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Temporal Changes in the Breeding Bird Community at Four Hudson River Tidal Marshes

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ABSTRACT

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In 1986 and 1987, the New York State Department of Environmental Conservation and the Hudson River Foundation sponsored a study of avian breeding habitats in six tidal marshes on the Hudson River Estuary. Local concern prompted a repeat of this study at Iona Island Marsh in 2004 and at four of the marshes in 2005 (Iona Island Marsh, Constitution Marsh, Tivoli North Bay, and Stockport Flats). This study had three main objectives: (1) to document bird species breeding in these four marshes, (2) to determine how the marsh-breeding populations have changed since the 1986–87 study, and (3) to relate the spatial distribution of marsh-nesting species to measurable habitat variables within marshes. A total of 3522 observations of birds, representing 83 species, were recorded from April 28, 2005, to June 30, 2005. These observations were made by sampling 109 fixed observation stations five times using both visual and vocalization sampling methods. Nineteen of those species are dependent on emergent marsh habitats. The most common marsh-dependent species encountered during this study were Red-winged Blackbird (*Agelaius phoeniceus*) and Marsh Wren (*Cistothorus palustris*). These two species each accounted for 23–47% of the marsh-dependent guild at Constitution Marsh, Tivoli North Bay, and Stockport Marsh. Marsh Wrens were nearly absent from Iona Island Marsh (<1.0%); there, Red-winged Blackbirds accounted for more than 77% of the marsh bird community. Red-winged Blackbirds also dominated the marsh avian communities at Constitution and Stockport Marshes. Bird species diversity decreased significantly since 1986–87 at Iona Island and Constitution Marshes. Decreased diversity corresponds with an increase in the density of Red-winged Blackbirds. At Iona Island Marsh, this shift in the avian community to almost entirely Red-winged Blackbirds coincided with a shift of the plant community dominance from narrowleaf cattail (*Typha angustifolia*) in 1986–87 to common reed (*Phragmites australis*) in 2004–05. This shift was not evident at Constitution Marsh, Tivoli North Bay, or Stockport Marsh, although the number of *Phragmites australis* has also expanded at these sites. In addition to our survey, we found a total of 230 nests in 2005. Major findings of the bird nest searches were (1) the very low density of nests found at Iona Island Marsh (five nests total in 2004 and 2005), (2) the most common nest encountered at the other three marshes was that of the Marsh Wren (83% of total nests observed), and (3) the highest bird nest density occurred at Tivoli North Bay (65 nests ha^{-1}).

ADDITIONAL INDEX WORDS: *Avian breeding habitats, tidal marshes, Hudson River Estuary.*

INTRODUCTION

The ecological capacity of tidal marshes to support healthy populations of marsh-dependent, breeding birds has become an important coastal management issue at local, regional, and national scales. This interest is being driven by both a documented decrease in some marsh-dependent bird species (CONWAY, 2004) and by the loss and degradation of tidal marsh habitat (HOWE, 1987; TINER, 1984) along the coasts of the United States. Fragmentation and the reduction in size of the remaining tidal marshes may also reduce the diversity of marsh-dependent bird communities (GREENBURG and MALDONADO, 2006).

The effect that the loss of tidal marshes has on marsh bird species is fairly predictable, but the continued degradation of the remaining marsh habitat can also reduce the diversity of this highly endemic bird community. Climate change with predicted increases in coastal flooding frequency can adversely affect the nesting success of resident, tidal-marsh, breeding birds because those birds are already subject to periodic flooding by spring and storm tides (GREENBURG and MALDONADO, 2006; REINERT, 2006). The alteration of marsh habitat structure by nonnative plant species, such as common reed (*Phragmites australis*), can negatively impact resident marsh birds (GUNTENSPERGEN and NORDBY, 2006) by reducing the marsh's capacity to support both the breeding and foraging habitats those specialized bird species require. Marshes composed of less than 50% native plants show a reduction in marsh bird species richness (SHRIVER *et al.,* 2004).

In 1986 and 1987, the New York State Department of Environmental Conservation (NYSDEC) and the Hudson River Foundation jointly sponsored a study of avian breeding hab-

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itats in tidal marshes on the Hudson River Estuary (SWIFT, 1987, 1998). Six Hudson River tidal marshes—West Flats, Stockport Marsh, Hudson North Bay, Tivoli North Bay, Constitution Marsh, and Iona Marsh—were selected for study. The objectives of this original study were to document bird species breeding in Hudson River tidal marshes, to relate the spatial distribution of marsh-nesting species to measurable habitat variables, and to develop models for predicting distribution and abundance of nesting species in tidal marshes throughout the Hudson River Estuary.

Results of the 1986–87 study indicated that Hudson River tidal marshes supported dense populations of breeding birds, characterized by a species composition typical of eastern North American tidal freshwater marshes (GREENBERG and MALDONADO, 2006). In general, tidal marshes had substantially fewer breeding species than nontidal marshes of similar vegetation types. Least Bittern (*Ixobrychus exilis*) and Virginia Rail (*Rallus limicola*) were the only nonpasserine species to make extensive use of these tidal marshes for nesting. No endangered or threatened bird species were found to regularly occur in the marshes during nesting season. Least Bittern, a New York state species of special concern, was a common inhabitant of the studied marshes.

The distribution and abundance of marsh-nesting birds were closely linked to microhabitat characteristics. Depth of tidal flooding and vegetation type was found to play significant roles in shaping the composition of the avian community. Cover types associated with the greatest abundance and nesting species diversity were a river bulrush (*Schoenoplectus fluviatilis*)–cattail (*Typha angustifolia*) association, purple loosestrife (*Lythrum salicaria*), and woody vegetation (*Salix* spp.).

In recent years, obvious changes in the vegetation of Iona Island Marsh, coupled with anecdotal reports of marked changes in the avian community, prompted renewed interest in the breeding birds of Iona Island Marsh and their habitat relationships. During the spring of 2004, NYSDEC and the Palisades Interstate Park Commission (PIPC) jointly supported a study to address this concern. Results of the 2004 study (discussed in this article) stimulated expansion of the work in 2005 to four of the six original Swift study sites: Stockport Marsh, Tivoli North Bay Marsh, Constitution Marsh, and Iona Island Marsh (SWIFT, 1987, 1998). Although we would have liked to repeat the study at all six sites, available funding restricted our study to just four of the original sites. We selected those four because three of them were part of the Hudson River National Estuarine Research Reserve (Stockport Marsh, Tivoli North Bay, and Iona Island Marsh), and Constitution Marsh is owned and managed by the Audubon Society; there was an expressed interest by the site-management agencies for those four sites to have this study undertaken.

The 2005 study had three primary objectives: (1) to document bird species breeding in the four marshes, (2) to determine how the marsh-breeding bird populations changed since the 1986–87 survey, and (3) to relate the spatial distribution of marsh-nesting species to measurable habitat variables within the marsh, such as changes in marsh vegetation.

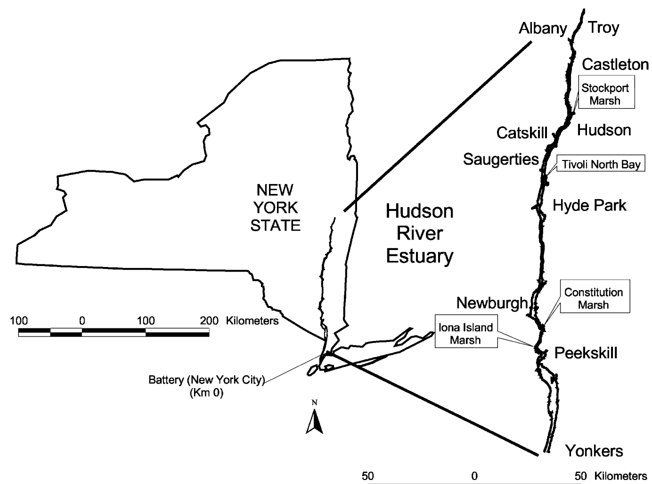

Figure 1. Location map of tidal marshes along the Hudson River Estuary included in this study (modified from Nieder *et al.,* 2004).

METHODS

Study Site Description

This study was conducted at four tidal marshes on the Hudson River (Figure 1). Each of the four sites is described separately below.

Iona Island Marsh

Iona Island Marsh (41°18′00″ N, 73°58′45″ W) is located on the west shore of the Hudson River, 2.1 km south of the Bear Mountain Bridge in Rockland County, New York. This southernmost site is a 76-ha, brackish marsh. Terrain elevation ranges from sea level to approximately 21 m. Iona Island Marsh is a component of the Hudson River National Estuarine Research Reserve. The study area is an approximately 70-ha parcel of tidal marsh lying between Iona Island and the west shore of the Hudson River. Historically, cattails (*Typha angustifolia* and *Typha glauca*) dominated the marsh, with smaller amounts of common reed (*Phragmites australis*), swamp rose-mallow (*Hibiscus palustris*), smartweed (*Polygonum* spp.), and others. Today, *Phragmites australis* dominates much of the marsh, making up greater than 80% of the emergent marsh habitat. The land surrounding the marsh is, for the most part, steep, rocky, undeveloped forestland.

Constitution Marsh

Constitution Marsh (41°24′28″ N, 73°56′38″ W) is located on the east shore of the Hudson River, 1.6 km southeast of Cold Spring in Putnam County, New York. The marsh is located between Constitution Island on the west and Foundry Cove to the northwest. It is a 161-ha, brackish tidal marsh dominated by narrow-leafed cattail (*Typha angustifolia*), but considerable amounts of purple loosestrife (*Lythrum salicaria*) and woody vegetation occur in shallow, flooded areas, especially around the wetland perimeter. The survey area represents an approximately 60-ha portion of the marsh. Bottom substrates are predominately silt, mixed with some muck in central portions of the marsh (SWIFT, 1987). To the east, an upland area with steep rocky slopes and a mature upland forest border the marsh.

Constitution Marsh has an extensive network of constructed channels throughout. These are the result of an effort in the 1830s to develop the area for wild rice (*Zizania aquatica*) production. The vegetation remains characteristic of a freshwater marsh, with arrow arum (*Peltandra virginica*), pickerelweed (*Pontederia cordata*), arrowhead (*Sagittaria latifolia*), *Zizania aquatica,* and *Phragmites australis.* Several bridges accommodate tidal flow from the river, but several manufactured dikes may dampen extreme flooding. Marsh waters are mainly fresh, but during the summer, they may become slightly brackish.

Tivoli North Bay

Tivoli North Bay (42°02′24″ N, 73°55′11″ W) is located on the eastern shore of the Hudson River in Dutchess County, New York. The small town of Tivoli is located approximately 1.6 km to the northeast. Tivoli North Bay is a part of the 485-ha Tivoli Bays component of the Hudson River National Estuarine Research Reserve and is a New York State Wildlife Management Area. The Tivoli Bays complex includes freshwater intertidal mudflats, freshwater intertidal shore, freshwater tidal marsh, freshwater tidal swamp, and shallow water channels. North Bay contains a mixture of freshwater tidal marshes, dominated by *Typha angustifolia* and intertidal mudflats, supporting large beds of spatterdock (*Nuphar advena*) and pickerelweed (*Pontederia cordata*), whereas Tivoli South Bay is largely shallows and mudflats, dominated by Eurasian water chestnut (*Trapa natans*).

The study area encompasses approximately 50 ha within Tivoli North Bay and extends approximately 2.25 km along the Hudson River. Originally, the area was a shallow bay along the eastern shore of the Hudson River, but it was cut off from the main channel by the construction of the east shore railroad in the late 1850s. Water exchange is maintained through two railroad bridges. Bottom sediments within the marsh are predominately soft muck and silt. Most of the study area is covered by dense growth of *Typha angustifolia* with interspersed *Lythrum salicaria, Phragmites australis,* and woody vegetation (SWIFT, 1987).

Stockport Marsh

Stockport Marsh is located on the eastern shore of the Hudson River (42°18′15″ N, 73°46′23″ W). The town of Stockport, Columbia County, New York, is located approximately 2.4 km to the northeast. The marsh is part of the Stockport Flats component of the Hudson River National Estuarine Research Reserve, which comprises approximately 648 ha of tidal freshwater habitats, including tidal marshes, swamps, and floodplain forests extending for about 8 km along the east shore of the Hudson River. Much of the natural shoreline of the reserve was altered in the early 20th century by the disposal of channel dredge spoil.

The Stockport Marsh study area is approximately 30 ha of tidal marsh, located just south of the mouth of Stockport Creek. The marsh is separated from the Hudson River to the west by a narrow peninsula of sandy dredge material (deposited in the 1950s). To the north lies a region of undeveloped deciduous forest, whereas along the eastern edge is the Conrail railroad. The marsh opens broadly to the Hudson River to the south. There are no well-defined channels within the marsh, only irregular patches of emergent vegetation. Vegetation is predominately *Typha angustifolia, Lythrum salicaria, Zizania aquatica, Nuphar advena, Peltandra virginica, Pontederia cordata,* and *Schoenoplectus fluviatilis* (SWIFT, 1987). Considerable growths of woody (black willow, *Salix nigra*) and upland vegetation occur in the northern portion of the study area. The marsh substrate is composed mainly of silt, sand, and muck (SWIFT, 1987).

Study Design

Establishing Sampling Sites

The intent of this study was to replicate at four of the original six sites, as closely as possible, the methods used by SWIFT (1987 and 1998). The initial step was to relocate the sampling points in the field from the original 1986–87 hand-drawn maps. These maps were scanned, converted to digital images, imported into the ArcGIS system (ESRI, 2004), and overlain with aerial photographs and 1 : 24,000 U.S. Geological Survey (USGS) topographic maps. The Universal Transverse Mercator–North American Datum (UTM NAD) 1983 Easting and Northing coordinates of the center point of each sampling points were then recorded. A total of 109 sampling plots were identified among the four sites as follows: 30 stations each at Iona Island Marsh and Constitution Marsh, 29 stations at Tivoli North Bay, and 20 stations at Stockport Marshes.

Once all sampling points were located, we established the boundaries and areas of the marsh study region and associated waterways using a geographic information system (GIS). From this information, a set of reference maps were printed for the survey teams to use in the field as an aid for navigation.

Before initiating the breeding bird survey, the UTM coordinates of all stations were downloaded to a Trimble Pathfinder Pro XRS Global Positioning System (GPS) unit and a three-person team placed semipermanent marker stakes at each station location. The Trimble GPS unit has 30-cm accuracy with 5 minutes of satellite tracking, so stations were located with a high degree of accuracy. Station markers were approximately 3-m-high wooden stakes with the upper end painted bright orange to increase visibility. Small pieces of surveyor tape were used to mark pathways to the stations. In cases where the 1986–87 station location could not be used (GPS coordinates placed it in a creek, road, or upland location), the closest suitable location was designated, and the UTM coordinates recorded.

Breeding Bird Survey Methodology

During May 1, 2004 to June 20, 2004 (Iona Island only), and April 28, 2005 to June 30, 2005, five breeding bird surveys were conducted at each marsh using variable circular-plot (Reynolds, Scott, and Nussbaum, 1980) point-counts at each fixed observation station. Surveys were conducted approximately once every 12 days during the morning (from sunrise to 4 h after sunrise) or evening (from 4 h before sunset to sunset). Surveys were conducted only during periods when fair weather was forecast (*i.e.,* no measurable precipitation or winds that would interfere in accurate observations) and were halted if thunderstorms occurred in the area.

We recorded tide height, air temperature, precipitation, and wind speed and direction on days when surveys were conducted. Meteorological data, including temperature, humidity, barometric pressure, rainfall, and wind speed and direction, were collected from a monitoring station located in Tomkins Cove, New York (41°15′29″ N, 73°59′35″ W). These data were periodically checked against National Oceanic and Atmospheric Administration (NOAA) data to ensure accuracy. The purpose of this information was to ensure that general regional weather conditions met survey guidelines for rain and wind; that is, no measurable precipitation and winds not exceeding 25 km hr^{-1} (Robbins, 1981; Swift, 1987, 1998). These data were used as a general indicator of field conditions.

The sequence in which stations were surveyed within a marsh was randomized before each census round. Sampling routes were switched among team members so that differences in ability between the observers could be assessed. Each point count was 11 minutes in duration, including a 1-minute "rest period" used to reestablish normal bird activity before beginning observations. During each point count, observers recorded the following information for each bird (or group of birds) seen or heard: station number, date, time, species, sex/age/number of individuals, distance to each individual, direction of each individual, a behavior/breeding code, movement direction (if moving), and vegetation. The observers also noted general activity (*e.g.,* flying through the area, feeding, resting, preening).

All birds seen or heard during the survey period were recorded. For passerine species, we included only data from birds detected (visual or aural) within a 30-m radius of the point count center, and for nonpasserine species, we included data from detections within a 60-m radius in our analysis.

During the 10-minute point count, we used broadcast calls to elicit vocalizations (*i.e.,* detections) because marsh birds, in particular nonpasserines, are secretive, seldom visually observed, and vocalize infrequently (Conway, 2004, 2005). We played recorded calls of nonpasserine marsh birds expected to breed in the area. including Green Heron (*Butorides virescens*), Least Bittern, American Bittern (*Botaurus lentiginosus*), Virginia Rail, Sora (*Porzana carolina*), and Common Moorhen (*Gallinula chloropus*). Calls were played for 40 seconds, followed by 20 seconds of silence. A Western Rivers Digital Game Caller was used for audio playback. Audio playbacks were broadcast at maximum playback volume (setting 31). Technicians tested the audio output of each unit to ensure a maximum sound pressure of 85–90 decibels at 1 m from the source following Swift (1987, 1998) and Conway (2004, 2005). Audio playback broadcast call sequence MPEG-1 Audio Layer-3 (MP3) files were constructed from compact disc (CD) audio clips from Walton and Lawson (1989, 1994) and from Elliott, Stokes, and Stokes (1997).

Nest Searches

Following the fifth breeding-bird survey, a thorough search of one quarter of each 30-m sampling plot (0.0706 ha) was conducted. A team of at least two individuals systematically searched each quarter plot by hand-combing vegetation along parallel routes (3–5 m apart). All nests encountered were counted, identified to species where possible, and photographed. The position of the nest was determined using GPS and the position along the transect line. Along with the GPS coordinates, the vegetation associated with the nest was recorded. Nesting cover was classified following the definitions in Swift (1987).

Avian Classification

For analytical purposes, and to follow the methods used by Swift (1987, 1998), birds were divided into two major taxonomic categories: passerine (members of the order Passeriformes), and nonpasserine (all other modern birds). Only the most abundant marsh-dependent species are presented in detail, including American Bittern, Least Bittern, and Virginia Rail, among the nonpasserines, and American Goldfinch (*Carduelis tristis*), Common Grackle (*Quiscalus quiscula*), Common Yellowthroat (*Geothylpis trichau*), Marsh Wren, Red-winged Blackbird, Song Sparrow (*Melospiza melodia*), Swamp Sparrow (*Melospiza georgiana*), Yellow Warbler (*Dendroica petechia*), and Willow Flycatcher (*Empidonax traillii*), among the passerines. Marsh-dependent birds were defined as (1) those species that nest and feed within the marsh, and (2) those species that often use the marsh for feeding, shelter, and sometimes, nesting. The former group may be found well into the interior regions of the marsh, whereas the latter species are typically found near the upland marsh border, seldom venturing deep into the marsh. Though not identified as a marsh-dependent species by Greenberg and Malonado (2006), American Goldfinch do nest and feed in Hudson River tidal marshes (Kiviat, 1996; Swift, 1998) and are, therefore, considered a marsh-dependent species in this study.

Vegetation Survey

Following the five census rounds, we sampled vegetation at each avian survey sampling point. From the center of each sampling point, two 30-m transects were laid out using a premeasured and marked cord. We determined the orientation of this transect by selecting a random compass bearing for each point. The second transect was offset 90° from the first transect. At 10-m intervals, from the plot center along each of the two transects, a 1-m^2 quadrat was located, and live-stem counts of emergent plant species were made. Important reference works used for plant identification included Peterson and McKenny (1968); Rawinski, Malecki, and Mudrak (1979); Newcomb (1977); Niering (1979); Tiner (1987); Gleason and Cronquist (1991); Grimm (1993); Mitchell and Tucker (1995, 1997); Uva, Neal, and Ditomaso (1997); and NYSDEC (1998).

Table 1. *Total number of marsh-dependent breeding-bird species detected from survey sites along the Hudson River Estuary in 2005, listed from most to least abundant.*

Scientific Name	Common Name	No. Observed
Agelaius phoeniceus	Red-winged Blackbird	1261
Cistothorus palustris	Marsh Wren	569
Melospiza georgiana	Swamp Sparrow	180
Dendroica petechia	Yellow Warbler	130
Rallus limicola	Virginia Rail	128
Geothlypis trichas	Common Yellowthroat	116
Branta canadensis	Canada Goose	88
Ixobrychus exilis	Least Bittern	68
Carduelis tristis	American Goldfinch	65
Aix sponsa	Wood Duck	61
Melospiza melodia	Song Sparrow	41
Quiscalus quiscula	Common Grackle	33
Empidonax traillii	Willow Flycatcher	31
Anas platyrhynchos	Mallard	22
Ceryle alcyon	Belted Kingfisher	7
Botaurus lentiginosus	American Bittern	6
Tyrannus tyrannus	Eastern Kingbird	2
Anas rubripes	American Black Duck	2
Porzana carolina	Sora	2

Statistical Analyses

Statistical analyses conducted for the 2004–05 survey followed as closely as possible those conducted by SWIFT (1987). Analyses included (1) mean and standard error (SE; extrapolated to number per 40 ha) for each species, with results compared with 1986–87 results using the Student's t test; (2) comparison (analysis of variance [ANOVA]) of morning and evening avian counts by species; (3) comparison (ANOVA) of avian counts between observers; (4) summary of habitat measurements (summary statistics); (5) correlation between avian species abundance and habitat variables; and (6) stepwise multiple linear regression of species abundance and habitat characteristics. In addition, relative abundance measures were based on the observed count divided by the area of a 30-m or 60-m circle (SWIFT, 1987). For the 30-m plot, the area is 0.28274 ha, whereas for the 60-m plot, the area is 1.13097 ha. No adjustments were incorporated for decreasing detectability with increasing distance from the plot center (REYNOLDS, SCOTT, and NUSSBAUM, 1980). Additional analyses included the Shannon Diversity Index (SHANNON and WEAVER, 1949; WIENER, 1948; ZAR, 1974), Evenness (PIELOU, 1966), and Percent Similarity Index (WHITTAKER, 1952). We used the results of these indices to detect changes since Swift conducted his work and to determine similarities and differences among the three marshes.

To elucidate differences in avian community structure among the four marshes, Canonical Variate Analysis (CVA) and Multivariate Discriminant Analysis (MDA) were used (COOLEY and LOHNES, 1971; LUDWIG and REYNOLDS, 1988; MARRIOTT, 1974; MORRISON, 1976). The number of individuals detected for each species (marsh-dependent species only) per station visit was entered into the analysis in a stepwise manner. The procedure then computed the greatest overall separation among marshes in the multivariate space. This separation among marshes is expressed as the Generalized Distance (Mahalanobis D^2). Stepwise multiple linear regression (DRAPER and SMITH, 1966) was used to determine the relationship between avian abundance and habitat variables.

All statistics and graphics, except diversity, evenness, and percentage of similarity, were computed using NCSS (HINTZE, 2000) and SYSTAT (SYSTAT, 2004).

RESULTS

Avian Survey Results

A total of 3522 observations of birds, representing 83 species, were recorded from April 28, 2005, to June 30, 2005. Of these 83 species, 19 have some dependency on the marsh for feeding, roosting, or nesting, and they comprised 80% of the total number of birds observed (Table 1). The most common species encountered during the survey were Red-winged Blackbird and Marsh Wren. These two species made up more than 65% of the marsh-dependent birds observed during the study and accounted for greater than 60% of the observations at all four study sites. However, Marsh Wrens were nearly absent from Iona Island (<1.0%), whereas Red-winged Blackbirds accounted for greater than 77% of the marsh bird community (Table 2). Red-winged Blackbirds also dominated the marsh avian communities at Constitution Marsh and Stockport Marsh, although Marsh Wrens were the dominant marsh species at Tivoli North Bay (Table 2).

Diversity of the marsh bird community was similar at three of the four marshes in 2005 but significantly lower at Iona Island Marsh ($p < 0.01$) (Table 3, Figure 2). Marsh bird diversity for Iona Island Marsh in 2004 was also significantly lower ($p < 0.01$) than at the other three marshes in 2005; therefore, it appears to be a significant shift in the community and not an anomaly. Species evenness was also lowest at Iona Island Marsh, indicating the dominance of a few species, in this case the Red-winged Blackbird (Figure 3). Red-winged Blackbirds also dominated the bird communities at Constitution and Stockport Marshes, but evenness and diversity were similar.

Table 2. *Percentage of occurrence of the 11 most-common marsh-dependent breeding-bird species surveyed at four marshes in the Hudson River Estuary in 2005 (RWBL = Red-Winged Blackbird, MAWR = Marsh Wren, SWSP = Swamp Sparrow, YEWA = Yellow Warbler, VIRA = Virginia Rail, COYE = Common Yellowthroat, CAGO = Canada Goose, LEBI = Least Bittern, AMGO = American Goldfinch, WODU = Wood Duck, SOSP = Song Sparrow).*

Marsh	RWBL	MAWR	SWSP	YEWA	VIRA	COYE	CAGO	LEBI	AMGO	WODU	SOSP
Iona	77.1	0.9	0.3	2.9	0.6	4.5	5.2	0.3	1.6	0.3	1.3
Constitution	46.8	20.1	5.1	3.1	8.5	4.2	0.9	2.7	1.1	1.8	1.4
Tivoli	23.4	42.4	12.6	3.7	3.8	4.2	0.6	3.8	1.2	0.3	0.1
Stockport	33.6	27.1	11.2	8.9	6.8	3.7	0.9	1.8	2.3	—	2.5
Average %	45.2	22.6	7.3	4.6	4.9	4.1	1.9	2.1	1.5	0.8	1.3

Table 3. *Diversity of marsh-dependent breeding-bird species observed at each of four marshes in the Hudson River Estuary in 2005. The average number of species, species richness, and the Shannon Diversity Index are calculated as averages per point.*

Marsh	*N* (number of sampling plot visits)	No. of Marsh-Dependent Birds	No. of Marsh-Dependent Species	Average No. of Species	Species Richness	Shannon Diversity Index
Iona	147	304	18	2.1	1.14 ± 0.07	1.51 ± 0.13
Constitution	146	770	25	5.7	2.71 ± 0.12	2.63 ± 0.07
Tivoli	133	629	15	4.7	2.79 ± 0.11	2.50 ± 0.06
Stockport	90	428	12	4.8	2.86 ± 0.15	2.65 ± 0.07

Species diversity decreased significantly at two of the four marshes since Swift conducted his study in 1986–87 ($p < 0.01$). At both Iona Island Marsh and Constitution Marsh, this drop in diversity corresponds with an increase in the density of Red-winged Blackbirds (Figures 4 and 5). The observed drop in diversity at Constitution Marsh resulted in a diversity value comparable to that calculated for Tivoli North Bay and Stockport Marsh. Diversity appeared to have changed little at Tivoli Bays, although more Red-winged Blackbirds were observed in 2005 than in either 1986 or 1987 (Figures 4 and 6). Surprisingly, species diversity and evenness at Stockport Marsh increased since the 1980s, though not significantly, even though Red-winged Blackbirds also dominated the avian community in this area (Figures 2, 3, and 7).

A broad, generalized overview of the avian community differences was accomplished using Stepwise MDA and CVA on the 2005 point-count survey data. This analysis was restricted to only those 17 species judged to be directly using the marsh, and abundance data, expressed as number or individuals per hectare, was entered into the analysis on a plot visit–by–plot visit basis. The Stepwise analysis revealed that nine species, (American Bittern, American Goldfinch, Canada Goose, Common Grackle, Common Yellowthroat, Mallard, Sora, Spotted Sandpiper, and Wood Duck) showed no significant difference in abundance between marshes, and thus, provided no useful information for discriminating among the four marshes (Table 4). The discriminatory information in the remaining species was partitioned onto three axes. All three axes explained a significant portion of the variance. Axis I accounted for 68.9% of the total variance; Axis II, 24.0%; and Axis III, 7.1%. Most (92.9%) of the total variability can be explained with only the first two axes (Table 5).

Examination of the canonical coefficients associated with the CVA indicated the species responsible for the similarities and dissimilarities among the four marshes. Separation among group means along Axis I resulted primarily from the strong influence of Marsh Wren, Swamp Sparrow, and Least Bittern (Figure 8). Separation along Axis II resulted primarily from Red-winged Blackbird and Virginia Rail. Yellow Warbler and Willow Flycatcher had the greatest influence on separation along Axis III. A plot of the canonical coefficients on Axis I and Axis II indicated that Constitution Marsh and Stockport Flats Marsh have in common a high abundance of Virginia Rail, Least Bittern, and Marsh Wren. Although Marsh Wrens were also relatively abundant at Tivoli North Bay Marsh, it also supported high numbers of Swamp Sparrows and Willow Flycatchers. Iona Marsh was characterized by few individuals of Marsh Wrens, Virginia Rails, Least Bitterns, and Yellow Warblers. However, Iona Marsh did have a relatively high number of Red-winged Blackbirds as did Constitution Marsh.

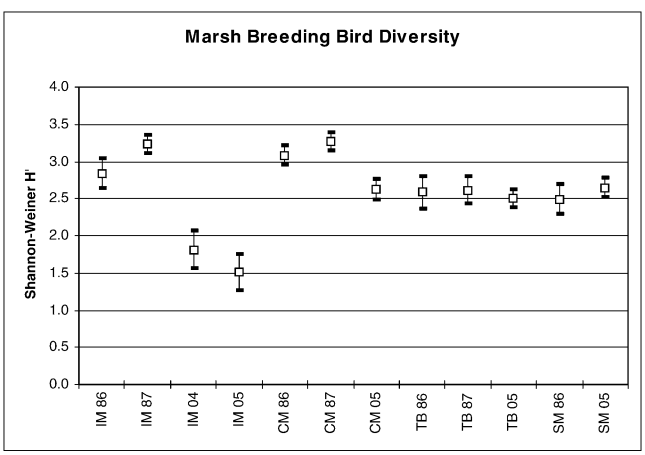

Figure 2. Comparison of mean Shannon Diversity (±95% CI) for Iona Island Marsh (IM), Constitution Marsh (CM), Tivoli North Bay (TB), and Stockport Flats Marsh (SM) for 1986, 1987, 2004, and 2005.

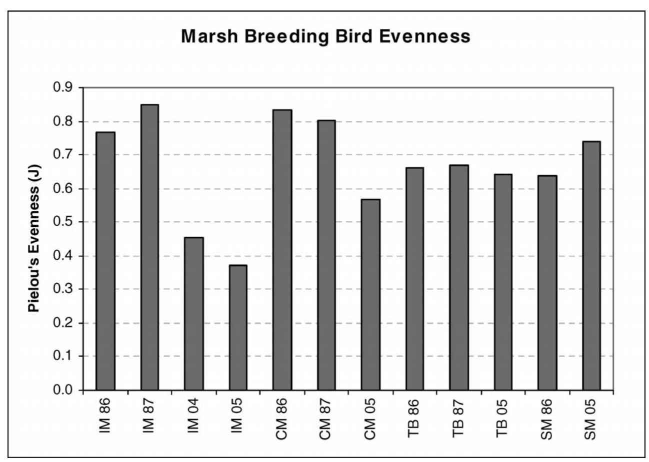

Figure 3. Comparison of mean Pielou's Evenness for Iona Marsh (IM), Constitution Marsh (CM), Tivoli North Bay (TB), and Stockport Flats Marsh (SM) for 1986, 1987, 2004, and 2005.

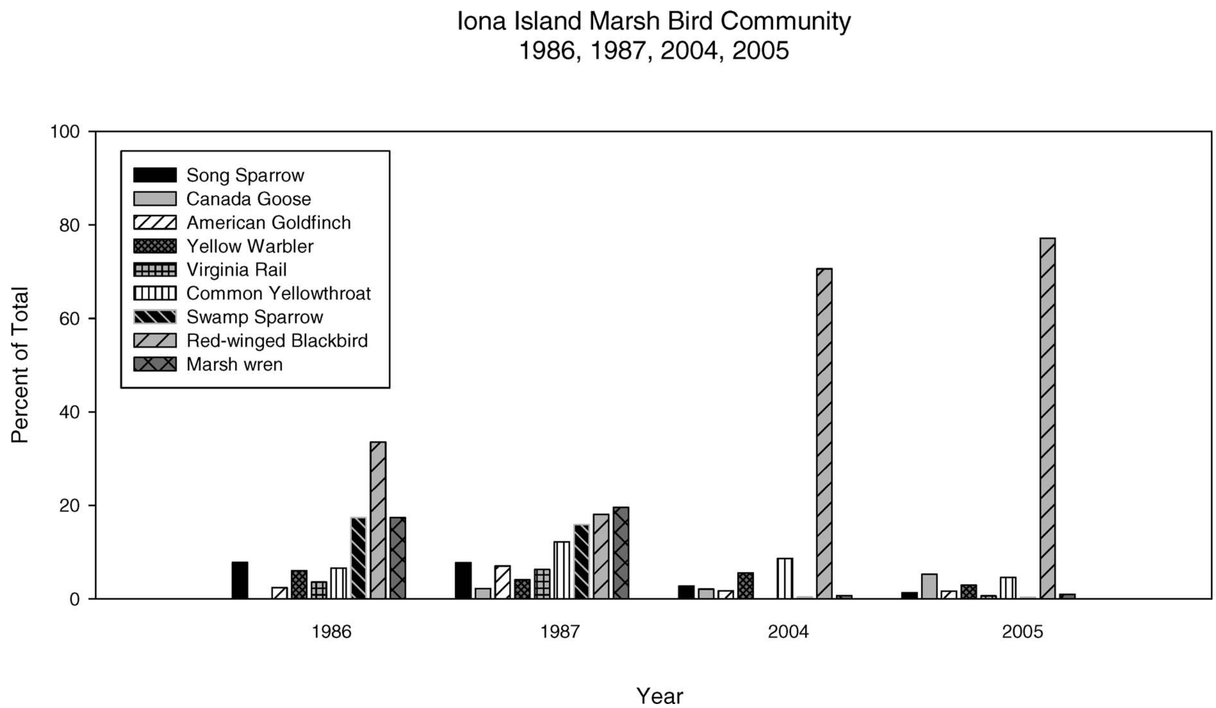

Figure 4. Iona Island Marsh, marsh avian species richness (percentage of total observations) for 1986, 1987, 2004, and 2005.

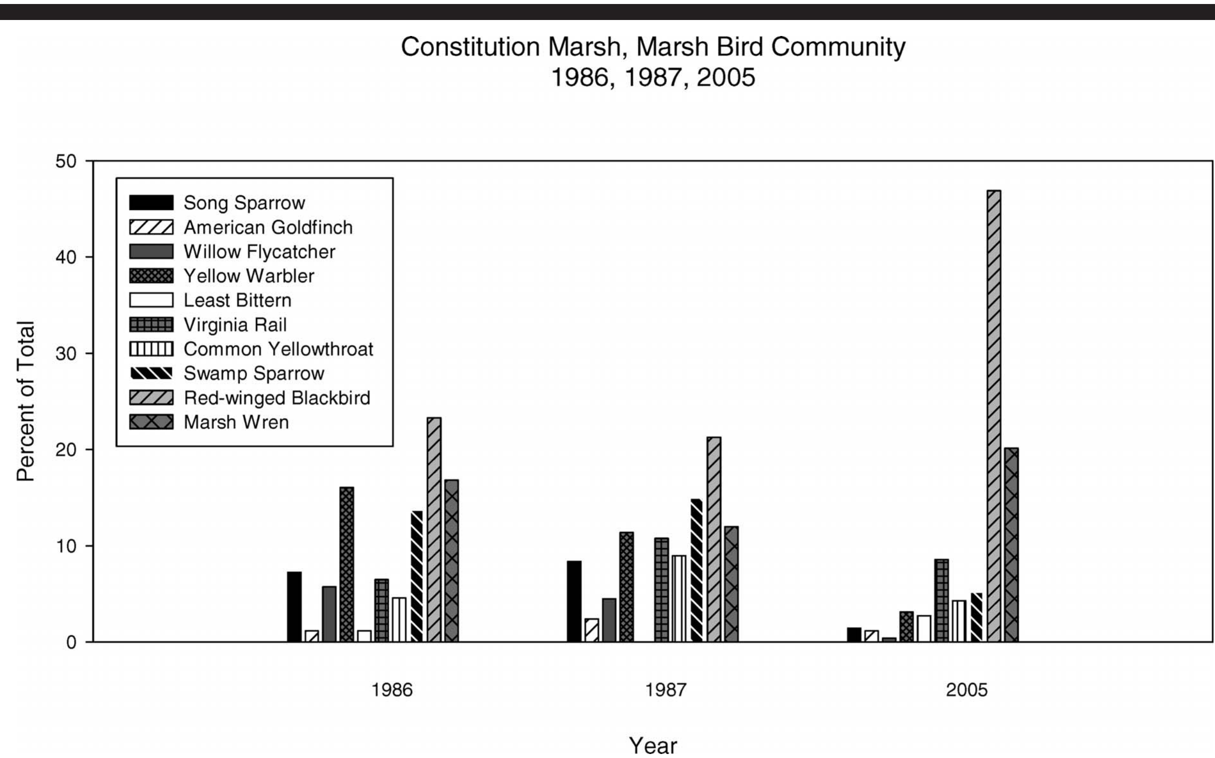

Figure 5. Constitution Marsh, marsh avian species richness (percentage of total observations) for 1986, 1987, and 2005.

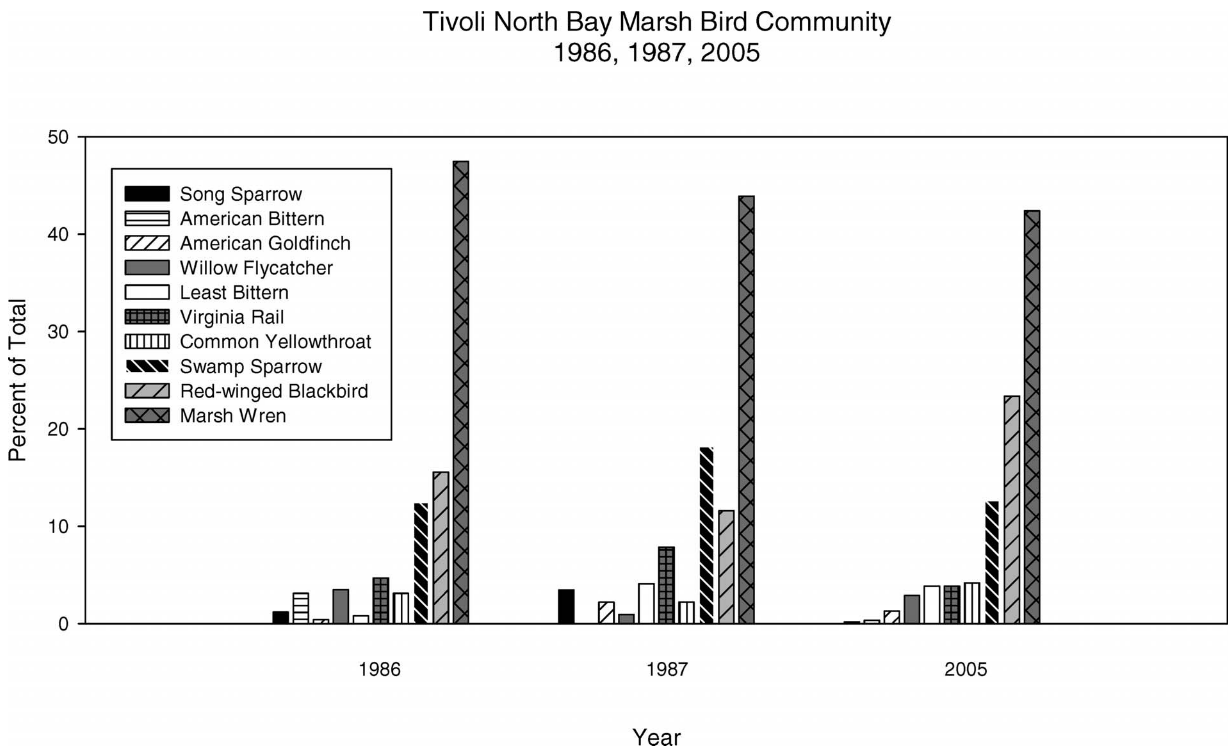

Figure 6. Tivoli North Bay marsh avian species richness (percentage of total observations) for 1986, 1987, and 2005.

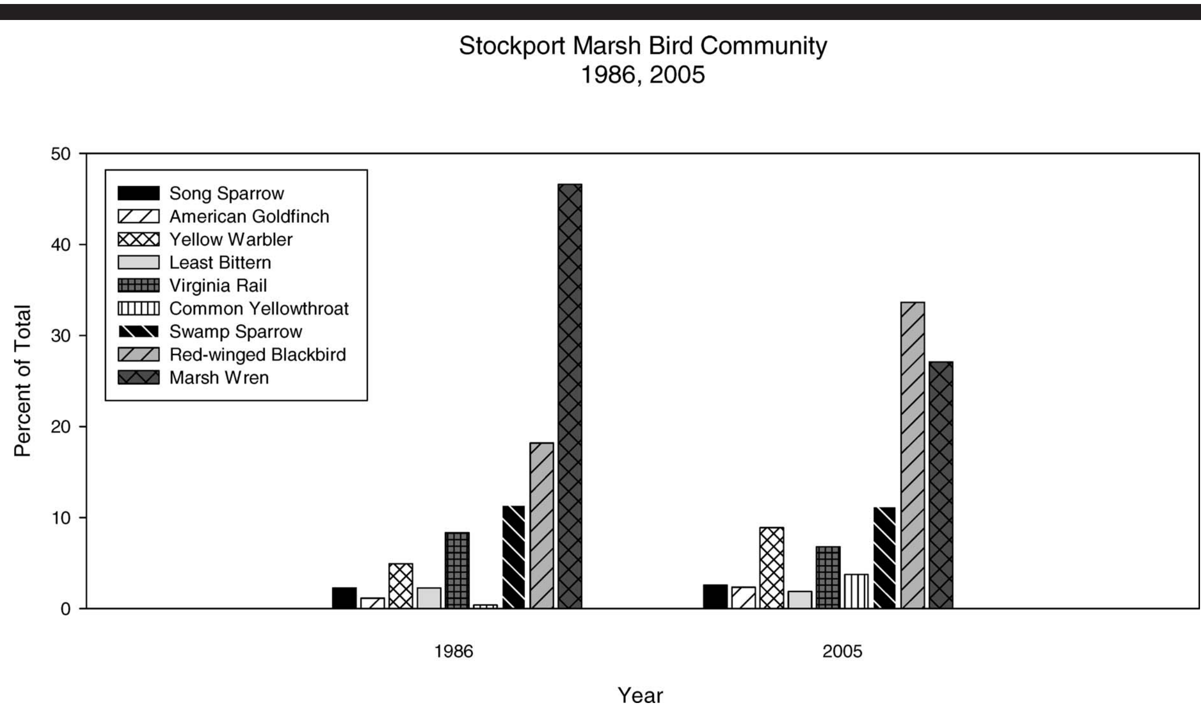

Figure 7. Stockport Marsh, marsh avian species richness (percentage of total observations) for 1986 and 2005.

Table 4. *Results of stepwise selection process of variables for multivariate discriminant analysis and Canonical Variate Analysis for marsh-dependent breeding birds in the Hudson River Estuary.*

	Initial ANOVA, Step 0		Final ANOVA, Step 8		
Species[1]	*F* Value	Probability	*F* Value	Probability	Status
LEBI	7.38	<0.001	5.32	0.001	In
MAWR	70.79	<0.001	63.23	<0.001	In
RWBL	19.56	<0.001	19.46	<0.001	In
SOSP	5.60	<0.001	2.87	0.036	In
SWSP	27.53	<0.001	24.20	<0.001	In
VIRA	18.29	<0.001	18.90	<0.001	In
WIFL	8.20	<0.001	5.40	0.001	In
YEWA	10.56	<0.001	8.33	<0.001	In
AMBI	1.12	0.340	1.09	0.352	Out
AMGO	1.10	0.349	0.57	0.633	Out
CAGO	1.60	0.188	1.15	0.327	Out
COGR	1.61	0.186	0.32	0.812	Out
COYE	2.33	0.074	1.75	0.156	Out
MALL	1.46	0.225	1.38	0.247	Out
SORA	0.96	0.412	0.29	0.835	Out
SPSA	1.68	0.169	1.41	0.238	Out
WODU	3.53	0.015	2.05	0.106	Out

[1] LEBI = Least Bittern, MAWR = Marsh Wren, RWBL = Red-Winged Blackbird, SOSP = Song Sparrow, SWSP = Swamp Sparrow, VIRA = Virginia Rail, WIFL = Willow Flycatcher, YEWA = Yellow Warbler, AMBI = American Bittern, AMGO = American Goldfinch, CAGO = Canada Goose, COGR = Common Grackle, COYE = Common Yellowthroat, MALL = Mallard, SORA = Sora, SPSA = Spotted Sandpiper, WODU = Wood Duck.

Table 5. *Summary statistics from Canonical Variate Analysis for marsh-dependent breeding birds in the Hudson River Estuary.*

Statistic	Axis I	Axis II	Axis III
Eigenvalue	0.730	0.254	0.075
Percentage	68.9	24.0	7.1
Cumulative %	68.9	92.9	100.0
Canonical correlation	0.6495	0.4499	0.2644
F value	20.7	11.6	6.4
Probability	<0.001	<0.001	<0.001
Standardized canonical coefficients[1]			
LEBI	−0.207	0.198	0.271
MAWR	−0.825	0.090	0.143
RWBL	0.056	0.713	0.344
SOSP	−0.043	0.200	−0.360
SWSP	−0.529	−0.258	−0.186
VIRA	−0.160	0.684	0.037
WIFL	−0.116	−0.275	0.420
YEWA	−0.188	0.091	−0.727
Canonical variates at group means			
Constitution Marsh	−0.012	0.734	0.171
Iona Marsh	1.217	−0.341	0.006
Stockport Marsh	−0.481	0.105	−0.571
Tivoli Marsh	−1.007	−0.499	0.191

[1] LEBI = Least Bittern, MAWR = Marsh Wren, RWBL = Red-Winged Blackbird, SOSP = Song Sparrow, SWSP = Swamp Sparrow, VIRA = Virginia Rail, WIFL = Willow Flycatcher, YEWA = Yellow Warbler.

Nest Survey Results

More than 230 bird nests were found among the four study areas in 2004–05. The greatest number of nests was found at Tivoli ($n = 134$), more than double what was found at Stockport, and more than 30 times that found at Iona ($n = 5$) (Tables 6 and 7). In addition, we found Marsh Wren nests to be the most common bird nest in our study sites. However, because male Marsh Wrens are known to build several dummy nests in a given territory, these data should be interpreted with caution. Of the 230 nests found, 215 occurred in marsh habitat dominated by *Typha angustifolia* (Table 7). We also found six nests in *Lythrum salicaria,* four in *Salix* spp., and one Red-Winged Blackbird nest in *Phragmites australis* at Iona. *Typha angustifolia* was the most common community type found at three of the four marshes; only Iona Marsh differed, being dominated by *Phragmites australis.*

The highest density of *Typha angustifolia*–dominated marsh habitat occurred at Tivoli North Bay (Table 8), and the highest density of Marsh Wren nests were found there (Table 6). Across all sites, Marsh Wren nest density was positively correlated with the density of *Typha angustifolia* ($r = 0.82$, $p = 0.17$), *Lythrum salicaria* ($r = 0.97$, $p = 0.03$), and *Sagittaria latifolia* ($r = 0.94$, $p = 0.05$) but negatively correlated with *Phragmites australis* ($r = -0.64$, $p = 0.35$).

Plant Community Results

We observed, based on our vegetation data, three major changes in plants communities between 1986–87 and 2004–05. The most obvious was the recent and rapid invasion of *Phragmites australis* at Iona Marsh. The shift from *Typha*

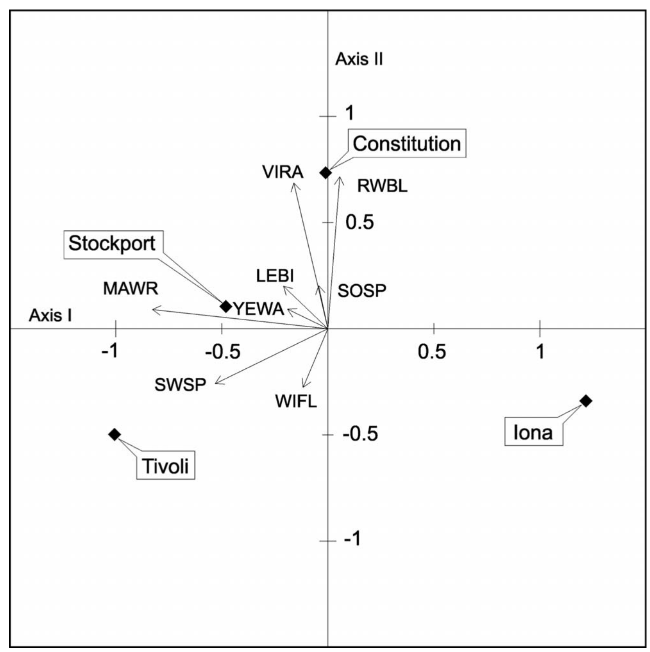

Figure 8. Stepwise Canonical Variate Analysis (CVA) group means (centroids) and canonical coefficients for Iona, Constitution, Tivoli, and Stockport marshes in 2005. Axis I explained 68.9% of the total variance; Axis II, 24.0% (LEBI = Least Bittern, MAWR = Marsh Wren, RWBL = Red-winged Blackbird, SOSP = Song Sparrow, SWSP = Swamp Sparrow, VIRA = Virginia Rail, WIFL = Willow Flycatcher, YEWA = Yellow Warbler).

Table 6. *Densities (No. of nests ha⁻¹) of marsh-breeding bird nests at four marshes in the Hudson River Estuary in 2005 (RWBL = Red-Winged Blackbird, MAWR = Marsh Wren, VIRA = Virginia Rail, SWSP = Swamp Sparrow, GRCA = Gray Catbird, AMRO = American Robin, WIFL = Willow Flycatcher, AMGO = American Goldfinch). Number in parentheses is the total number of nests found for that particular species.*

Marsh	RWBL	MAWR	VIRA	SWSP	GRCA	AMRO	WIFL	AMGO	TOTAL
Iona	1.9 (6)	—	—	—	—	—	—	—	1.9
Constitution	3.8 (8)	13.7 (29)	—	—	—	—	—	—	17.5
Tivoli	0.5 (1)	60.5 (124)	1.5 (3)	1.0 (2)	—	—	1.5 (3)	—	65.0
Stockport	2.8 (4)	26.9 (38)	—	2.8 (4)	0.7 (1)	0.7 (1)	—	2.1 (3)	36.0

angustifolia to *Phragmites australis* in the 1990s can be seen in the station-by-station comparison presented in LMS (2005a, 2005b) and in this report, as well as the NYSDEC vegetation maps from 1991 and 1997 (unpublished data). Of the four marshes studied in 2005, Iona Marsh was the only one with significant amounts of *Phragmites australis.*

The second change we observed was the apparent filling-in by *Typha angustifolia* at several areas. In his 1986–87 survey, SWIFT (1987) categorized most habitats in Constitution, Tivoli North Bay, and Stockport Flats Marshes as "sparse *Typha angustifolia*" (plants $\leq$1.5 m tall, considerable amounts of bulrush and broad-leaf plants present). In 2005, we categorized most habitats as dense *Typha angustifolia* (plants $\geq$1.5 m tall, nearly pure stand of *T. angustifolia*). *Typha angustifolia* densities were quite high for Constitution, Stockport Flats, and Tivoli North Bay Marshes. The highest density of *Typha angustifolia* occurred at Tivoli North Bay Marsh, where there was an average of 47 stems m^{-2}. At Constitution and Stockport Flats Marshes, there was an average of 35 and 21 stems m^{-2}, respectively. Iona Marsh only had an average of 12 stems m^{-2} (Table 8).

The third trend we observed was an apparent reduction in *Lythrum salicaria,* a nonnative, invasive plant. This trend may be associated with the trend toward greater concentrations of *Typha angustifolia. Lythrum salicaria* was not particularly dense in any of the four marshes. The highest density occurred at Tivoli North Bay Marsh (average of 2.5 stems m^{-2}), whereas the lowest density was at Iona Marsh (average of 0.1 stems m^{-2}).

DISCUSSION

Results of the 1986–87 and 2004–05 marsh-breeding bird studies revealed an overall similarity among Stockport Flats, Tivoli North Bay, and Constitution Marshes in 2005. Further, the Stockport and Tivoli marshes have changed little since the late 1980s. Although there has been a slight, though significant, decrease in marsh bird diversity at Constitution Marsh, this drop has brought it more in line with the diversity measured at Stockport and Tivoli. Overall, the changes that were seen generally indicated an increase in numbers of marsh birds. Only Iona Island Marsh showed a significant, large decline in overall marsh bird diversity. Numbers of individuals, numbers of species observed per station, diversity, and species evenness were all lower for Iona Island Marsh when compared with the three upriver marshes. In addition, marsh-dependent species, other than Red-winged Blackbird, were nearly absent. Our data indicated a decline in the numbers of Least Bitterns, Virginia Rails, and Marsh Wrens. Swamp Sparrow numbers in Iona Island Marsh were equivalent to the upriver marshes in 1986–87, but this species was nearly absent in 2004–2005. Because the results at Iona Island Marsh (using largely different personnel) were so similar between the 2004 and 2005 surveys, it is believed that these findings reflect real changes and are not related to year-to-year variation or sampling bias.

Results of the nest surveys at all four marshes clearly indicated the minimal importance of Iona Island Marsh for avian nesting. There were significantly fewer numbers of nests found in Iona Marsh relative to the three other marshes. This was particularly true for the marsh-dependent species, such as Least Bittern, Virginia Rail, and Marsh Wren. Though there were large numbers of Red-winged Blackbirds present in the marsh during this study, they did not appear to be nesting there in any sizable number because only five nests (all Red-winged Blackbird) were found in 2005, and no nests were discovered in 2004. These birds appear to use this marsh primarily for perching and roosting.

Our study found only Red-winged Blackbirds to have similar population changes occurring at all four marshes. For these species, a single "global-scale" causative agent is likely. Red-winged Blackbird numbers increased at each marsh, and the rate of increase was nearly identical at all locations. This trend is in contrast to the perceived statewide trend of declining numbers. SAUER, HINES, and FALLON (2005) report a significant downward trend of -1.7%/y ($p < 0.01$) for New York during the period from 1980 to 2004, based on the

Table 7. *Total number of nests found within the dominant plant communities at four marshes in the Hudson River Estuary in 2005. Other category includes equal mixes of* Typha angustifolia *and* Lythrum salicaria *or other species, including* Impatiens capensis *and* Acorus calamus. *Nests found in less-dominant plant communities are not included in the table.*

Marsh	*P. australis*	*T. angustifolia*	*L. salicaria*	*Salix* spp.	Other	TOTAL
Iona	1	4	—	—	—	5
Constitution	—	39	—	—	—	39
Tivoli	—	131	1	2	—	134
Stockport	—	39	3	2	8	52

Table 8. *Density of plant stems (No. of stems m^{-2} [±1 standard deviation]) at the four Hudson River marshes in 2005.*

Plant Species	Iona	Constitution	Tivoli	Stockport
Phragmites australis	35.36 (25.15)	0	0	0
Typha angustifolia	12.29 (21.83)	34.63 (22.2)	46.73 (17.46)	21.36 (15.74)
Lythrum salicaria	0.11 (0.62)	0.32 (1.26)	2.51 (5.48)	1.53 (4.82)
Peltandra virginica	0.71 (2.45)	12.74 (14.54)	4.58 (4.24)	6.26 (6.33)
Sagittaria latifolia	0	0.39 (1.39)	0.75 (1.9)	0.42 (1.19)
Schoenoplectus fluviatilis	0.05 (0.69)	0.41 (2.6)	1.01 (6.05)	4.14 (7.16)
n	208	205	166	108

Breeding Bird Survey (BBS) program. The only species showing declines at three of the four marsh locations was Song Sparrow. This is primarily an upland–edge species that seldom ventures deep into the marsh. SAUER, HINES, and FALLON (2005) also reports a nonsignificant statewide decline, -0.6% yr^{-1} ($p = 0.07$), for this species during 1980–2004.

Proliferation of *Phragmites australis* appears to be the proximal cause of the avian community changes at Iona Island Marsh. GUNTENSPERGEN and NORDBY (2006) state that the shift in habitat structure caused by *Phragmites australis* will likely have the greatest impact on marsh resident species. SHRIVER *et al.* (2004) observed a 24% decrease in avian species richness in marshes composed of less than 50% native vegetation in Long Island Sound marshes, and BENOIT and ASKINS (1999) found that *Phragmites australis* reduces avian diversity in salt marshes. This could be due to a loss of desired nesting material or nesting and habitat. Rails and bitterns typically use coarse grasses, rushes (*Schoenoplectus* spp.), cattail (*Typha* spp.), and similar vegetation, for nest construction (BAICICH and HARRISON, 1997; HARRISON, 1975), of which there is now a relative shortage at Iona. *Phragmites australis* may be too coarse to be suitable for nest construction. Rails and bitterns also generally require open pools and channels in which to feed (BENOIT, 1997; BENOIT and ASKINS, 1999). Often pools are kept free of encroaching vegetation by the feeding activities of muskrats (*Ondatra zibethicus*). Little muskrat activity was observed in Iona Island Marsh, and no open pools were noted. Additionally, relatively few open channels were present. The small channels had filled-in with dense stands of *Phragmites australis,* with only large channels remaining. The loss of small channels and pools from Iona likely reduces the opportunity for larger wading birds to access food (*i.e.,* mummichogs [*Fundulus heteroclitus*] and killifish [*Fundulus diaphanus*]) (GUNTENSPERGEN and NORDBY, 2006).

Marsh Wren populations declined significantly at Iona Island Marsh since 1986–87. When viewed from a broad perspective, such a decline would not be unexpected. Statewide, Marsh Wren numbers appear to have declined from 1980 through 2004 (-3.2%/y, $p < 0.01$) (SAUER, HINES, and FALLON, 2005). Although statistically significant, the small number of BBS routes covered for this species ($n = 6$) suggests that these results should be viewed with caution (SAUER, HINES, and FALLON, 2005). Such a decline would not be unexpected because many marsh birds throughout New York and the country are thought to be declining because of wetlands habitat loss and invasive species encroachment (BURGER and LINER, 2005; CONWAY, 2004, 2005).

Marsh Wren population numbers may fluctuate in response to a large number of habitat factors (ZIMMERMAN et al., 2002), including a complex interplay of vegetation and interspecific aggression. GUTZWILLER and ANDERSON (1987) noted that *Typha* spp. marshes are one of the highest-ranking habitats in terms of Marsh Wren cover and reproduction suitability, whereas *Phragmites australis,* on the other hand, is considered one of the least suitable habitats. MCGLYNN (2006) studied marsh birds in six Hudson River tidal marshes in 2001 and 2002 and found Marsh Wrens to be the most abundant bird in *Typha* spp.–dominated marshes. The replacement of *Typha* spp. with *Phragmites australis* could lead to decreased cover and limited reproductive success; yet, along the eastern seaboard, Marsh Wren appears to be quite successful in some *Phragmites australis*–dominated marshes. Members of our survey team have frequently noted Marsh Wrens in nearby marshes, including Grassy Point Marsh (9 km south of Iona Marsh in Stony Point, New York) and Piermont Marsh (30 km south in Piermont, New York), both with large stands of *Phragmites australis.* KANE and GITHENS (1997) and A. SEIGEL (personal communication) have noted successful nesting in the *Phragmites australis*–dominated marshes of the Hackensack Meadowlands. BENOIT and ASKINS (1999) found Marsh Wren to be the most abundant species in the Connecticut *Phragmites australis* marshes they studied. Overall, this suggests that the dominance of *Phragmites australis* alone is likely insufficient to cause the observed decline in wren density.

Studies conducted in the late 1970s and early 1980s point to another possible contributing factor to our observed decline of Marsh Wrens at Iona Marsh. PICMAN (1980, 1982, 1983) studied the interaction between breeding Red-winged Blackbirds and Marsh Wrens. Marsh Wrens are a highly aggressive species and are known to attack the eggs and nestling of other birds nesting nearby (PICMAN and PICMAN, 1980). Red-winged Blackbirds have been demonstrated to counter this threat by acting aggressively toward adult Marsh Wrens and even seek out wren nests in search of adult Marsh Wrens. PICMAN (1980, 1983) believed that examination by Red-winged Blackbirds of wren nests and aggression toward adults reduced the nesting success of the wren. In addition, PICMAN (1982) found that wrens prefer to sing from the tops of *Typha* spp. However, because of their larger size and greater weight, Red-winged Blackbirds were forced to sing from lower perches on *Typha* spp. Red-winged Blackbirds typically prefer more durable stems (ÖZESMI and ÖZESMI, 1999), where they may perch near the top. Thus, the shift to a more *Phragmites australis*–dominated marsh may reduce the number of singing perches resulting in fewer wren territories while possibly increasing singing perches usable by Red-winged Blackbirds. This, in turn, could favor the blackbird populations, increase the aggression toward Marsh Wrens by Red-winged Blackbirds, and further lower the reproductive success of Marsh Wrens.

Swamp Sparrow has also shown a significant decline in Iona Island Marsh since the 1980s. This decline may be related to changes in surface water availability as expanding *P. australis* stands fill the marsh. GREENBERG (1988) found that Swamp Sparrow territories were strongly associated with open surface water and believed that this single habitat feature could bring about major changes in habitat distribution. Statewide, there is no significant trend, either upward or downward, for this species (+0.2%/y, $p = 0.82$) (SAUER, HINES, and FALLON, 2005).

The above-described trends and immediate cause in all cases may be closely tied to the recent extensive encroachment of *P. australis* within Iona Island Marsh. Studies of sediment pollen and macrofossils indicate that Iona Island Marsh was probably brackish and contained vegetation, such as bulrush (*Schoenoplectus* spp.) and flatsedge (*Cyperus* spp.) (MERLEY and PETEET, 2001). Historic accounts suggest that by at least the 1700s, the marsh was dominated by *Typha angustifolia,* which dominated the marsh at least through 1991 (NYSDEC, 1998; SWIFT, 1987, 1998). Vegetation surveys conducted in 1997 indicated that in less than a decade, dominance had shifted to *Phragmites australis.*

Phragmites australis is native to North America, occurring in the fossil record to the Cretaceous Period (BERRY, 1914; CHAMBERS, MEYERSON, and SALTONSTALL, 1999; LAMOTTE, 1952). The species, however, is widespread, occurring throughout Eurasia as well as North America. The North American populations tend to be slow growing, localized, and found predominately in freshwater habitats, typically in the oligohaline portions of brackish marshes. Sometime within the last 200 years, the European form became established in North America. The European form has proved to be much more invasive than the native form (SALTONSTALL, 2002). This form spreads rapidly, by as much as 3% annually by area (RICE and STEVENSON, 1996; WINOGROND, 1997), and is more tolerant of increased salinities. WINOGROND (1997) estimated expansion rates of 0.01–0.09 ha y^{-1} for Stockport Flats and Tivoli North Bay marshes, 0.10–1.12 ha y^{-1} at Iona Marsh, and 0.12–3.70 ha y^{-1} for Piermont Marsh during the 1960s through 1991. The rate of spread at Iona Island Marsh was exponential ($r = 0.98$, $p < 0.01$) between 1974 and 2005 (Figure 9). BATCHER (2003) reported expansion rates of 2.5 ha y^{-1} from 1974 through 1989 and 3.4 ha y^{-1} from 1989 through 2000 for Wertheim National Wildlife Refuge, New York. Small clusters of *Phragmites australis* began occurring in Constitution Marsh in the early 1980s, but are being actively controlled (E. LIND, personal communication). CHAMBERS, MEYERSON, and SALTONSTALL (1999) indicate that the annual expansion is 0.1–38% annually in freshwater (<0.5 ppt), 0.4–74% in oligohaline waters (0.5–5 ppt), and 0.7–83% in mesohaline waters (5−18 ppt).

MCGLYNN (2006) compared small mammal and avian use of invasive plant (*Phragmites australis, Lythrum salicaria*)

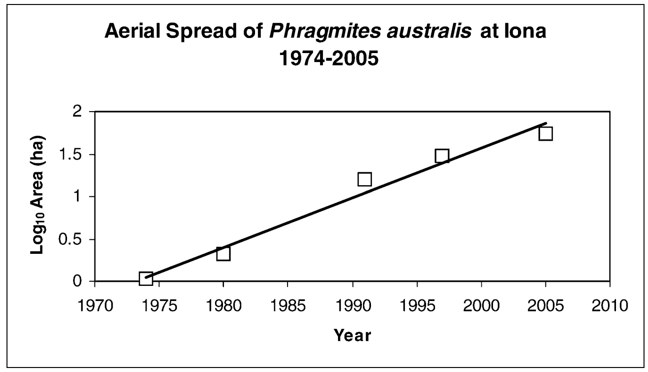

Figure 9. Aerial spread of *Phragmites australis* at Iona Island from 1974 to 2005 ($r = 0.98$, $p = 0.0015$). Data compiled from Winogrond (1997).

and *Typha angustifolia* marsh communities in six tidal marshes on the Hudson River and found that effects were species-dependent. Furthermore, MCGLYNN observed that *P. australis* stands were primarily used by birds for foraging and perching, but not nesting, and found Red-winded Blackbirds to be most abundant in *Typha* spp. marshes. However, the stands of invasive plants she studied were isolated patches, and the surrounding habitat and land use had a greater influence on the mammal and avian community she observed.

Several studies indicate that the presence of homogeneous stands of *Phragmites australis* in a tidal marsh can cause a number of ecological changes on the marsh environment (CHAMBERS, MEYERSON, and SALTONSTALL, 1999). Overall plant diversity is reduced (CHAMBERS, MEYERSON, and SALTONSTALL, 1999; ODUM *et al.,* 1984; SALTONSTALL, 2002, 2005) as *Phragmites australis* forms monoclonal stands. Often accompanying the reduction in plant diversity is a reduction in animal diversity, with the greatest impact on resident species (GUNTENSPERGEN and NORDBY, 2006). Vertebrate use is restricted to the edges of homogeneous stands, mixed-reed stands, and smaller stands (GUNTENSPERGEN and NORDBY, 2006). Resting, feeding and breeding areas are diminished for migratory waterfowl (HAUBER *et al.,* 1991); large wading birds may be excluded, whereas generalists may replace many avian marsh specialists. Overall avian species richness may be reduced (BENOIT and ASKINS, 1999). Although the density and biomass of insects can be high (supporting marsh aerial feeders), RAICHEL, ABLE, and HARTMAN (2003) found that the number of aquatic invertebrate taxa were fewer and less available to predators in *Phragmites australis* marshes relative to *Spartina* spp. marshes. They also found that the distribution and abundance of fish eggs, larvae, and small juveniles of mummichog (*Fundulus heteroclitus*), a major prey species for many birds and other fish species, was reduced in *Phragmites australis* marshes.

The European form of *Phragmites australis* established in North America represents a distinct haplotype. Externally, the invasive M haplotype is very similar in appearance to the nonexpanding, North American, native haplotypes (SALTONSTALL, 2002, 2005). Experimental work has demonstrated, however, substantial physiological differences, including the following: (1) a greater rate of new shoot initiation, (2) a higher growth rate across salinity ranges, (3) an ability to survive at higher salinities, and (4) a lower content of water in the aboveground tissues (Vasquez *et al.,* 2005). The rapid shoot initiation rate allows the invasive form to rapidly cover bare ground and to be more competitive in mixed stands of plants, especially in areas of brackish water. The high salt tolerance allows *Phragmites australis* to invade marshes formerly dominated by *Spartina alterniflora.* In these marshes, dense stands of *Phragmites australis* effectively reduce light penetration and, consequently, *Spartina* spp. growth. *Typha* spp. prefers areas of freshwater and is increasingly disadvantaged as salinity increases.

Of ultimate concern is the cause for the increase in *Phragmites australis* at Iona Island Marsh. Iona Island and Marsh has a long history of human activity. During the Civil War, a resort hotel was built (National Estuarine Research Reserve, 2001) on the island. In April 1900, the Department of the Navy acquired the property and used the island as an active ammunition depot through 1947. During that period, a causeway was built straight across the marsh to facilitate the movement of ammunition trucks from the island to the mainland. The site was conveyed to the Palisades Interstate Park Commission in 1965 and currently houses a maintenance facility (Binnewies, 2001). This construction, along with that of the railroad causeway in the mid-19th century, significantly altered the surface hydrology of the site. The long history of human disturbance, coupled with the salt tolerance of *Phragmites australis,* has likely contributed to the exponential spread of *Phragmites australis* at Iona Island Marsh.

CONCLUSIONS

The marsh breeding-bird community of the Hudson River estuary appears to have changed little at three of the four marshes studied since the 1986–87 period. This is an encouraging finding and contradicts evidence of declining bird populations statewide (Sauer, Hines, and Fallon, 2005). The two most abundant species encountered in 1986–87 and during this study were the Red-winged Blackbird and the Marsh Wren. McGlynn (2006) also found these species to be the dominant birds in the Hudson River tidal marshes.

There has been a significant decrease in bird diversity at Constitution Marsh and Iona Island Marsh, and these decreases correspond with an increase in Red-winged Blackbird numbers. Although Constitution Marsh still appears to support a healthy breeding bird community, the change at Iona Island Marsh has been dramatic, with the overwhelming dominance of the Red-winged Blackbird. In addition, little, if any, active nesting is taking place at Iona with only five nests observed in 2005 and none in 2004.

With the exception of Iona Island Marsh, the total number of individual marsh-breeding birds increased at our study sites since 1986–87. At Iona Island Marsh, the number remained the same, but diversity decreased, with a decrease in numbers of almost all species, with the exception of the significant increase in Red-winged Blackbirds and a slight increase in Willow Flycatchers. At the other sites, Least Bitterns (Stockport, Tivoli, Constitution), Virginia Rails (Stockport and Constitution), Common Yellowthroat (Stockport, Tivoli, Constitution), Marsh Wren (Tivoli and Constitution), Swamp Sparrow (Stockport and Tivoli), and Yellow Warbler (Stockport and Tivoli) showed population increases. These increases do not indicate a trend, and further monitoring would be needed to determine the significance of this finding. At a minimum, it indicates that these sites are providing adequate breeding habitat for marsh birds.

The observed change at Iona is a concern because the findings are consistent over 2 study-years (2004 and 2005). This indicates that the observed decline is real and not just a year-to-year variation or sampling bias. This change is likely due, in part, to the change in dominant vegetation from *Typha angustifolia* in 1986–87 to the European strain of *Phragmites australis.* This change in vegetation dominance likely increased the competition between Red-winded Blackbirds and Marsh Wrens for nesting territories. It also has altered the marsh topography, reducing the number of small tidal creeks and pools, which are important microhabitats for other marsh-dependent birds, such as the Virginia Rail (Benoit and Askins, 1999), a species that was present at Iona Island Marsh in 1986–87, but absent in 2004 and 2005.

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