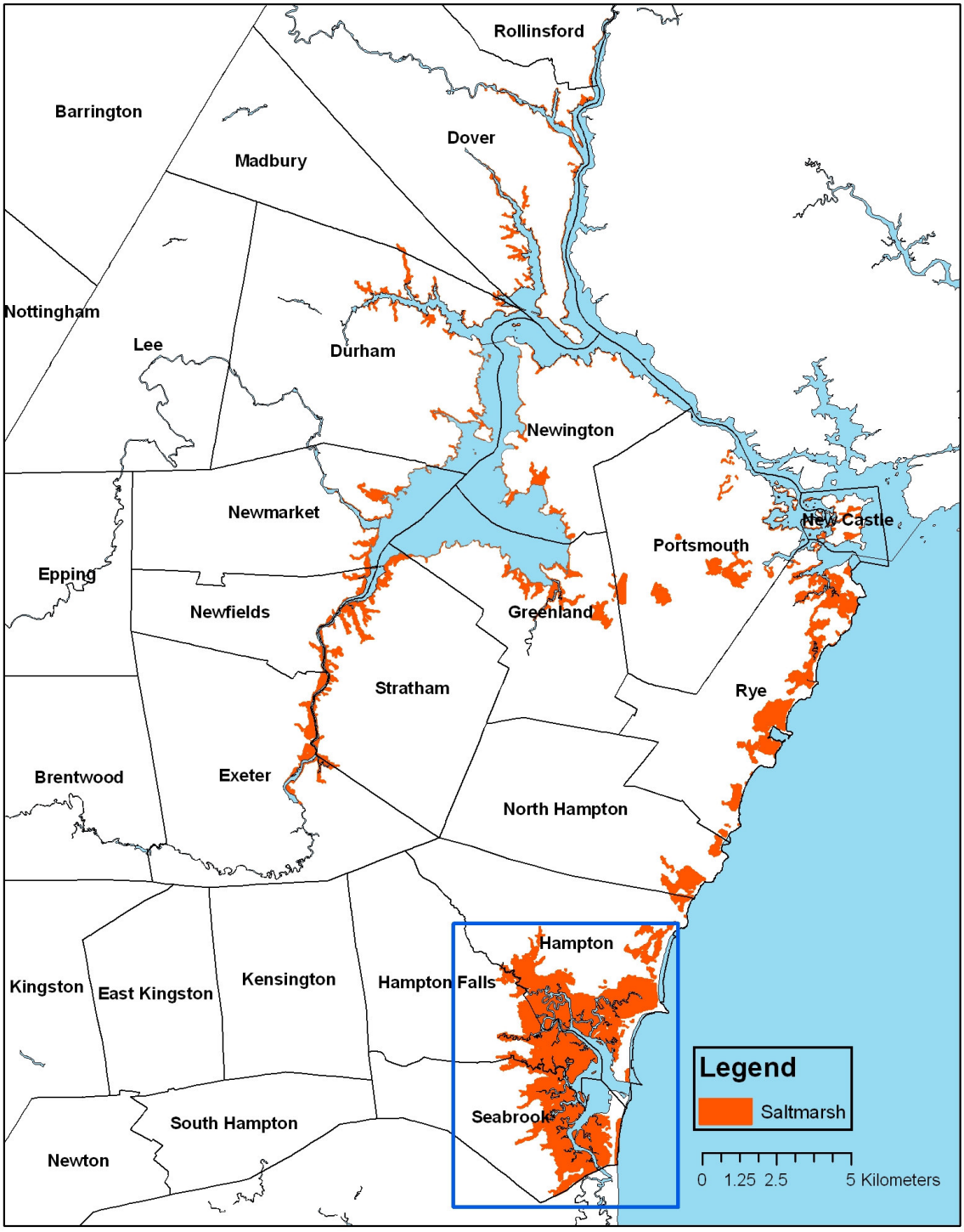


Figure 1. Extent of salt marsh in southeastern New Hampshire. The Hampton-Seabrook Estuary is indicated by the blue outline. Saltmarsh data from the New Hampshire Wildlife Action Plan.

Shorebird Use of the Hampton-Seabrook Estuary: 2006-2007

Introduction

Shorebirds have long fascinated both ornithologists and amateur naturalists because of their exceptional migratory journeys (Matthiessen 1994). The majority of North American species nest in the tundra and high latitude boreal forests of Canada and Alaska, and winter in coastal areas from the Caribbean to the extreme southern end of South America. In between they pass over or stop in a wide variety of wetland or grassland habitats to rest and feed, and consequently this group of birds can truly be considered part of a hemispheric ecosystem.

Stopover habitats are a critical component of this migration system because they provide much-needed sites where shorebirds can rest and refuel after non-stop flights of potentially thousands of miles. Good stopover sites are those that enable birds to replenish fat stores in the least amount of time, especially during northbound migration when there is strong pressure to reach nesting areas and capitalize on the short but productive summer breeding season. Southbound migration is more protracted, and adults often leave soon after young are independent of their parents. The juveniles remain on the breeding grounds for up to a month after their parents have left, resulting in separate peaks of the two age classes at fall stopover sites. By late fall, the majority of species have left the northeastern United States, leaving only a handful that spend the winter at higher latitudes.

This reliance on often a few key stopover sites has resulted in shorebirds facing some unique conservation challenges (Brown et al. 2001). Historically, large numbers were shot for market at sites such as Nantucket and the north coast of the Gulf of Mexico, and this market hunting led to the likely extinction of the Eskimo Curlew and severe population declines for several other species (e.g., American Golden-Plover). While market hunting is a thing of the past, migratory shorebirds now face numerous indirect threats relating to their habitat or food supplies. Depletion of a key food resource at a key site – horseshoe crab eggs in Delaware Bay – by commercial interests is believed to be among the causes of significant recent declines in the east coast population of Red Knots (Niles et al. 2007). Filling or draining of coastal wetlands and development of high tide roosting areas also compromise shorebirds' ability make effective use of stopover sites. Finally, the extensive human presence in most coastal areas results in inevitable interactions between people and birds. For example, repeated disturbance of roosting shorebirds has been shown to increase energy expenditures above energy gains (B. Harrington pers. comm.), a discrepancy that reduces the birds' ability to put on fat and subsequently their chances of surviving migration (Pfister et al. 1998).

To begin to address threats to shorebird populations, the United States Shorebird Conservation Plan (Brown et al. 2001) identifies the following priorities for migrating shorebirds in the Northeast:

1) Begin region-wide coastal surveys conducted by individual state agencies and coordinated by the USFWS throughout the region.
2) Work on-site at known important areas to reduce disturbance, identify and protect critical food resources, and control predation.

3) Significantly improve impoundment management, and coordinate habitat availability throughout the region.
4) Create a strong emphasis on volunteer banding and wardening, as methods to increase awareness.
5) Develop coordinated state and federal satellite habitat mapping, delineating all important shorebird habitats.
6) Establish a number of "all bird" Joint Venture projects.
7) Improve spill prevention and emergency response

Within the Northern Atlantic Region, the following specific strategies to enhance shorebird conservation in New Hampshire were reported by Clark and Niles (2000):

1) Assess existing data on known shorebird areas (breeding and migratory)
2) Conduct surveys of breeding shorebird (i.e., PIPL, UPSA, SPSA, WILL, COSN) populations, habitat use, and productivity.
3) Document migratory shorebird populations, feeding areas, and roosting sites.
4) Develop and implement invertebrate monitoring in shorebird habitats.

In addition, the New Hampshire Wildlife Action plan identifies the need for consistent effort to quantify the seasonal and spatial distribution of New Hampshire's shorebirds.

Because the Hampton-Seabrook Estuary is clearly the most important stopover site for shorebirds in New Hampshire, a key goal of this project was to address the state-specific needs outlined above. In particular, we focused on Strategy 3 (which overlaps with the WAP strategy), with initial efforts at Strategy 4 and Strategy 2 as pertains to Willet breeding populations.

Study Area and Methods

Survey Sites

The importance of the Hampton-Seabrook Estuary to migrating shorebirds in New Hampshire is well known, and thus the object of this study was to gather more detail on shorebird use of the marsh on both a temporal and spatial scale. To this end, an effort was made to survey peripheral areas that were not necessarily visited by casual observers and relate these to patterns seen at more traditional sites. As a result, the entire estuary can be considered the study area, although there was certainly more intensive effort at two categories of sites: traditional feeding sites exposed in Hampton Harbor at low tide and small pools scattered around the periphery of the marsh that are used for both roosting and foraging. Special effort was made to investigate the several creeks that enter Hampton Harbor on the west and north and which are generally inaccessible to casual observers. These areas were regularly surveyed by kayak.

Foraging sites on tidal flats generally occur along a gradient from mud-dominated to sand-dominated. The former is typical of areas at the edges and mouths of smaller creeks, while the latter is found primarily in the main flats. The presence of sand at this location is partially due to dredge spoils. A mix of sand and mud dominates at the mouths of larger creeks. Areas of flat in the main harbor are also characterized by the presence of extensive mussel beds, particularly along the western shore, north flats, and northern edge of the south flats (see Figure 2). Substrate in pools is almost entirely mud.

Shorebird Monitoring

Migrant shorebirds were surveyed regularly from July 20 to November 1, 2006, and from May 2 to September 13, 2007. Intensive surveys took place on a total of 25 days in 2006, or on average every 4 days, with less intensive surveys on an additional 10 days. In 2007, comparable figures are 29 intensive survey days, 4.7 days between surveys, and 16 less intensive survey days. In addition, six brief surveys were conducted from January to April 2007 to monitor bird activity in the marsh during winter and early spring.

Most of the surveys in 2006 were conducted with multiple observers (2-4), with individuals stationed at different sites in the estuary at which they recorded all shorebird activity observed. Data collected included species, number of birds, time, location, behavior, and – if appropriate – direction of movement. Observers were most frequently stationed at the following types of sites: major roosts, pools used for roosting and foraging, and the larger exposed flats at low tide. When possible, 1-2 observers also kayaked into tributary channels to document shorebird activity at these otherwise inaccessible sites. Since times of observations were recorded, it was possible to estimate estuary-wide species counts by adding simultaneous observations together (unless movement was noted, it is assumed that counts within 15 minutes of each other pertain to different birds). In addition, when movement was noted, it was possible to reconstruct the general paths taken by birds as they shifted between foraging and roosting sites within the estuary. Timing of surveys was designed to capture behavior across the full tidal cycle, although in most cases only 3-5 hours were spent surveying on any given day.

Similar techniques were employed in the late summer and fall of 2007, when a focus was on understanding movements to and from a major evening roost located just south of the state line in Salisbury, Massachusetts. In this study, one observer was generally stationed at the south end of Hampton Harbor in a kayak, with a second at the Route 286 bridge over the Blackwater River. When a third observer was present, they were stationed at the northeast corner of Hampton Harbor at the Hampton Marina. These roost movement surveys always occurred on the last rising tide of the day. During the spring and early summer of 2007, and on non-intensive days in 2007, a single observer surveyed the marsh by systematically circumnavigating the estuary and visiting key roosting and feeding sites.

Invertebrate Sampling

Based on data collected on shorebird use during the fall of 2006, 11 sites were selected for invertebrate sampling in 2007. One to eight samples were collected at each site, for a total of 35 sampling locations (Figure 3). All samples were collected within one hour of low tide. All 35 sites were sampled in late April and late July using a 7.6-cm diameter PVC pipe inserted 20 cm into the sediment. The resulting sediment core was placed in a sediment bag and placed in a mixture of Rose Bengal and ethanol for staining. The sample was strained and washed with water in the laboratory, and remaining material sorted in an enamel tray. In addition to the sediment cores, sites at pools were sampled with by dip net in late July. One sample was collected per site using a 15-cm diameter net inserted into sediment at the water's edge. These samples were processed using a strainer in the field. In September 2006 a subset of both pool and

mudflat sites was also sampled by inserting a round-tipped shovel into the sediment and scooping up a shovel-full of mud. As with the dip net samples, this sediment was processed in the field using a strainer.

Results

Twenty-three species of shorebirds were detected in the estuary during the study (Table 1). Of these, 10 occurred in high enough numbers or with sufficient regularity to allow an overview of their spatial and/or temporal use of the study area. One species, the Willet (scientific names in Table B) breeds in the estuary and is discussed in a separate section of this report. The bulk of migrating shorebirds pass through coastal New Hampshire between mid-July and late September, with a much smaller peak from mid-May to early June (Figure 4). Daily totals can show considerable variation (e.g., Figure 5), largely a result of variation in coverage or shifts in concentration areas in response to tides, human activity, or even prey density. Daily totals also tend to show two peaks during a given fall migration, with the former reflecting the bulk of adults and the second (roughly a month later) consisting primarily of juveniles. Temporal patterns of shorebird abundance across a season are generally well known (see Hunt et al. 2004), and will not be discussed further in this document.

Shorebird Abundance

Peak shorebird counts on a given day or week provide only a snapshot of total shorebird use of a stopover site. An accurate assessment of the number of individuals actually using an area throughout a season requires knowledge of the length of time birds remain at a site before continuing their migration. Estimates of this stopover period range from 4-5 days (Farmer and Durbian 2006) to 10 days (Short-billed Dowitcher: Jehl et al. 2001) and 23 days (Semipalmated Plover: Smith and Houghton 1984).

Our data (Figures 4 and 5) often show a gradual decline in numbers of a given species after an initial pulse (e.g., Black-bellied Plover and Greater Yellowlegs in Figure 5), suggesting a single cohort of migrants departing from the stopover site at different times. This pattern generally occurs over a period of 2-3 weeks, and we have thus chosen to use a conservative estimate of three weeks for the stopover period in the estuary. Using this stopover length, we were able to estimate the total population of common species that passed through the study area during a given season (Table 1). Note that these estimates are often lower in 2007 because of the early end to the field season. The estimates are also likely low for species such as yellowlegs and Least Sandpipers that spend significant amounts of time in the marsh where detection and enumeration are more difficult. Taken together, we estimate that 3000-3500 shorebirds use the Hampton-Seabrook Estuary during the peak migration period between late July and late September.

Based on both daily and seasonal population estimates, it is clear that the vast majority of shorebirds using the estuary are of two species: Semipalmated Plover and Semipalmated Sandpiper, with at least 1000 individuals passing through the system in a given fall. Black-bellied Plovers, Greater and Lesser Yellowlegs, Least Sandpiper, and Short-billed Dowitcher occupy a second tier. These species are common and widespread in the estuary, but never approach the high numbers seen for the preceding two shorebirds. One other common species,

the Dunlin, tends to arrive later in the fall, usually peaking after all other species have left, and is the primary species using the site during the winter. Among the rarer species, only the Whimbrel is detected with any frequency.

Shorebird Habitat Use

Shorebirds using the Hampton-Seabrook Estuary during migration have two primary habitat needs: foraging areas and roosting areas. Because most foraging habitat is only exposed during low phases of the tidal cycle, birds seek alternate sites to rest – with limited foraging activity – at or near high tide. Birds also use this resting period to metabolize food into stored fat to fuel the next stage of their migration. In the course of this study, we identified several key foraging and roosting sites, as illustrated in Figure 2 and described in Table 2.

By far the most important sites used for foraging are the flats located in the southern portion of Hampton Harbor. This complex consists of three distinct sites, from west to east: 1) the mouth of Mill Creek, 2) Knowle's Island, and 3) the main harbor flats. Because of differences in elevation, these flats become available at different times during the tidal cycle, and thus provide foraging opportunities across a wider time span than if only a single flat was present. At some point during the study, all but two of the 23 species observed during this study (Piping Plover and Purple Sandpiper, which use different habitats) were seen foraging in this complex. Flats at the northern end of the harbor or at the mouth of the Hampton/Taylor River complex see much less use and lower species diversity, and appear to be used either by larger species (Black-bellied Plover, Whimbrel) or later in the season (Dunlin).

Three sites not directly associated with the harbor flats were also found to be important foraging areas. These were three freshwater or brackish pools in the northern portion of the study area: 1) Meadow Pond, Landing Road pool, and Henry's Pool. All three differ markedly in their characteristics (Table 2), but consistently contained large concentrations of several shorebird species at high tide or, in the case of Henry's Pool, when the main flats were dry and exposed. These pools appear to provide an alternative foraging site when the main flats are not accessible, and also serve as a daytime temporary roost for several species. Similar sites at the western (Depot Road pools) and southern (Route 286 pools) edges of the estuary are used far less often, by significantly fewer individuals, and by a limited number of species.

Selection of roost sites by shorebirds within the estuary is far more complex. Sites identified during this study include freshwater or brackish pools, high points within the marsh, barrier beach, and in some cases human structures such as parking lots. Roost sites that are consistently occupied (e.g., Mill Creek mouth, Route 286 bridge) tend to be high banks at the edge of major tributaries at the southern portion of the harbor. These are dominated by *Spartina* and include substantial amounts of peat. While smaller species such as Semipalmated Plover and Semipalmated Sandpiper will roost in or near pools, these *Spartina* banks are the primary roost site for larger species such as Black-bellied Plover, Whimbrel, and Short-billed Dowitcher. Other roosts within the system are used more opportunistically. A very large roost was discovered on a grassy gravel area at the Fisherman's Co-op in 2006, but its use was limited to extremely high tides when presumably the normal roost sites of the smaller species were flooded. Roosting on the outer beach at Seabrook, and flats near the mouth of Hampton Harbor, was limited to later in

the season (September and October) when these areas were not regularly overrun by people and their pets. A final roost site discovered in 2007 is a high area of marsh south of the border in Massachusetts, which is discussed in more detail below.

Diurnal shorebird movement patterns

During the fall migration of 2006, shorebirds were observed flying south in large numbers to a yet unknown site at the southernmost area of the estuary in Massachusetts. More detailed observations of these movements were conducted in 2007 to elucidate the overall daily pattern of shorebird use of the entire system. From these observations, it appears that 50-90% of the daily populations of Semipalmated Plover, Semipalmated Sandpiper, Least Sandpiper, and Short-billed Dowicher migrate daily between foraging and roosting sites in the Salisbury Marsh and foraging sites in the vicinity of Hampton Harbor. The general pattern of this movement is depicted in Figure 6. Roughly an hour after high tide, birds begin to leave Salisbury and work their way north. Some fly directly to roost sites at the southern edge of Hampton Harbor, while others may detour via the outer beach, particularly later in the season.

Because they are exposed early in the tidal cycle, the south flats are often the first area used by shorebirds on a falling tide. They congregate here and forage until the flats at the mouths of Mill Creek and Brown's River are exposed, at which point most birds shift to the latter areas, and work their way up creeks as more habitat becomes available. Up to two-thirds of local populations of Semipalmated Plovers, Semipalmated Sandpipers, and Short-billed Dowitchers follow this pattern, with lesser numbers of Black-bellied Plovers and Greater Yellowlegs. The former tend to remain longer on the south flats or those around Knowle's Island, rather than working their way up the creeks. Yellowlegs and Least Sandpipers tend to focus their foraging activity more on creek edges and pools rather than the main harbor flats. In contrast, Whimbrel and Willet tend to remain on the north and south flats, with only limited foraging actively in other areas.

As flats in the southern portion of the estuary become more exposed and dried out, many shorebirds continue north to the freshwater/brackish pools discussed previously. Of these locations, only Henry's Pool is tidal, and because the outgoing tide is delayed here it offers a foraging opportunity when other tidal areas are less suitable. As substrate in Henry's Pool also dries out, birds often move to the Landing Road pool where water levels are stable. The outgoing tide operates in a similar fashion at the southern extreme of the estuary. Some birds return to Salisbury Marsh as early as four hours before high tide to forage on recently-exposed tidal creeks at the upper edge of the tidal range.

On a rising tide, birds that have not already returned to Salisbury either remain at the northern pools or gradually move to roosts in the southern portion of the estuary (e.g., Mill Creek, Route 286 bridge). The larger species tend to remain at these roosts, while the smaller ones eventually continue south into Salisbury Marsh, usually arriving 1-2 hours before high tide. Here they wait until the next falling tide to begin the cycle again.

Invertebrates

No invertebrates were detected in any sample collected in April 2007. The dominant invertebrates found in summer (2007) and fall (2006) samples were marine worms (Phylum Annelida, Classes Polychaeta and Oligochaeta), Ostracods (Subplylum Crustacea, Class Ostracoda), and water boatmen (Class Insecta, Order Hemiptera: Family Corixidae). Polychaete and Oligochaete worms were found primarily in two locations: Henry's Pool at the northeastern corner of the marsh and near the mouth of Mill Creek in the southwest. Sites containing worms were characterized by medium-grained sandy mud. Ostracods and water boatmen dominated samples from the Landing Road pool at the northern edge of the marsh. No invertebrates were detected in any other samples from other portions of the estuary. It is particularly worth noting that Henry's Pool and Landing Road Pool were the only pools regularly used by shorebirds and the only pools containing invertebrate prey.

Other Bird Species

During the course of regular monitoring, several other species of birds were observed using the marsh. These species, with brief notes on the nature of their use, are listed in Appendix B.

Discussion

It can be hard to draw clear conclusions when faced with a data set as broad and complex as one involving the daily and seasonal movements and behaviors of thousands of birds of several species across an area of 5000 acres. However, several patterns regularly present themselves, and are worth summarizing more concisely. These statements pertain only to the southbound fall migration given the much larger amount of data available. Spring migration occurs over a much shorter period of time, and specifics of shorebird usage may be significantly different than described in this report. More data from spring would be needed to make comparisons, but the low densities of spring migrants make this action a low priority.

Based on the data collected in 2006 and 2007, 3000-3500 shorebirds use the estuary each fall, two thirds of which are either Semipalmated Plovers or Semipalmated Sandpipers. These two species show very similar patterns of habitat use. The majority roost in Salisbury Marsh just south of the state line, with smaller concentrations at the northern pools or banks in the vicinity of the Blackwater River. On a falling tide, birds shift north to the southern flats in Hampton Harbor to feed, moving upstream along tributary creeks as more foraging habitat becomes available. At the lowest tides, most birds shift to the pools at the northern edge of the estuary, where prey appear to remain available either continuously of for a longer portion of the tide cycle. These same pools are also used as shorter-term resting areas between foraging bouts at any point in the cycle. On the rising tide, most birds eventually return south to roost in Salisbury, sometimes with stops at other roosts or foraging sites along the way.

Use of the estuary by these two species also appears clearly tied to the limited amount of data available on food resources. Of 11 areas sampled for invertebrate prey during this study, prey items were only detected in three: the mouth of Mill Creek, Landing Road pool, and Henry's Pool. All three of these sites regularly supported over half the estuary's shorebird population at

one or more points in a tidal cycle. This correspondence between shorebird use and known invertebrate sites should not be interpreted as a suggestion that other areas lacked prey entirely. Such sites clearly support foraging shorebirds, and it is likely that the invertebrates present are either difficult to sample using our methods, occur in lower densities, or a combination of the two.

Other common shorebird species tend to show a similar overall behavioral pattern, with a few notable exceptions. The largest species (Black-bellied Plover, Willet, Whimbrel, and godwits) spend most of their time foraging at the mussel beds in or around the main harbor flats, are rarely if ever detected at the northern pools, and tend to roost much closer to the harbor rather than continuing south to Salisbury. Yellowlegs and Short-billed Dowitchers exhibit something of a mixed strategy. Some individuals clearly accompany the smaller species to the Salisbury roost, while others remain with the larger species or – in the case of Greater Yellowlegs – roost on their own in the vicinity of pools (including those in the south and west). Yellowlegs of both species – as well as Least Sandpipers – spend more time foraging dispersed across the marsh than on either creek or harbor flats, while dowitchers focus on the latter habitats and the northern pools.

While most species appear to roost predominantly within the marsh, under certain conditions other sites become important. At extreme high tides, even high marsh islands may be flooded, and smaller species shift to higher ground such as the Fisherman's Co-op in Seabrook. The fact that shorebirds of several species begin using Seabrook Beach as a roost or staging area after the summer tourist season suggests that this area also has desirable features, perhaps also related to extreme tides or proximity to foraging areas.

In summary, migrating shorebirds in the Hampton-Seabrook Estuary do not use habitat in proportion to its availability, instead selecting a relatively small number of key foraging sites and roost sites that are probably chosen based on some combination of prey availability, amount of time available for foraging, and degree of inundation by high tides. The conservation implications of such site selection are discussed in the final section of this report.

Table 1. Shorebirds recorded in the Hampton-Seabrook Estuary during 2006-2007, with notes on relative abundance, seasonal population size, and habitat affinities. Abundance categories as follows: A = abundant (counts regularly exceed 100 birds), C = common (counts between 20 and 100 birds), U = uncommon (5-20 birds), R = rare (less than five records, usually involving only 1-2 individuals). Seasonal population estimates are provided only for the most common species.

Common Name (species code)	Scientific Name	Relative Abundance	Population Estimate		General Habitat Affinities
			2006	2007	
Black-bellied Plover (BBPL)	*Pluvialis squatarola*	C	165	135	Throughout
Semipalmated Plover (SEPL)	*Charadrius semipalmatus*	A	1200	1000	Throughout
Piping Plover	*Charadrius melodus*	R			Beach and dunes
Killdeer	*Charadrius vociferus*	R			Marsh edge and pools
Spotted Sandpiper	*Actitis macularius*	U			Creek edges
Greater Yellowlegs (GRYE)	*Tringa melanoleuca*	C	125	60	Marsh and pools
Willet (WILL)	*Tringa semipalmata*	C			Throughout
Lesser Yellowlegs (LEYE)	*Tringa flavipes*	C	50	35	Marsh and pools
Whimbrel (WHIM)	*Numenius phaeopus*	U	5-10	5-10	Marsh and flats
Hudsonian Godwit	*Limosa haemastica*	R			Marsh and flats
Marbled Godwit	*Limosa fedoa*	R			Marsh and flats
Ruddy Turnstone	*Arenaria interpres*	R			Flats
Red Knot	*Calidris canutus*	R			Marsh and flats
Sanderling	*Calidris alba*	U			Beach and flats
Semipalmated Sandpiper (SESA)	*Calidris pusilla*	A	2000	1500	Throughout
Least Sandpiper (LESA)	*Calidris minutilla*	U	45	40	Marsh and pools
White-rumped Sandpiper	*Calidris fuscicollis*	R			Throughout
Baird's Sandpiper	*Calidris bairdii*	R			Marsh and pools
Pectoral Sandpiper	*Calidris melanotos*	R			Marsh
Purple Sandpiper	*Calidris maritima*	C			Jetty
Dunlin* (DUNL)	*Calidris alpina*	C	360*		Jetty, beach, flats
Stilt Sandpiper	*Calidris himantopus*	R			Marsh and pools
Short-billed Dowitcher (SBDO)	*Limnodromus griseus*	C	70	220	Throughout

* Unlike most other species, Dunlin spend the entire winter in or near the estuary, and do not show significant temporal overlap with other shorebirds during fall migration (see Figure G).

Table 2. Significant landscape features used by shorebirds in the Hampton-Seabrook Estuary. Sites are arranged roughly from north to south and west to east (see Figure 2 for specific locations). Species codes in Table B.

Patch	Use	Characteristics	Predominant Species
Meadow Pond	Provides high tide roosting and foraging opportunity with consistent water levels	Wet mud and freshwater with no tidal influence. Recharged by freshwater stream. Relatively free from human disturbance.	SEPL, SESA, and GRYE
Landing Road pool	Provides high tide roosting and foraging opportunity with consistent water levels	Wet mud and freshwater with no tidal influence. Recharged by hardwood swamp. Only site sampled with insect and crustacean prey. Relatively free from human disturbance.	50-80% of SESA, SEPL, and SBDO across the entire estuary routinely use this area from 3 hours after low tide to 1 hour after high tide.
Henry's Pool	Because of delayed exposure and flooding relative to main harbor, provides foraging opportunities when main flats are dry and exposed	Wet mud and brackish water, affected by tides with daily flooding and exposure delayed from main harbor by 90 minutes. Fed by continuous freshwater or brackish water input from stream draining meadow pond. Contains many annelid worms.	40-60% of SESA and SEPL, and 90% of SBDO across the entire estuary routinely use this area. Important foraging area for GRYE and LEYE.
Taylor River	Roost and Foraging, generally low use	Creeks and abundant bank flats and mid-creek flats.	SESA, LESA, GRYE, and Spotted Sandpipers. Some foraging by SESA and SEPL prior to or following use of the Landing Road pool.
Depot Road pools	Roost and foraging; highest use on extreme hide tides	Mix of gravel, high marsh pools, creeks, and creek banking.	SESA, LESA, SEPL, and GRYE
Hampton River Flats	Infrequent foraging when main flats were dry and exposed following low tide.	Large exposed flats	Greatest use is by BBPL during fall, some use by SEPL and DUNL
North Flats (west)	Infrequent foraging when main flats were dry and exposed following low tide.	Large exposed flats	Greatest use by DUNL during fall and winter
North Flats (east)	Foraging on mussel beds, roost site on northeast bank across from flats	Dark mud and mussel flats with adjoining bank of peat and *Spartina*.	WHIM, SBDO, and WILL (forage); BBPL, DUNL, SBDO (roost)
Mouths of Brown's River and Mill Creek	Birds roosting here typically forage the adjacent flats at the Mill Creek mouth and pocket flats behind the marsh islands nearby. Offers forage site at start of tide dropping and after low tide on a rising tide when main flats are exposed and dry.	Important complex of creeks, creek flats, pocket flats and opportunistic roost sites, including a *Spartina* bank roost south of the mouth of Mill Creek. Diverse topography provides numerous moist microsites and ample tall *Spartina alterniflora* cover. Invertebrate sampling detected annelid worms.	Foraging by highest diversity of shorebird species including SESA, SEPL, Sanderling, DUNL, SBDO, WILL, WHIM, and Hudsonian Godwit. Roost also supports high diversity, including Hudsonian Godwit, WILL, SESA, SBDO, WHIM, Ruddy Turnstone, and White-rumped Sandpiper.

Knowle's Island	Used by foraging birds in association with creek mouths at slightly lower tides.	Has greater proportion of mussels and varied micro-topography with numerous pools and mounds of dark to light colored mud and sand.	Used by high diversity of shorebirds, including SESA, SEPL, BBPL, WHIM, SBDO, LESA, Ruddy Turnstone, WILL, DUNL, and Sanderling among others.
South Flats	Use starts at the extreme southern end of the flat as it is exposed first. Foraging use tracks the receding water or is concentrated around microtopography providing areas of pools. Toward low tide and several hours into the rising tide the area is abandoned in favor of the mouth of Mill Creek.	This is the main flat in Hampton Harbor, with extensive mussel beds near the southern end. The central and southeastern portions have been built up by dredge spoils and stabilized by a bulkhead, resulting in parts of this flat drying out earlier than in the past.	Important foraging site for DUNL, SESA, BBPL, SEPL, Hudsonian Godwit, and WHIM; particularly at the mussel-dominated southern portions.
West side of Blackwater River above mouth	Occasional roost and foraging, also a post-foraging staging area on rising tide.	*Spartina* bank and associated river flats	WHIM
Fisherman's Co-op	Roost area during extreme high tides	Gravel and grassy area at edge of parking lot	Occasionally used by entire estuary population of SEPL and SESA
Seabrook Beach and flats at mouth of Hampton Harbor	Used as a roost and for limited foraging, predominantly during tourist off-season. Also a staging area at start of dropping tide prior to moving to South Flats and the mouth of Mill Creek	Outer barrier beach and flats. During most of the migration season this area is heavily used by people and thus does not provide a secure roosting area for shorebirds.	50-75% of BBPL, DUNL, Sanderling, SEPL, and SESA in late fall. Extensive use by Sanderling, Purple Sandpiper, and DUNL in late fall and winter.
Route 286 Bridge	Primarily a roost site, with limited foraging at high tide. The water levels of the Black River respond quickly to the dropping tide and possibly serve as a cue to search the emerging flats. Birds roosting here may head to Seabrook Beach for short foraging bout prior to heading in to the South Flats.	Mix of *Spartina* and pools adjacent to east bank of Blackwater River. Presence of restaurants and fishing access makes this site highly susceptible to human disturbance.	Second highest roost diversity after mouth of Mill Creek: entire population of BBPL typically roosted here, along with SBDO, DUNL, SESA, and GRYE.
Route 286 pools	Roost and foraging at high tide	Pool	GRYE

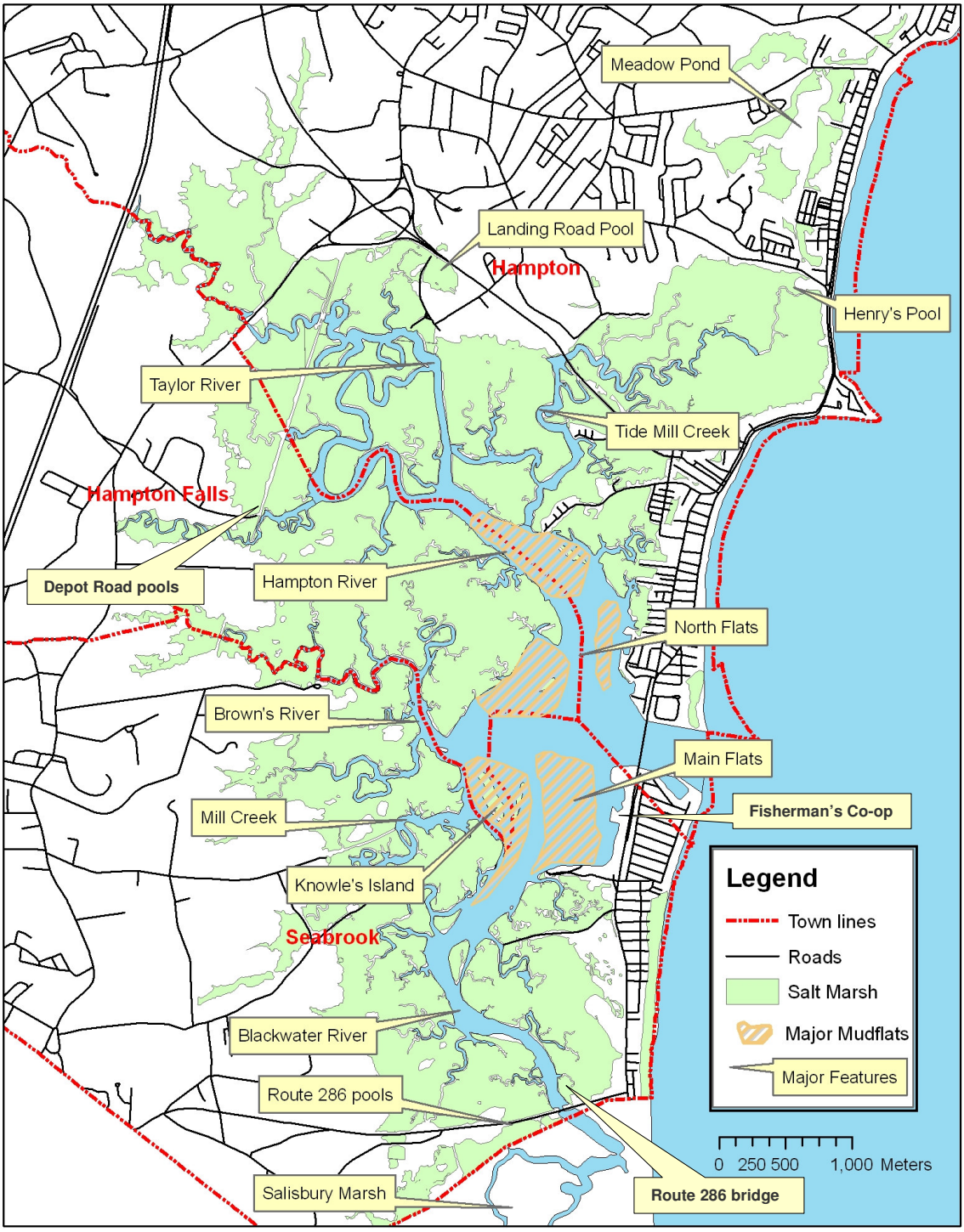


Figure 2. Map of the Hampton-Seabrook Estuary showing important habitats and the locations of sites mentioned in the text.

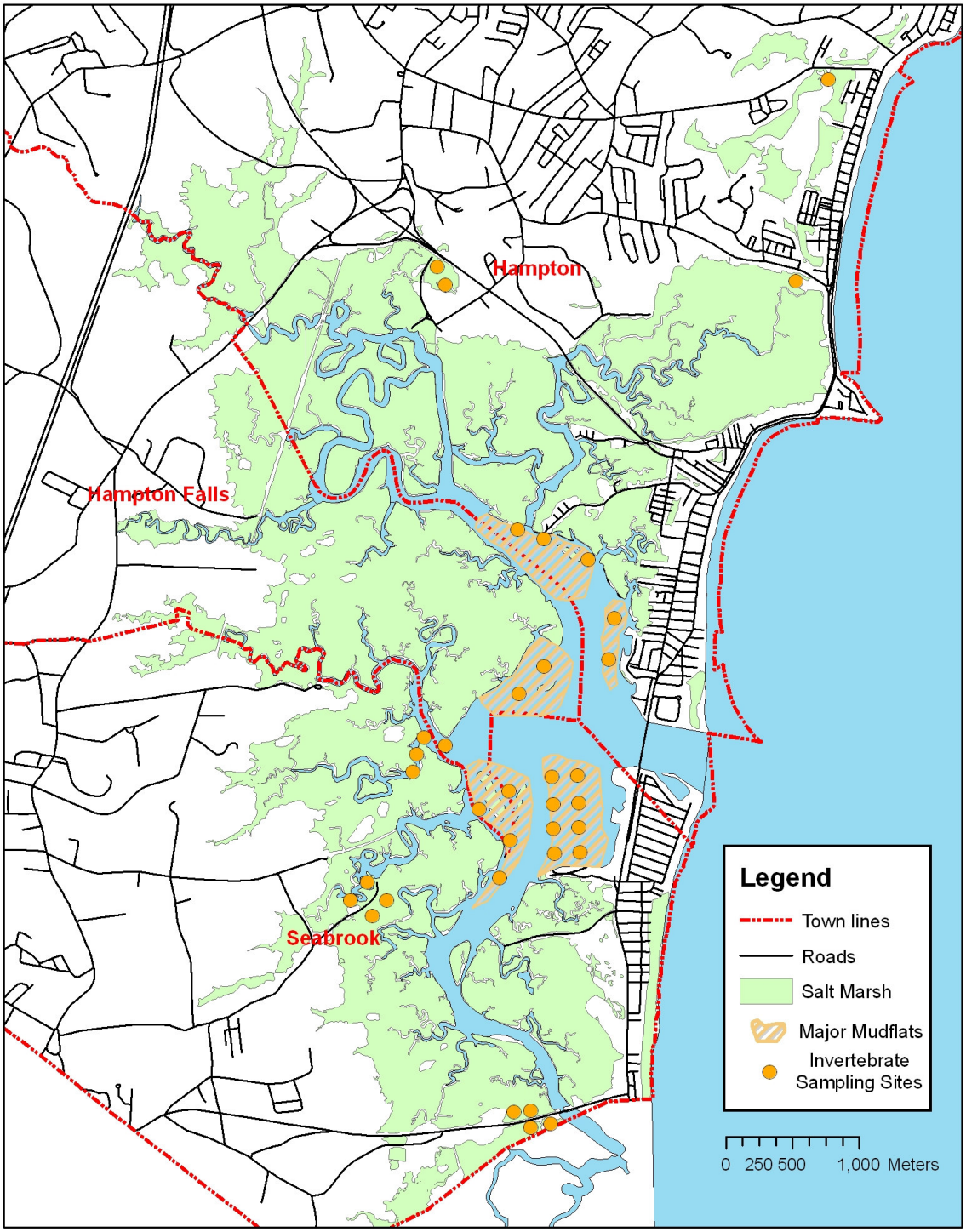
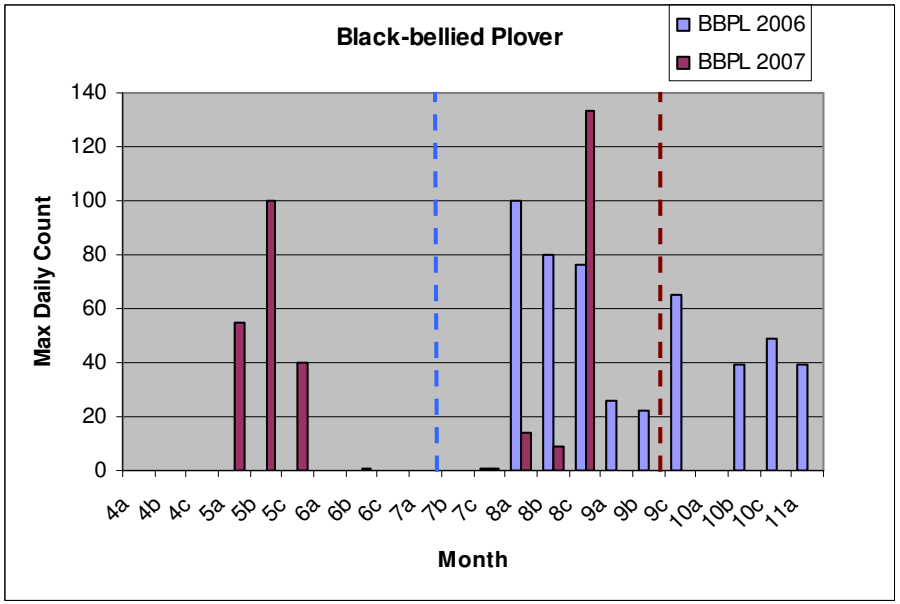
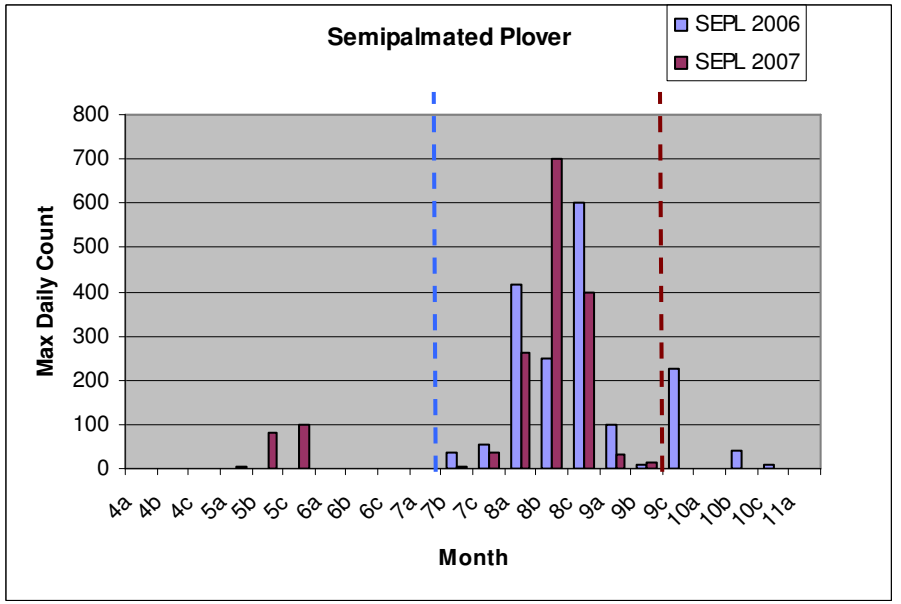
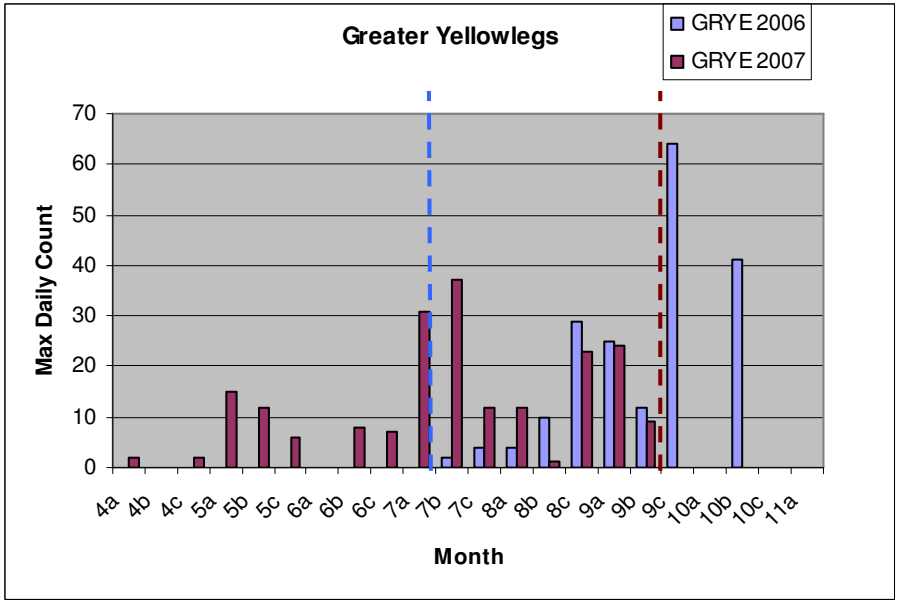


Figure 3. Invertebrate sampling locations in the Hampton-Seabrook Estuary.







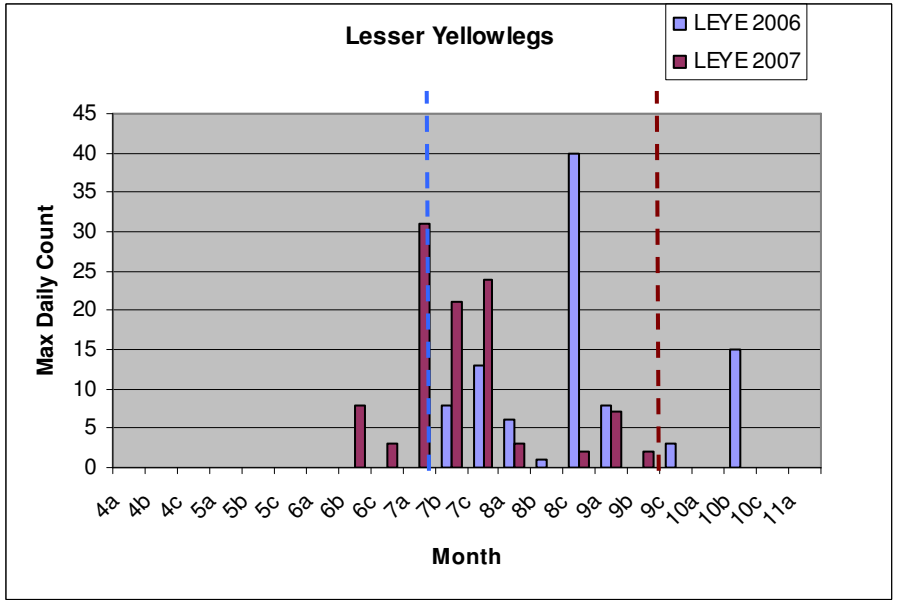
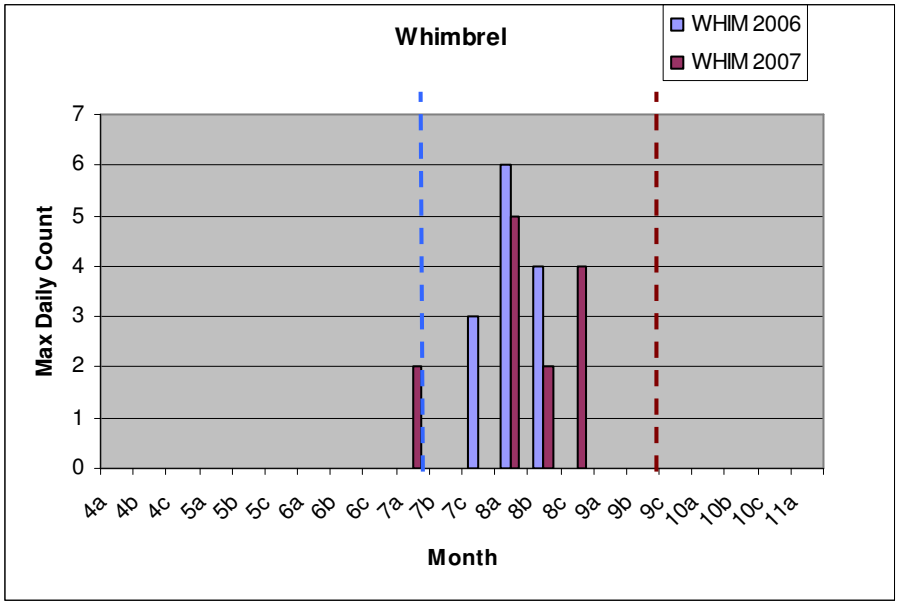
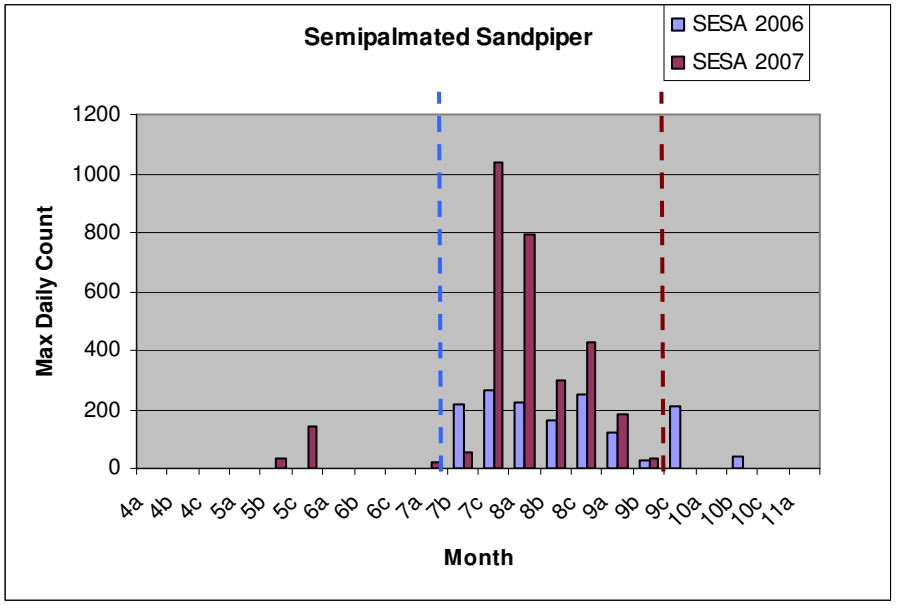
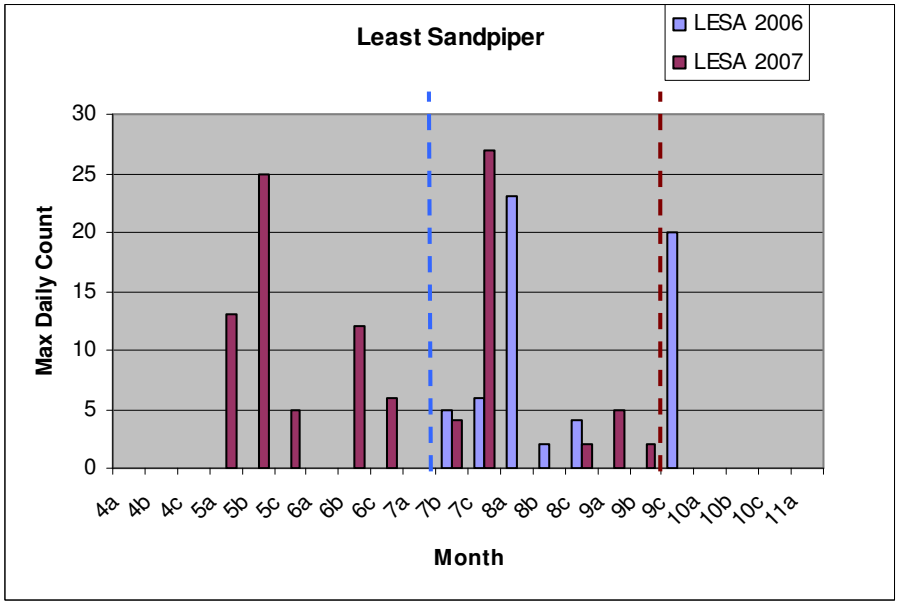
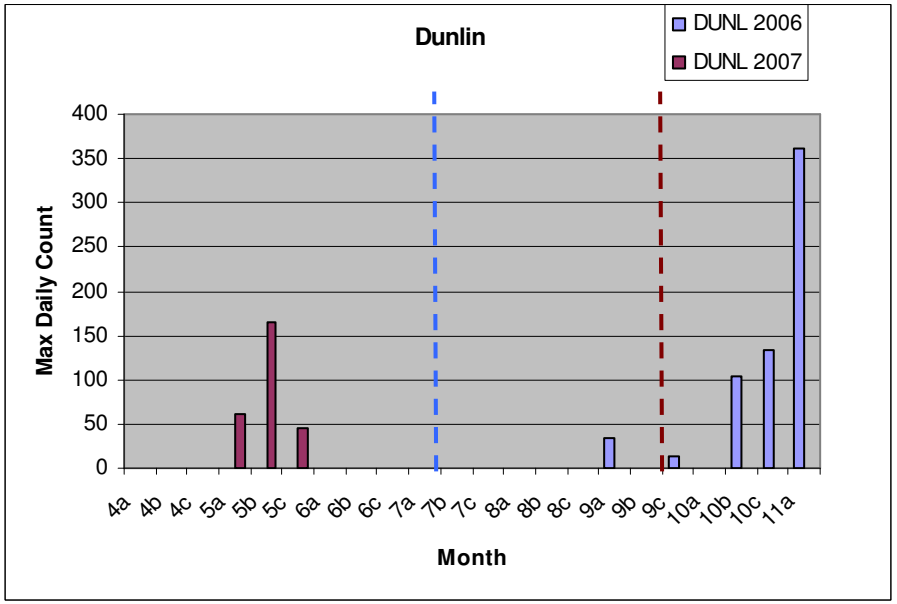


Figure 4. Seasonal abundance patterns of selected migrant shorebird species in the Hampton-Seabrook Estuary. Numbers are the highest total observed at any point in a given 10-day period, with these periods coded as follows: 4a = April 1-10, 4b = April 11-20, 4c = April 21-30, etc. The blue dashed line indicates the approximate beginning of surveys in 2006, and the red dashed line the approximate end of surveys in 2007.









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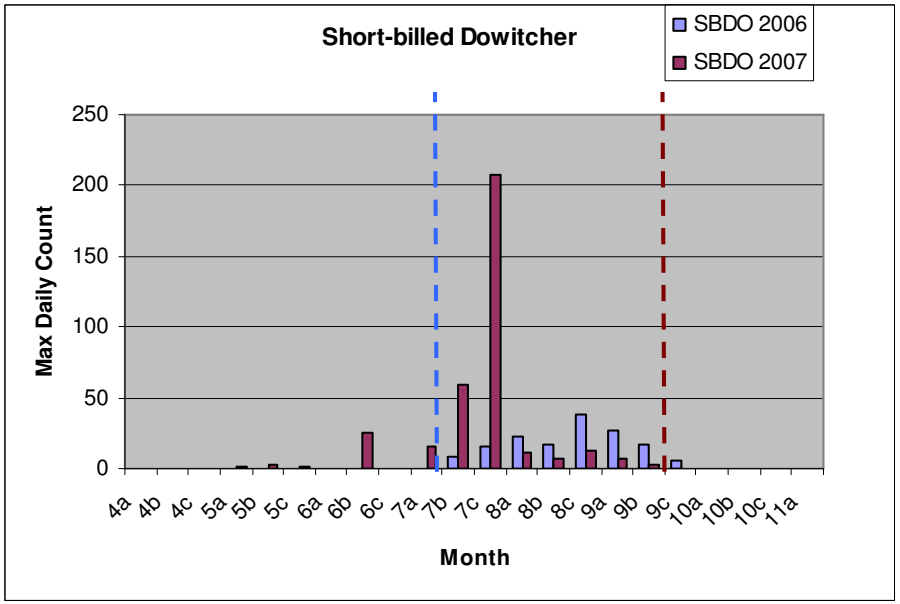

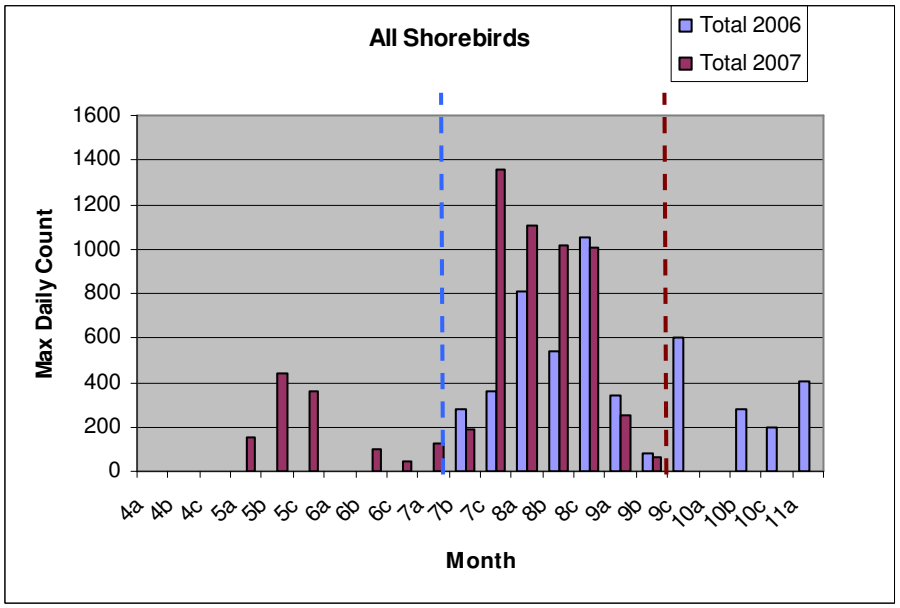

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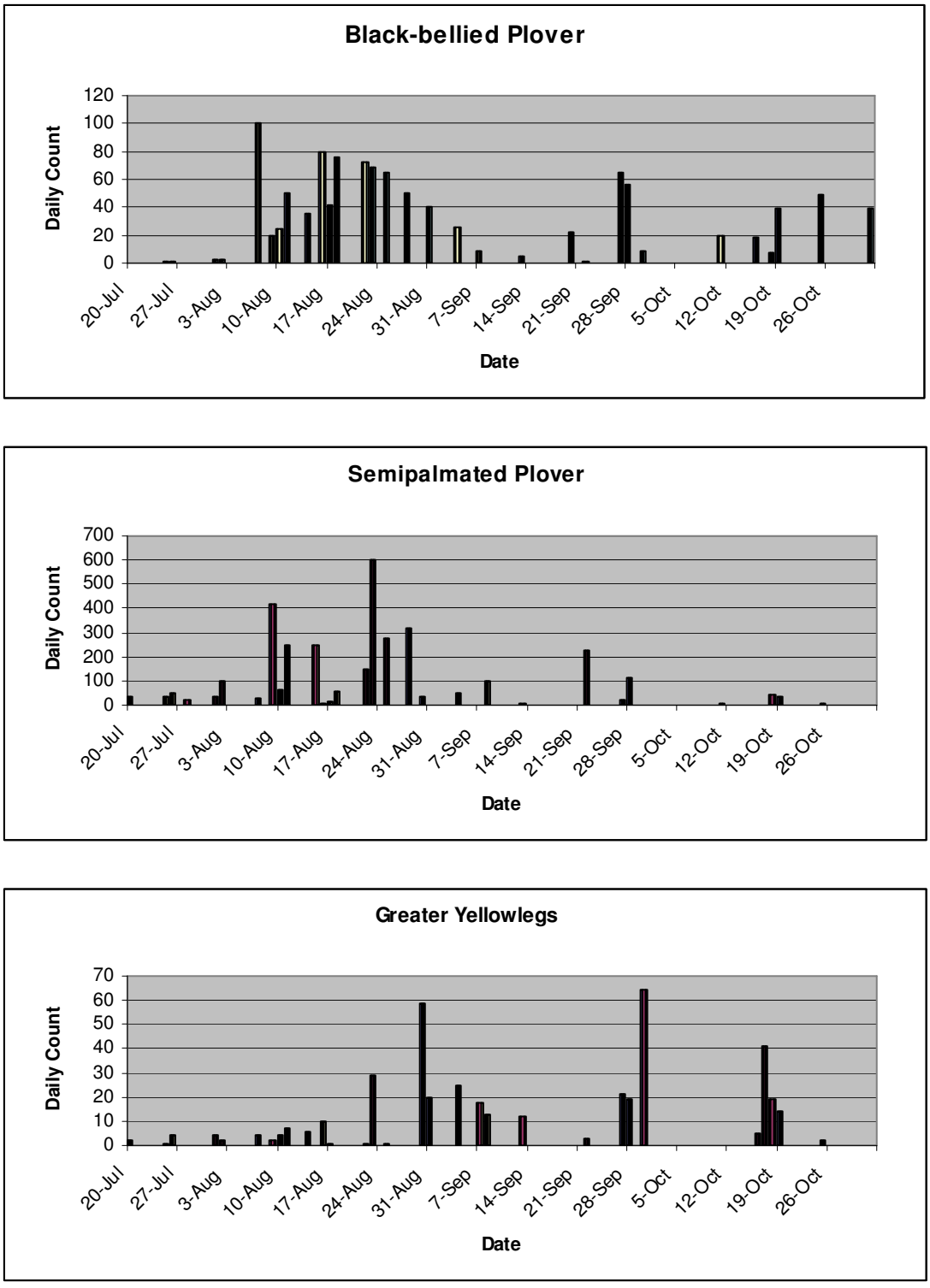
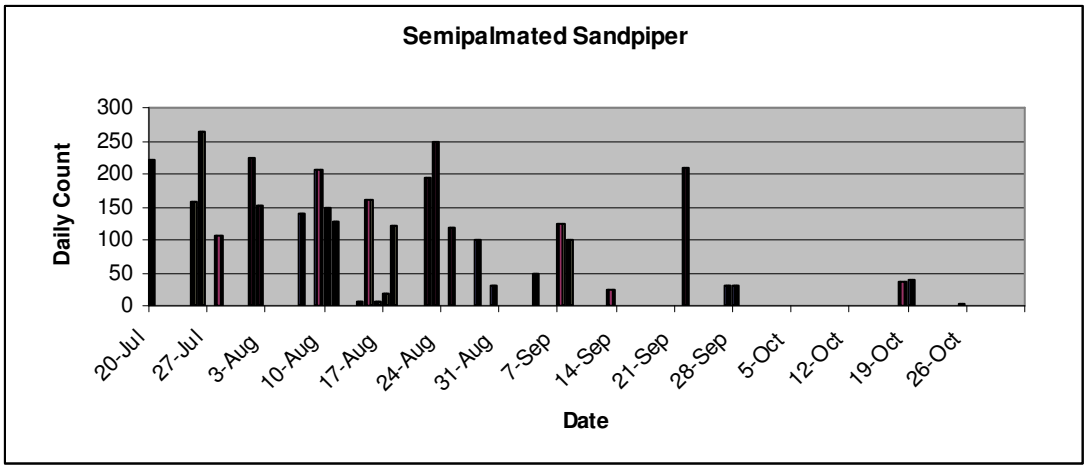
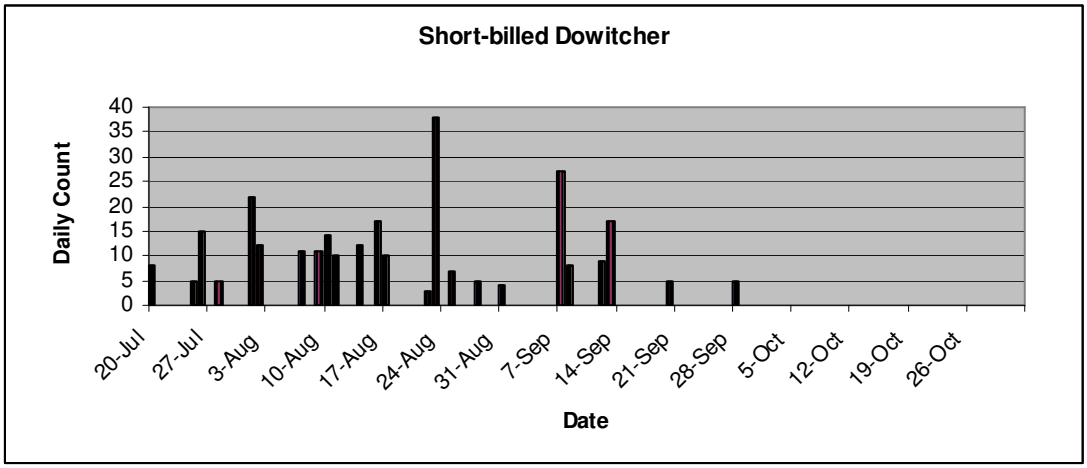


Figure 5. Daily abundance patterns for five common shorebirds that used the Hampton-Seabrook Estuary in the fall of 2006. In all cases the earlier peak is due to migrating adults while the later peak is of juveniles.





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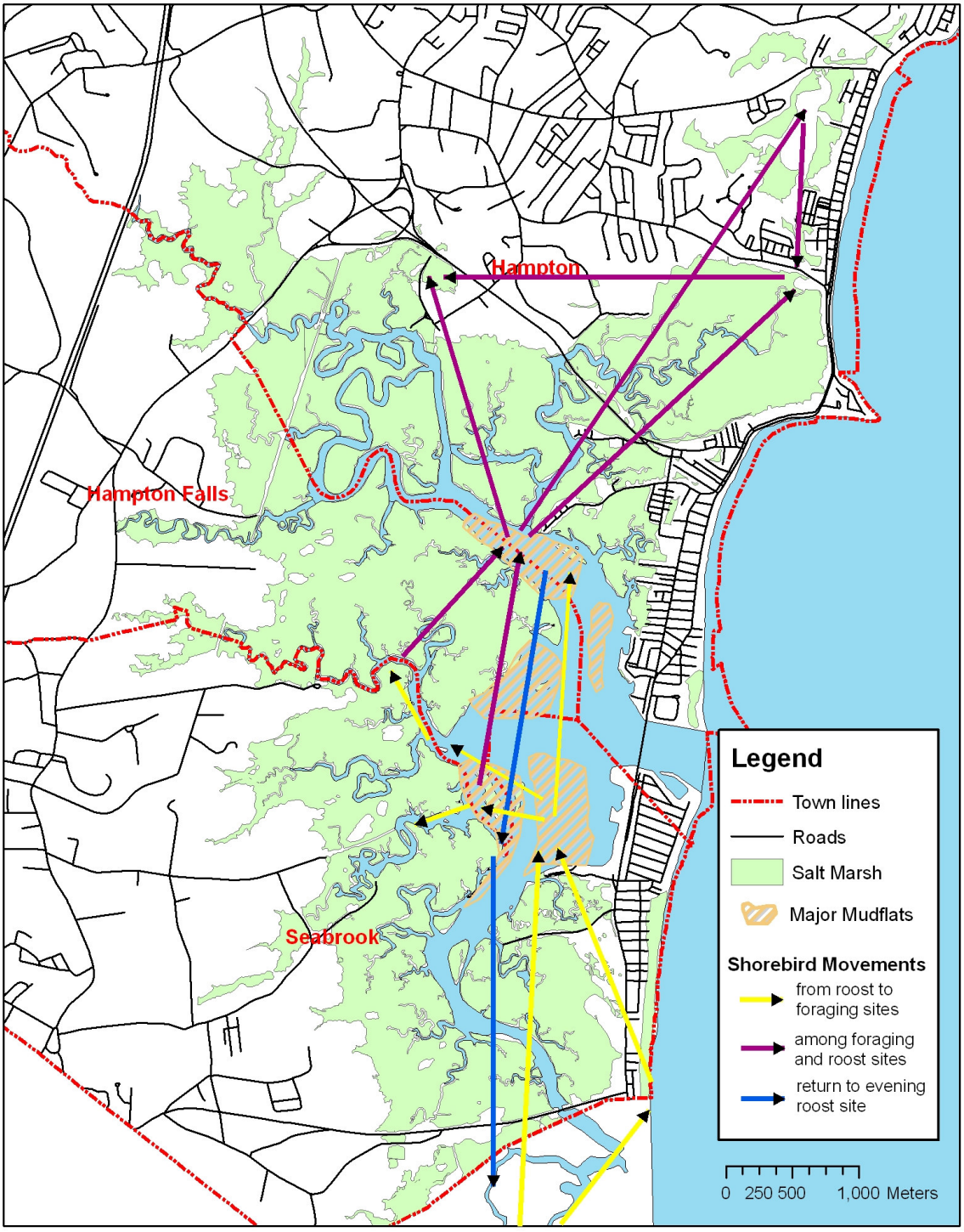

Figure 6. Generalized pattern of daily shorebird movements within the Hampton-Seabrook Estuary. See text for details.

Salt Marsh Breeding Birds in the Hampton-Seabrook Estuary: 2007

Introduction

The northeastern coast of the United States is relatively unique among salt marsh systems in that it supports a high diversity of breeding birds, many of which have evolved adaptations to deal with the extreme conditions typical of such habitats (reviewed in Greenberg et al. 2006). Because these species are usually restricted to narrows bands of habitat in heavily-developed areas, they have been recognized as priorities in both national and regional bird conservation plans (e.g., Rich et al. 2004). At the same time, because of difficulties associated with accessing and working in these habitats, there is limited information on the status, abundance, and even biology of many species, making additional research and monitoring a key strategy in furthering their conservation.

In response to this need, considerable recent effort has been put into study of three salt marsh obligate sparrows: Saltmarsh Sharp-tailed Sparrow (*Ammodramus caudacutus*), Nelson's Sharp-tailed Sparrow (*A. nelsoni subvirgatus*), and Seaside Sparrow (*A. maritimus*), at least one species of which occurs from Texas to the Gulf of St. Lawrence. All three species co-occur in salt marshes from New Hampshire through central Maine, although the Seaside Sparrow is rare. In New Hampshire, Saltmarsh and Nelson's Sharp-tailed Sparrows may segregate to some degree, with the former in larger marshes and those with less freshwater influence, and the latter in smaller marshes and those with generally less saline conditions (M. McElroy, unpubl. data). This pattern is consistent with observations that Nelson's Sharp-tailed Sparrow is a more recent colonist of the region's salt marshes and appears less adapted to their sometimes extreme conditions (Shriver et al. 2007).

Research on the Saltmarsh Sharp-tailed Sparrow in New England has identified specific conservation issues. The species appears to be somewhat area-sensitive, at least to the extent that it is more likely to occur in marshes with other marshes nearby (Shriver and Vickery 2001, Benoit and Askins 2002). Numbers are also lower in areas with relatively high road density (Shriver and Vickery 2001). This species is extremely susceptible to nest loss following extreme high tides, and as a result a local population converges on synchronous breeding following the first such tide of a season (Gjerdrum et al. 2005, Shriver et al. 2007). Tidal restrictions thus have the potential to affect breeding success in this species if the breeding area is subject to higher than normal flooding as a result. At the same time, because Salt Marsh Sharp-tailed Sparrows tend to occur in areas of high marsh, loss of such habitat through intrusion by non-native invasive plants (e.g., *Phragmites*). Such invasions are facilitated by tidal restriction, salt marsh ditching, or other alterations that reduce the regular inundations by salt water that reduce survival by invasive species. In addition to habitat-level threats, recent research has also documented relatively high levels of methylmercury in sharp-tailed sparrows (Shriver et al. 2006), although the biological effects of these levels remain unknown.

The overall effect of such threats on these species' demographic processes is generally unknown. There is some evidence that Saltmarsh Sharp-tailed Sparrows have declined in some portions of their range (Greenlaw and Rising 1994), but more systematic monitoring is required to fully understand population trends and the factors that influence them (Rich et al. 2004).

Another breeding species restricted to salt marshes in the Northeast is the Willet (*Tringa semipalmata*). This shorebird, like the Saltmarsh Sharp-tailed Sparrow, appears area sensitive (Shriver and Vickery 2001, Benoit and Askins 2002), although other habitat variables are generally poorly known. Because Willets in the region are subject to the same threats as salt marsh sparrows, the North Atlantic Regional Shorebird Plan (Clark and Niles 2000) rates this species as "a species of high concern," a higher ranking than it attains on the national level. Because Willets are also long-distance migratory shorebirds, they may also be subject to threats that operate on stopover habitat as discussed in the shorebird portion of this report.

As the largest area of salt marsh in New Hampshire, the Hampton-Seabrook Estuary is clearly a critical site for the state's breeding populations of Willet and Saltmarsh Sharp-tailed Sparrow. Some research has been conducted on habitat selection and productivity in salt marsh sparrows in the state (M. McElroy, unpubl. data), but these data have yet to be analyzed. Until such a time as those analyses are completed, an important intermediate step is to gain a better understanding of breeding species' distributions within the estuary, which in turn can guide future conservation or restoration efforts.

Study Area and Methods

Survey Sites

A total of 15 sites were selected for the purposes of breeding bird survey work. These sites (Table 3, Figure 7) were defined largely based on access points, as all points within a site were surveyed consecutively on the same day. Most sites were located in areas of the marsh that were not subject to daily flooding, since such locations cannot support nesting sparrows. Site selection was further informed by data collected by a UNH graduate student in 2004-2005, in that the 2007 sites included a mix of previously surveyed areas and sections of the estuary that had not been previously inventoried for salt marsh nesting birds. For the purposes of some analyses, sites were further grouped into seven "zones" (Figure 7) which were defined by both position in the estuary and broad habitat characteristics. The six zones and their basic characteristics are described below.

The Northwest zone includes two sites (Drakeside and Depot Road) located in the upper reaches of the Taylor and Hampton Falls Rivers. Both sites are at the upper elevational limit of salt marsh in the estuary. The Depot Road site has been moderately ditched, while Drakeside more closely approaches a natural system. Drakeside is also entirely upstream of a tidal restriction resulting from a culvert under Route 1. The North Central zone includes three sites (Taylor Trestle, Landing Road, and Tide Mill Creek) located in that portion of the estuary between the Taylor River and Route 101. As with the Northwest sites, these sites are near the upper elevational limit of salt marsh. Most are also heavily ditched, while the Landing Road site is an isolated pool. The Northeast zone is a well defined area located between Routes 101 and 101E and drained by the upper reaches of Tide Mill Creek. Unlike other northern sites, this area is almost entirely natural, and the two sites here (Apartment Buildings and Little Jack's) are essentially without ditching. However, both sites are in close proximity to roads and development.

The Central zone is an area of marsh between the mouths of the Taylor and Brown's Rivers at the northwest edge of Hampton Harbor. This is an area of low marsh that is flooded several times a month. The Mill Creek zone includes two sites (Beckman's Landing and Caine's Brook) on either side of Mill Creek where it enters the southwestern portion of Hampton Harbor. With the exception of the upper portions of Caine's Brook, this area is extensively ditched. It also tends to be a lower section of marsh than those discussed previously. The Southwest zone includes two sites (Walton's Landing and Lower Collin's Road) along the southwestern fringe of the estuary in Seabrook. Both sites are extensively ditched and located in high marsh. The Southeast zone is a loose collection of three sites (Route 286, Seabrook Condos, and River Road) associated with the southern and eastern drainage of the Blackwater River. Of these sites, the Seabrook Condos is heavily ditched, while the other two (with only a single point each) are relatively unaltered. All three sites are in close proximity to roads and developed areas.

Bird Surveys

A total of 61 points at the above sites (see Table 3) were surveyed for Saltmarsh Sharp-tailed Sparrows during the summer of 2007. 52 points were accessed on foot, while the nine points in the Central zone were surveyed by kayak. Surveys were conducted from 28 June through 1 August, with one additional site (Route 286) also surveyed on 23 August. All points were separated by at least 250 meters. At each point, an observer conducted a standard 10-minute point count, with the total count divided into three time periods: 0-3 minutes, 3-5 minutes, and 5-10 minutes. For each time period, the observer recorded the total number of sparrows detected within 50 meters of the point. Sparrows were also counted during transit between points or while entering or exiting the site. For the purpose of analysis, we will use the maximum number of sparrows recorded during any of the three intervals. Sparrows detected at a site but not on point counts were used to estimate total site populations and rough distributions of birds within a site (e.g., if birds were detected between points 1 and 2 but not at either point, both points are recorded as having sparrows in Figure 8).

In the process of conducting sparrow surveys, observers also noted the presence of Willets and Common Terns. However, because both these species have larger home ranges than sparrows, the point count technique was not an appropriate means of estimating population size. Instead, Willet and tern locations noted in the course of sparrow surveys were compared with observations taken during other monitoring activity in the estuary and used to estimate the distribution of these species on the marsh. For Willets, particular attention was paid to display flights and interactions between territorial birds. Later in the season, young birds were noted as an indirect means of assessing reproductive success or failure.

Habitat Characterization

Vegetation characteristics were measured at all sparrow survey points using the methods of Benoit and Askins (2002) and James-Pirri et al. (2002). At each point two 50-meter transects were laid out perpendicular to each other, with one transect oriented toward the nearest creek. At 10-meter intervals along each transect, percent cover was estimated within a meter-square plot. Within each plot we estimated percent for each plant species (*Spartina alterniflora*, divided into

tall and short forms), thatch, pool, creek, and river. Individual points were characterized by the mean percent cover of each cover type. For purposes of analysis, this set of variables was reduced to the following major vegetation or substrate types: *Spartina alterniflora* (tall form), *S. alterniflora* (short form), *S. patens*, *Distichlis spicata*, *Triglochin maritimum*, thatch, other vegetation, and water (pool or creek).

Variables related to habitat condition were collected at the scale of sites or zones from aerial photographs or the New Hampshire Wildlife Acton Plan (WAP) habitat maps. Based on aerial photographs, sites were classified into three categories reflecting the extent of ditching: ditched, minor ditching, or natural. The following patch-level variables were examined from WAP habitat maps: percent invasive species, road density, and overall condition.

Results

Saltmarsh Sharp-tailed Sparrow

During the course of surveys in 2007, the only *Ammodramus* sparrow detected was the Saltmarsh Sharp-tailed Sparrow, and all further mention of "sparrow" in this document refer to this species. Sparrow densities were highest at the peripheries of the marsh (Table 3, Fig. 8), particularly in the Northeast zone (mean = 10.29 per point). Low or intermediate densities (means = 0.75-1.3) occurred in the Northwest and Southwest. Sparrows were rare or absent in areas of the marsh closer to major creeks or in the vicinity of isolated pools. Not surprisingly, they were completely absent from the regularly flooded Central zone. This variation among zones was highly significant (ANOVA: $F = 25.67$, $p < 0.001$).

Multivariate analysis of vegetation variables at sparrow points revealed no consistent interactions among variables that would allow simplification of the data into a smaller number of descriptive variables. Across the study area as a whole, *Spartina patens* was the dominant species, constituting an average of 40.5% of ground cover across all points. The short form of *Spartina alterniflora* was the second most abundant cover at 22%, followed by *Distichlis spicata* at 9.8% and *Spartina alterniflora* (tall form) at 5.0%. Areas covered by water covered an average of 9.9% of the survey plots. When the four main vegetation types were compared across zones, the Northeast differed significantly from all other zones in both *S. patens* and *S. alterniflora* (short form). Specifically, the average cover of *S. patens* in the Northeast was 20.5%, whereas in the other zones it ranged from 33-49% (ANOVA: $F = 2.755$, $p = 0.03$). In contrast, the short form of *S. alterniflora* occupied 48.7% of plots in the Northeast, and only 13-23% in other zones (ANOVA: $F = 2.96$, $p = 0.02$). Across all points, there was a significant negative correlation between *S. alterniflora* (short) and both *S. patens* ($r = -0.573$, $p = 0.0$) and *S. alterniflora* (tall) ($r = -0.279$, $p = 0.045$). These correlations are consistent with the typical distribution of *Spartina* species within a salt marsh. Tall *S. alterniflora* predominates in the lowest areas proximate to creek channels or larger open water areas, with the short form taking over at the crest of the banks. *S. patens* takes is most common in the highest sections of the marsh that are least subject to flooding, as this species is less salt-tolerant than the other.

Based on both sparrow and plant distributions, it appears that Saltmarsh Sharp-tailed Sparrows reach their highest densities (mean per point) at sites dominated by the short form of *S.*

alterniflora (r = 0.28, p = 0.041), with relatively low amounts of *S. patens* (r = -0.24, p = 0.083). However, this relationship is driven almost entirely by the seven points in the Northwest zone, which were characterized by high sparrow density and a high proportion of short *S. alterniflora*. If the Northeast points are removed from the analysis, these relationships are no longer evident. The other underlying characteristic of the Northeast zone is the absence of extensive ditching. While this feature may in turn be related to the dominance of short *S. alterniflora*, it may also be an important habitat selection criterion for the sparrows. The other site most closely approaching a natural condition was the marsh of Drakeside Road, and which had the highest sparrow densities outside the Northeast zone. This observation supports the hypothesis that sparrows avoid heavily ditched areas within the Hampton-Seabrook estuary.

When WAP habitat condition variables were compared among sites, there were no clear patterns related to either sparrow density or vegetation characteristics. Specifically, all study sites had high biological and landscape condition scores, and low cover in invasive plants (all < 4.5%). Areas in the Northeast and Southeast had the highest road density and percentage of development, and as a result also scored relatively low for human impacts (meaning that impacts were moderate to high). Only in the Northwest is there a significant amount of conserved land, and as a result this zone scored the lowest for overall risk. To summarize, sparrows achieve their highest densities in the Northeast, despite high human impacts in that zone. This pattern is likely a result of the marsh's natural condition in this area, perhaps complimented by high cover of short *S. alterniflora*.

Willet

The majority of Willets were found in two areas of the estuary: 1) the northeastern portion above Route 101 and 2) around the mouth of the Blackwater River at the southern edge of Hampton Harbor (Fig. 9). A few pairs were also located in the northwestern portion of the marsh, upstream along the Blackwater, and upstream along Mill Creek in Seabrook. None were detected in the Central zone. The total minimum population size for the study area is 28 pairs, although this is a conservative estimate and the actual population may be in the 30-35 pair range. During salt marsh sparrow surveys conducted by UNH in 2004-2005, Willets were found in these same areas and at the same relative abundance. Numbers were highest in the northeast, with smaller numbers in the south and northwest. Breeding was confirmed in the northeast, off Drakeside Road, and along the Hampton Falls River (M. McElroy, unpubl. data). Unlike the sparrows, Willets were observed to move large distances within the estuary, with many birds leaving core nesting areas to forage at the mouths or edges of major creeks. This behavior is well-documented in eastern populations of the species (Lowther et al. 2001) and makes estimation of home range size difficult. As a result, it is not currently possible to extrapolate our results to a population estimate for the estuary as a whole. Sites used by Willets were disproportionately located near creeks, rivers, or the harbor, in direct contrast to the high marsh areas selected by breeding sparrows. Other important habitat features for this species are structures used as display posts, including boulders, bird boxes, greenhead traps, and remnant pilings.

Other Bird Species

During the course of regular monitoring, several other species of birds were observed using the marsh. Of these additional species, the Common Tern is of particular interest because the Hampton-Seabrook Estuary was traditionally the major breeding site in New Hampshire until the species was restored to the Isles of Shoals in 1997. As the latter colony has grown, little effort has been expended monitoring the state's remaining mainland sites, so recent data from the traditional site in Hampton are valuable. During the summer of 2007, Common Terns were found regularly in both the Northeast and the southern portion of the Harbor. Breeding evidence was not noted in either location, but the regularity of sightings in the Northeast suggests that 10-15 pairs were nesting there. Terns seen elsewhere in the estuary were probably foraging birds from colonies in either the Northeast or Isles of Shoals, and included large flocks of birds in the southern portion of the harbor in early August. For more details on other species observed using the estuary during this study, see Appendix B.

Discussion

Saltmarsh Sharp-tailed Sparrows were not evenly distributed across the estuary, and reached their highest densities in the northeastern section of the marsh that is in a relatively natural condition. This section also has a higher proportion of its surface dominated by the short form of *S. alterniflora*, and less *S. patens* then the marsh as a whole. This relationship between sparrows and vegetation type is different than that detected in other studies, where *S. patens* is the dominant species in areas occupied by Saltmarsh Sharp-tailed Sparrows (Shriver and Vickery 2001, Gjerdrum et al. 2005). However, there is significant regional variation in these relationships, suggesting that at some scale other habitat features may be equally important habitat cues.

For example, in the Hampton-Seabrook Estuary, the presence of unditched marsh such as in the northeast may be more important than a particular vegetation composition. Data from elsewhere in the estuary lend some support to this conclusion, in that the only other area to have a relatively large sparrow population was the lightly ditched section near Drakeside Road in the northwest. In all other areas the species was rare (southwest) or absent, with many of the latter areas clearly subject to the regular flooding that sets the lower limits of sparrow nesting within this habitat. When sparrows were present away from the northeast or Drakeside Road, they tended to occur in areas of high marsh dominated by *S. patens* or the short form of *S. alterniflora*.

Although Willets also used the natural section of salt marsh in the northeast, this species was also a common nester in *Spartina* banks in the vicinity of the major southern tributaries to the harbor. These data would suggest that Willets may be less sensitive to ditching or other alterations, although more detailed data – preferably including nest locations – would be required prior to making management recommendations. Willet breeding in the southern portion of the estuary coincides with areas where the species usually feeds and roosts during the late breeding season (see previous section of this report), which may also be an important factor underlying habitat selection.

Both the above species are known to show some degree of area sensitivity (Shriver and Vickery 2001, Benoit and Askins 2002), and as such the Hampton-Seabrook Estuary is clearly the core of their range in New Hampshire. While the sparrow occurs in smaller numbers in other salt marsh patches both along the coast and in Great Bay, the only suspected breeding site for Willet outside those presented here is at Meadow Pond (see Figure 2). Although this is a freshwater wetland, there are breeding season records from the site, and more research is needed to determine whether these represent occasional breeding or use by non-breeding individuals. The former would be noteworthy because the species generally avoids such habitats along the Atlantic coast (Lowther et al. 2001).

Overall, data collected in 2007 on the primary breeding species of the Hampton-Seabrook Estuary point to distinct areas of the marsh that support the majority of the system's – and possibly the state's – populations of Willet and Saltmarsh Sharp-tailed Sparrow. Both species reach high densities in an unaltered section of marsh in the estuaries northeast corner, with Willets also common around the southern fringe of Hampton Harbor. The conservation implications of these findings are discussed in the final section of this report.

Table 3. Areas of Hampton Marsh surveyed for Saltmarsh Sharp-tailed Sparrows in 2007. Maximum site totals include birds detected between points. Site locations indicated in parentheses as follows: H = Hampton, HF = Hampton Falls, S = Seabrook. Comparable means for the same general survey zones in 2004-2005 are provided for comparison (M. McElroy, unpubl. data). See also Figures 7 and 8.

Site	# points	# visits	Sparrows present*	Maximum site total	Mean birds/point	2004-05 comparison
Northwest						
Drakeside Road (H)	5	3	Y	29	2.27	2.29
Depot Road (HF/H)	7	5	Y	14	0.69	.44
Overall Zone					1.23	1.25
North Central						
Taylor River Trestle (H)	4	3	Y	4	1.33	
Landing Road (H)	1	1	N	0	0.0	
Tide Mill Creek (H)	3	2	Y	3	0.33	
Overall Zone					0.26	N/A
Northeast						
Apartment Buildings (H)	4	2	Y	93	8.13	
Little Jack's (H)	3	2	Y	104	13.17	
Overall Zone					10.29	6.25
Central (HF)	9	2	N	0	0.0	N/A
Mill Creek						
Beckman's Landing (S)	7	3	Y	2	0.0	
Caine's Brook (S)	6	4	Y	9	0.71	
Overall Zone					0.21	0.11
Southwest						
Walton's Landing (S)	4	4	Y	16	1.0	
Lower Collin's Brook (S)	3	3	Y	8	0.0	
Overall Zone					0.57	N/A
Southeast						
River Road (S)	1	4	N	0	0.0	
Seabrook Condos (S)	3	2	N	0	0.0	
Route 286 (S)	1	2	Y	1	0.0	
Overall Zone					0.0	0.0
				(285)		

* At some sites, sparrows were detected between points but not during actual point counts. These sites are indicated as having sparrows present even though the mean per point is zero.

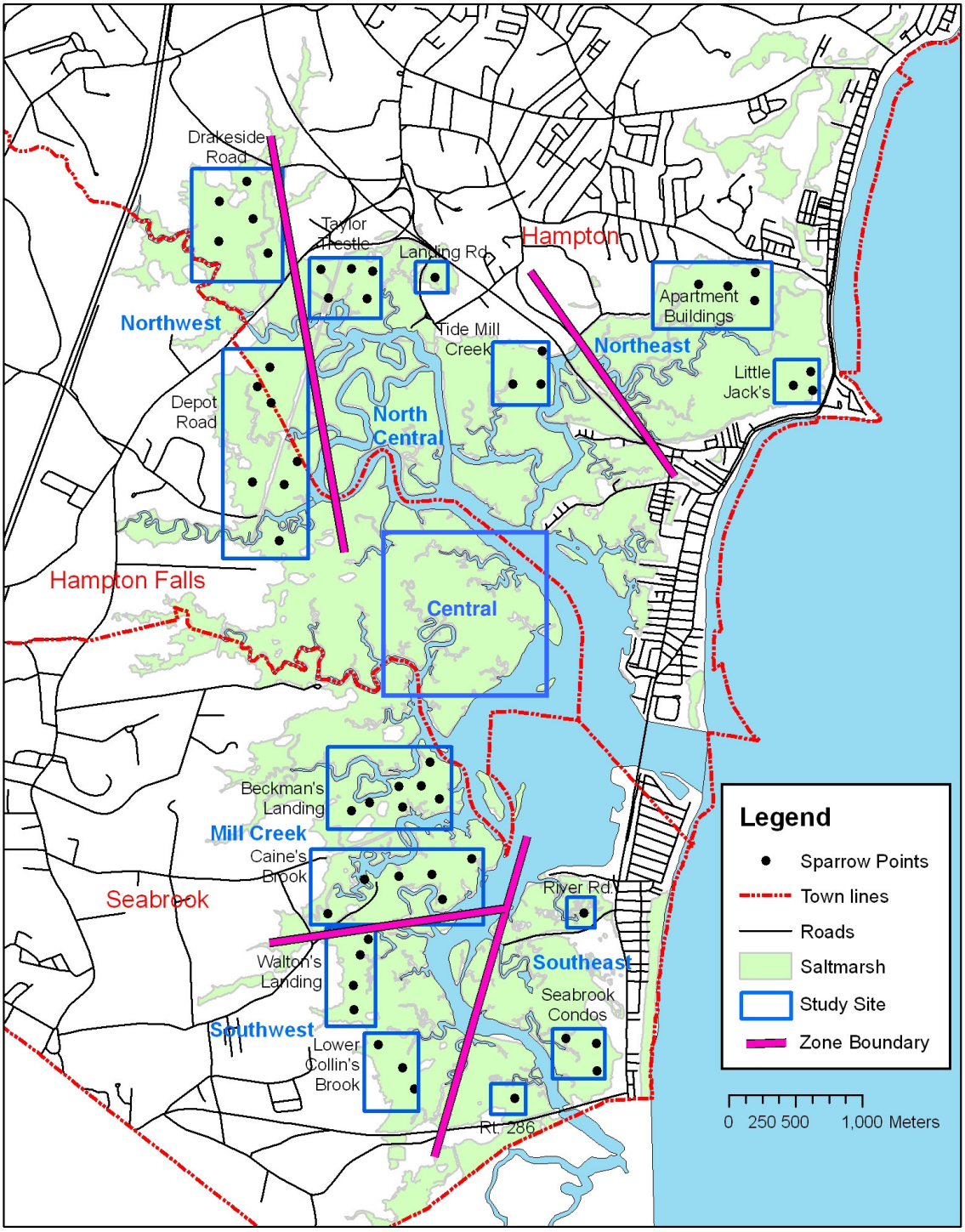

Figure 7. Locations of salt marsh sparrow study sites and zones in the Hampton-Seabrook Estuary in 2007.

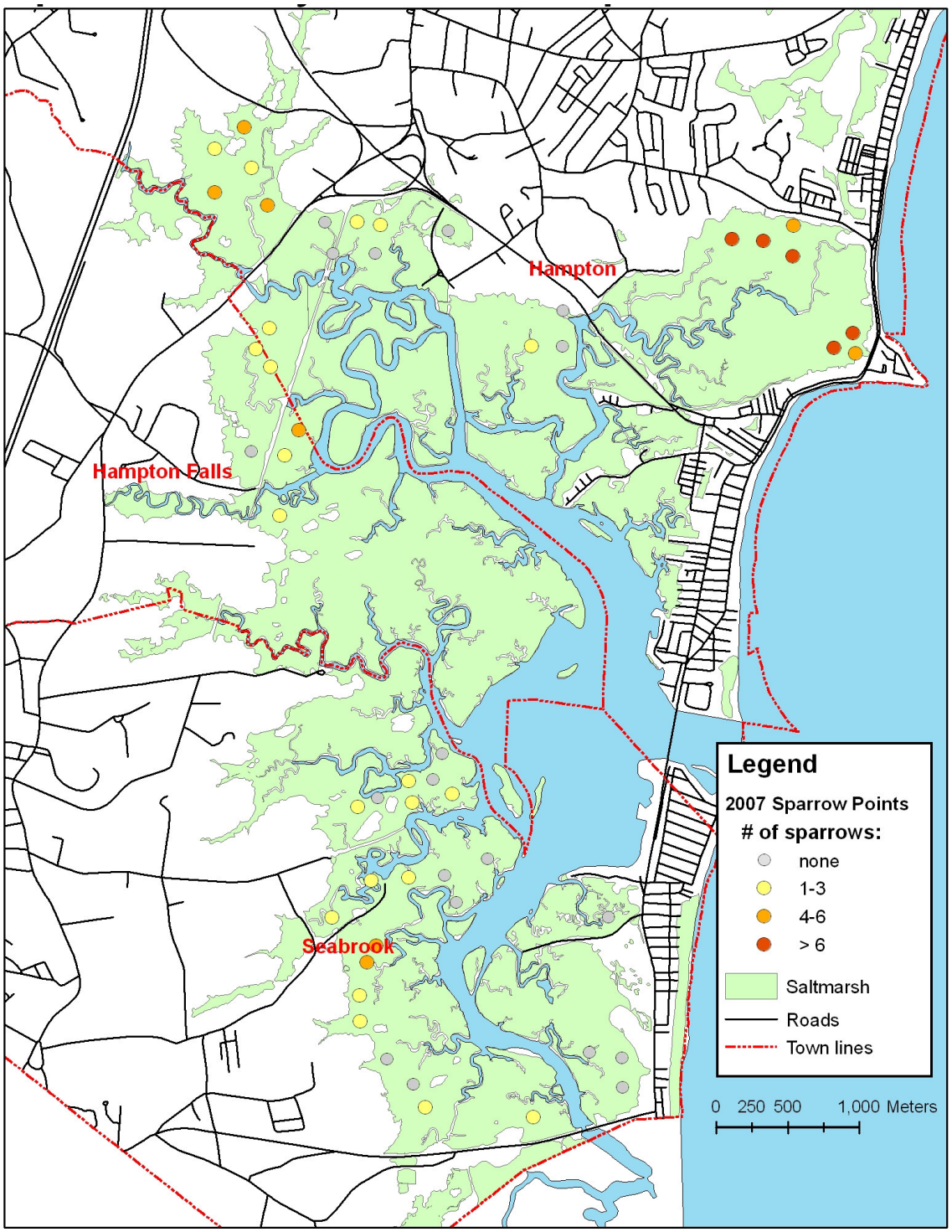

Figure 8. Distribution and abundance of Saltmarsh Sharp-tailed Sparrows in the Hampton-Seabrook Estuary during 2007. Data are not displayed for the Central zone (no sparrows at any point) because GPS coordinates were unavailable.

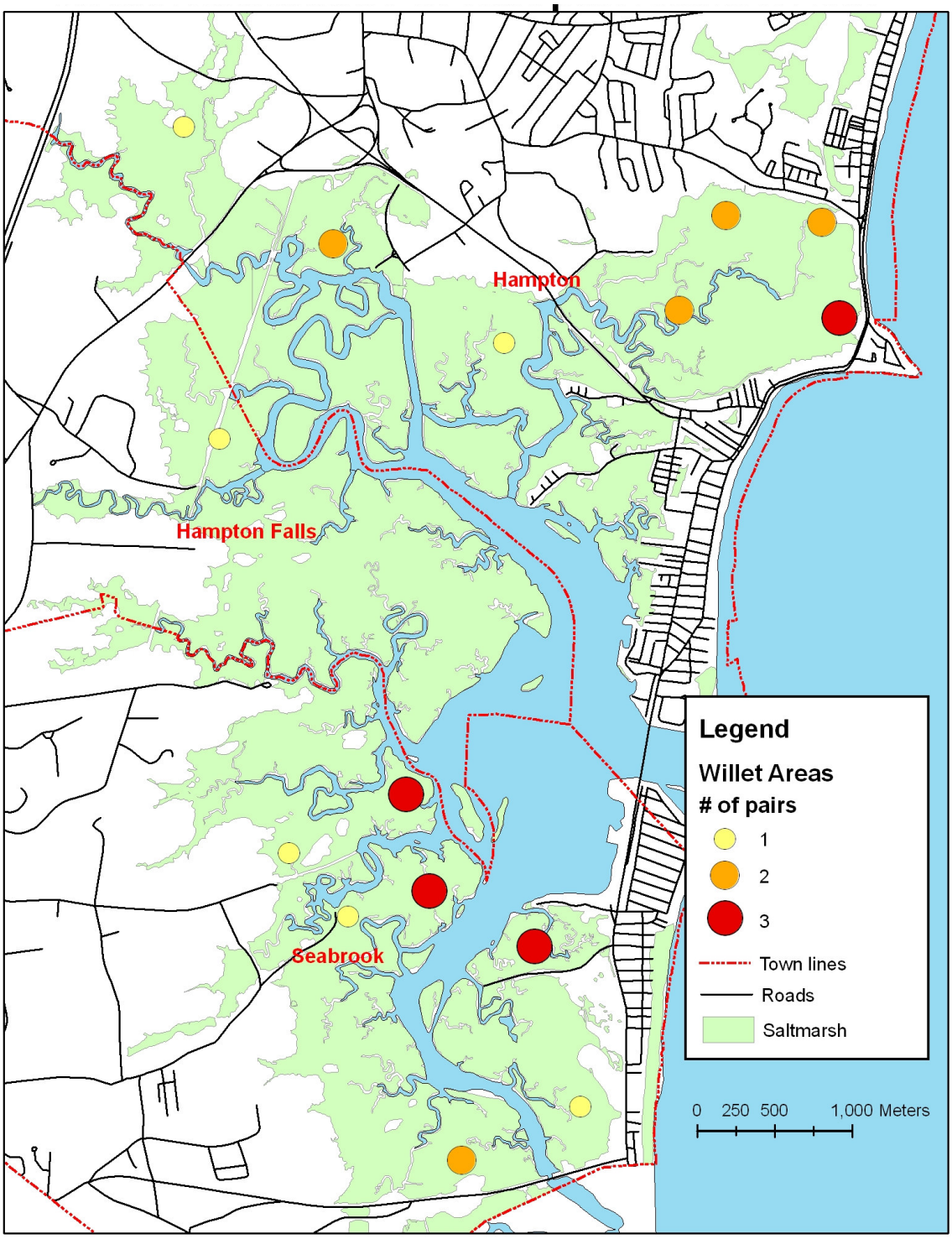

Figure 9. Approximate locations of Willet breeding concentrations in the Hampton-Seabrook Estuary during 2007.

Conclusions and Recommendations

This study is the first to systematically survey most areas of the Hampton-Seabrook Estuary for birds. Its goal is to identify those areas of the estuary that are most important for both migrating shorebirds and those species that breed in its extensive salt marshes. In the following section we summarize the key findings of this study, identify the most important focal areas within the estuary, and make recommendations for future monitoring, management, conservation, and restoration. It is our goal that these recommendations serve as the first step toward a larger conservation plan for the estuary, one that will benefit not only birds but other organisms and the habitat on which they all depend.

Based on our population estimates, a total of 3000-3500 shorebirds use the Hampton-Seabrook Estuary in a given fall migration. This number is quite small by regional standards. While such numbers certainly make the estuary the most significant shorebird stopover site in New Hampshire, they pale in comparison to concentrations recorded both to the north (e.g., Bay of Fundy: Gratto-Trevor 1992) and south (Cape Cod: Veit and Peterson 1993) within the Gulf of Maine. Shorebirds using the New Hampshire coastline should probably be considered part of the larger concentrations in the Newburyport Harbor/Plum Island marsh complex just to the south, especially since they regularly roost in the upper reaches of the Blackwater River drainage across the border in Salisbury. Although overall shorebird numbers in Hampton are relatively low, our estimate of a passage population of 1000-1200 Semipalmated Plovers is close to 1% of the estimated North American population estimate of 150,000 for this species. This would qualify the Hampton-Seabrook Estuary as a site of regional importance for the Western Hemisphere Shorebird Reserve Network (www.whsrn.org), and more careful study is recommended to refine this population estimate.

The estuary supports the majority of New Hampshire's breeding populations of Willets and Saltmarsh Sharp-tailed Sparrows. The former is a species of high regional priority, while the latter – as an endemic to the Atlantic coastal plain – is considered not only a national priority but a global one as well. Both species reach high densities in the unditched northeastern portion of the marsh, making this area a clear conservation priority. In addition, this distribution suggests that restoration of currently degraded salt marsh has the potential to benefit both species of conservation concern.

Focal Areas within the Hampton-Seabrook Estuary

Although a system of this size and complexity cannot easily be broken into smaller portions that function independently, there are four areas that warrant special attention (Figure 10), each of which has its own set of challenges and opportunities.

1) The northeastern portion of the marsh above Route 101 is almost unique in the estuary in that it remains in a largely natural condition, with ditching limited to small areas in its north-central portion. This absence of ditching is almost certainly behind the high densities of nesting Saltmarsh Sharp-tailed Sparrows in this area, and perhaps is also behind its use by nesting Willets and the only colony of Common Terns in the marsh. However, while this area remains in a natural condition, it is completely surrounded by roads and housing, and thus subject to poorly

understood human impacts such as chemical contamination in run-off from roads and lawns. A relatively small portion of this area is protected, and while development threats to salt marsh are relatively low, additional conservation acreage would minimize future effects and perhaps allow for habitat shifts in response to potential sea-level rise. This area should continue to be a priority for further research into marsh biota in comparison to sections subject to more intensive human impacts.

2) In the far northwestern corner of the marsh is another area (Drakeside Road) that has relatively little ditching, but that is also subject to tidal restriction by a culvert under Route 1. Sparrow densities here are significantly lower than in the northeast, but still higher than any other area of the estuary. The extent of tidal restriction by the Route 1 culvert and any effects on sparrow habitat are unknown, but bear additional investigation. Because there is a core area of conservation land here and a less developed upland buffer, the Drakeside Road marsh may present an excellent opportunity for future restoration.

3) Pools at the periphery of the marsh – particularly in the north – appear to be critical foraging and roosting areas for most of the migrating shorebirds that use the estuary. Two such areas (Henry's Pool and Landing Road pool) were the only pools where invertebrate prey were detected, and – along with Meadow Pond to the north – are either entirely freshwater or subject to regular freshwater inputs. If their low salinity is related to prey availability and the latter to high shorebird use, these two pools may be among the most important sites in proportion to their area in the entire system. They occupy less than two acres of the 5000 acre estuary, and yet regularly support more than 50% of some shorebird populations. The hydrology of these pools is a subject needing further research, and in any event restoration and conservation of peripheral freshwater and brackish systems is an important goal.

4) At the southern edge of Hampton Harbor is a large area that encompasses the mouths of the major southern tributaries (Brown's, Mill, Blackwater), the south flats of Hampton Harbor, and a significant shorebird roost below the mouth of Mill Creek. The creek mouths and south flats exhibit high topographic and substrate diversity, contain annelid worm prey, and support up to 75% of the daily shorebird population on at least one tide daily as soon as they are available for foraging. Recent alteration to the south flats through the installation of a retaining bulkhead has resulted in these flats drying out relatively early in a tidal cycle. Anecdotal reports suggest that this alteration has also resulted in a decline in shorebird use, although these flats are still an important staging area as other flats are being exposed on falling tides. In addition to the roost below Mill Creek, this focal area could arguably include another significant roost upstream near the Route 286 bridge, and ultimately the Salisbury Marsh roost in Massachusetts. The addition of the latter two areas would effectively incorporate the majority of sites used by the larger shorebird species into a single functional unit. This area – not including the latter two roost sites – is also the other important Willet nesting area within the estuary.

Critical Threats and Strategies

Extensive areas of the marsh are still heavily ditched, and data on Saltmarsh Sharp-tailed Sparrow distribution suggest that this priority species reaches its highest densities in unditched portions of the estuary, and is exceedingly rare or absent from heavily ditched areas. While

reasons for this pattern of habitat selection are unclear, consideration of overall improvement of marsh condition would dictate that restoration of currently ditched areas would also benefit sparrow populations. However, it should be noted that restoration can result in temporarily reduced local populations of sparrows (e.g., DiQuinzio et al. 2002), and that several years may be required before restoration effects on sparrows can be documented. The high sparrow population in the unditched northeastern portion of the marsh would likely serve as a source of colonists to restored areas in the event that local restoration activity resulted in short-term extirpations. One reason the Salisbury Marsh may be an important roost is that the absence of ditching has resulted in a number of pools on the marsh surface. Ditching in the rest of the estuary may serve to drain such pools and reduce their value as roosting or feeding areas.

Restoration should also take into account the freshwater or brackish pools that are important to roosting and foraging shorebirds. This might be achieved through restricting further construction in the wooded buffers around the freshwater and brackish streams feeding the estuary. Along the same lines, a better understanding of how such pools are maintained may allow for restoration of sites that are no longer extensively used by shorebirds, such as those at the end of Depot Road in Hampton Falls.

Human disturbance has been shown to potentially reduce the capacity of shorebirds to successfully complete their migrations. Because the coastal portions of both Hampton and Seabrook are heavily used by people during the peak of the shorebird fall migration, this threat deserves further research in the estuary. The fact that shorebirds begin use of Seabrook Beach only after the close of the tourist season is preliminary evidence that human activity already alters shorebird behavior in this system – with currently unknown effects. The two major roost sites near the Blackwater River are subject to disturbance by boat traffic, and one of these – at the Route 286 bridge – is also accessible to foot traffic. Protection of sensitive roost sites should be a priority within the estuary, with public outreach being perhaps the most important means of accomplishing this goal. We acknowledge the need for periodic dredging of Hampton Harbor, and based on annual patterns of shorebird use recommend that such activity take place between November and June. During this period, non-breeding shorebird use is significantly lower than in July-September, and harbor maintenance outside of the peak fall migration would result in lower overall disturbance to birds during this critical stage of their annual cycle.

Although state wetland regulations make direct loss of additional salt marsh habitat unlikely, there are still benefits to direct land conservation in the estuary. Such conservation should particularly focus on high marsh or upland buffers around the periphery of the estuary, which would serve the dual purpose of reducing external impacts to the marsh and potentially allow for habitat migration in the event of sea level rise. Consideration of marsh connectivity and tidal restriction in the latter context are also important considerations. In addition, further development that encroaches on important roost sites should be minimized through direct conservation, regulation, or a combination of the two.

Next Steps

In addition to the conservation recommendations outlined above, there are still topics needing further research in the estuary. These include more detailed study of invertebrate populations

with respect to shorebird foraging patterns, the role of freshwater inputs into the pools used by shorebirds along the estuary's northern edge, analysis of existing data on nest site selection by salt marsh sparrows, and a more accurate estimate of the area's breeding Willet and Common Tern populations – including productivity measurements.

However, such research can take place in parallel with a concerted effort to promote the most appropriate conservation strategies for the Hampton-Seabrook Estuary. The logical next step is thus to move forward with development of a conservation plan, including consideration of other plans already in existence for larger geographic areas (e.g., NH Estuaries Project 2000, Zankel et al. 2006). Such a plan should begin by gathering the appropriate experts in the estuary's ecology together and compiling a broader base of data to guide conservation decisions. Areas and threats in need of immediate conservation can be prioritized using the best available science, and the more appropriate parties to implement conservation strategies can be identified. Key players in any such effort include many of those listed in the Appendix to this report, and every effort should be made to cross state lines and involve partners in Massachusetts. Like the shorebirds that pass through here twice a year on their trans-hemispheric journeys, the issues facing this estuary are not constrained by political boundaries, and neither should be our efforts to improve the system's ecological condition.

Acknowledgments

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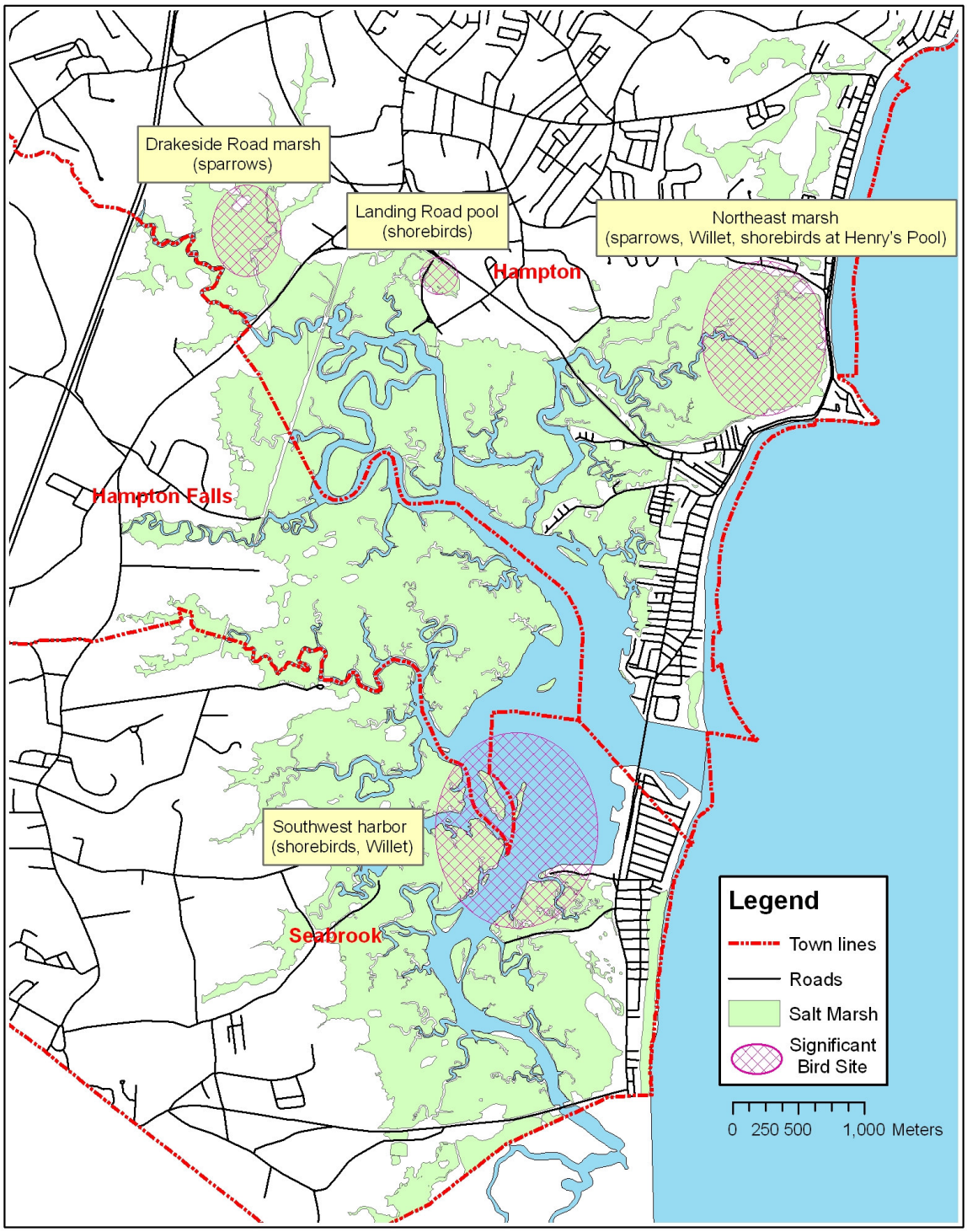

Figure 10. Sites of conservation priority for birds within the Hampton-Seabrook Estuary based on occurrence of migrating shorebirds, breeding salt marsh sparrows, or breeding Willets.

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Appendix A: **Overview of public outreach and partnership building component**

Concurrent with the field component of this study, we initiated a process of convening and informing numerous stakeholders in the Hampton-Seabrook Estuary. Stakeholders range from state and federal agencies and organizations charged with management and conservation of the landscape and its associated wildlife, to businesses and communities whose economic well-being is somehow tied to a functional and productive estuary, to members of the general public who simply appreciate the opportunities to catch a glimpse of an egret standing still on the marsh.

Such entities all have different reasons for being a stakeholder and play different roles in the process of developing and supporting policy. Reasons for being a stakeholder might include administrative or legislative decree as with state or federal agencies charged with management and maintenance of landscapes, open space, transportation systems, water quality, and biological diversity. A consulting firm might be a stakeholder via its client's interests and based on the firm's own business plan and mission. A non-profit conservation group is often a stakeholder based upon its mission statement, board of directors, members, and interests of its staff. Irrespective of institutional affiliation, professionals across state, federal, and private agencies and sectors are usually invested personally in environmental management and find such a career works with their value sets.

Other stakeholders include businesses dependent upon tourism, recreation, recreational fishing, and commercial fishing. Such a list could even include the banks that hold notes on the aforementioned businesses. Stakeholders include landowners from private residences on the edge of the marsh, to residences in the watershed, to large scale industrial owners such as the Seabrook Power Station. Stakeholders include businesses located further up the watershed well away from the main commercial area in Hampton Beach. Buffer zone policies and water quality policies miles from the marsh and harbor center affect commercial and residential development old and new. While many stakeholders in the estuary are ready to participate in decision making, many stakeholders do not even realize they might be a stakeholder.

The preliminary stages of stakeholder involvement in this project focused on public outreach. Table 4 lists all talks, field trips, or interviews by the project coordinator between July 2006 and September 2007. The project coordinator's experiences during these events suggest that the story of shorebird migration is a good way to get people interested in the estuary and its conservation. Birds are often an excellent vehicle to inspire conservation, likely more so than discussion of nutrient cycling and fish nurseries. The latter are obviously critical for ecosystem functioning, and likely more important to human economic interests, but they are not something easily visible and capable of inspiring awe. Birds that travel thousands of miles a year do have this capacity, and their potential role in raising awareness of estuarine issues should not be understated.

At the same time, the project coordinator made professional contact with other stakeholders active in the estuary or in the broader field of shorebird and marshbird conservation. These organizations or individuals are listed in Table 5. This combination of public outreach and stakeholder involvement will be important to build upon when the Hampton-Seabrook Estuary Conservation Project moves forward into Phase 2, the development of a Conservation Plan.

Table 4. Public presentations, field trips, or publicly associated with Phase 1 of the Hampton-Seabrook Estuary Conservation Project.

NH Coastal Watershed Weekend (with NH Coastal Program and SPNHF) (October 2006)
Hampton Falls Conservation Commission (Fall 2006)
Seabrook Conservation Commission (Fall 2006)
Great Bay Resource Protection Partnership (Fall 2006)
Osher Lifelong Learning Institute (Granite State College): Indoor presentation to 15 people (Spring 2007)
NH Estuaries Program: meeting of partners with coastal interests (Spring 2007)
Seabrook Station: classroom session and four field trips to discuss shorebirds (15-20 employees) (Spring 2007)
Hampton Rotary (Spring 2007)
Seacoast Chapter of NH Audubon (May 2007)
Hampton Public Library (May 2007)
Seabrook Women's Club (June 2007)
Osher Lifelong Learning Institute: two field trips with 37 and 20 attendees (late summer 2007)
NH Public Radio interview on climate change (August 2007): http://www.nhpr.org/node/13575
Article in Seacoast Sun Journal (October 2007): http://amykane.typepad.com/northhampton/2007/10/conservation-pl.html

Table 5. Stakeholders contacted during Phase 1 of the Hampton-Seabrook Estuary Conservation Project.

New Hampshire Fish and Game: Nongame and Endangered Species Program
New Hampshire Coastal Program
Nature Conservancy: New Hampshire Chapter
New Hampshire Estuaries Project
University of New Hampshire
Florida Power and Light: Seabrook Nuclear Power Facility
Hampton Rotary Club
Normandeau Associates
Great Bay Association
Wells National Estuarine Research Reserve
Society for the Protection of New Hampshire Forests
Hampton Conservation Commission
Hampton Falls Conservation Commission
Seabrook Conservation Commission
Rockingham County Conservation Commission
Atlantic Cooperative Wildlife Ecology Research Network (Canadian Wildlife Service and Maritime Universities)
Seabrook Fisherman's Co-op
Western Hemisphere Shorebird Reserve Network
Manomet Center for Conservation Sciences
Massachusetts Audubon

Appendix B: Other birds species using the Hampton-Seabrook Estuary in 2006-2007

During the course of regular surveys for both migrating and breeding priority species, observers noted all other bird species, their relative abundance, and locations within the marsh. While this study was not designed to be a complete avifaunal analysis and inventory, we present a summary of these additional species as a measure of the overall breadth of bird use of the area. This list does not include species believed to be peripheral to the estuarine ecosystem, including birds only seen flying over or that wander into the marsh edge from nearby forested or residential areas.

Species	Abundance and Season	Use of Estuary
Black Duck	Uncommon year-round visitor and probable breeder	Forage in high marsh creeks and pools
Common Goldeneye	Uncommon winter resident	Forages in main harbor and at creek mouths, especially at lower tides when prey may be concentrated
Red-breasted Merganser	Common winter resident	Forages in main harbor and at creek mouths, especially at lower tides when prey may be concentrated
Common Merganser	Uncommon fall and winter visitor	Forages in main harbor and at creek mouths, especially at lower tides when prey may be concentrated
Red-necked Grebe	Rare winter visitor	Single bird used area in vicinity of Brown's River mouth, presumably for foraging
Double Crested Cormorant	Common to abundant visitor spring through fall	Roosts in large numbers on north flats, forages in harbor and larger creeks
American Bittern	Rare migrant, primarily in fall	High and low marsh creeks with adequate cover, and high marsh areas associated with input of freshwater streams.
Great Blue Heron	Uncommon from early spring through late fall	Forages in high marsh creeks and creek flats, roosts in large trees around marsh periphery
Great Egret	Uncommon to common spring and summer visitor	Forages in creeks, pools, and edge of harbor. Marsh surface occasionally serves as staging area for birds heading to roost
Snowy Egret	Common to abundant spring and summer visitor	Forages in creeks, pools, and edge of harbor. Marsh surface occasionally serves as staging area for birds heading to roost
Little Blue Heron	Rare summer visitor	Associated with egrets in marsh
Green Heron	Uncommon in summer, probably breeds	High marsh streams and wooded areas at perimeter of marsh and free from human traffic
Black-crowned Night-Heron	Uncommon summer visitor, may breed near Meadow Pond	High and low marsh creeks with adequate cover, and high marsh areas associated with input of freshwater streams
Glossy Ibis	Uncommon summer visitor	High and low marsh creeks and pools
Osprey	Two breeding sites, uncommon migrant	Nests on structures in marsh. Hunts over harbor and larger tributaries
Northern Harrier	Rare migrant	Hunts over most areas of marsh
Coopers Hawk	Uncommon resident	Hunts shorebirds over flats or pools
Peregrine Falcon	Rare migrant	Hunts shorebirds over flats or pools
Roseate Tern	Uncommon summer visitor	Foraging terns from Isles of Shoals use main harbor channel, migrating terns use harbor flats under shallow water cover
Ring-billed Gull	Common year-round resident	Roosts and feeds in main harbor
Herring Gull	Common year-round resident	Roosts and feeds in main harbor
Great Black-backed Gull	Common year-round resident	Roosts and feeds in main harbor
Belted Kingfisher	Uncommon breeder and migrant	High marsh pools, ponds, and freshwater streams
Tree Swallow	Common breeder and abundant late summer migrant	Nests in boxes scattered throughout marsh; in August large numbers congregate in the southern portion of the estuary, where they roost in the Seabrook Dunes or nearby areas of marsh, and forage over grasses and pools
Nelson's Sharp-tailed Sparrow	Uncommon fall migrant	High marsh, particularly in northeast portion of estuary
Snow Bunting	Common, late fall and winter	Barrier dunes.