BREEDING BIRD COMMUNITIES

IN HUDSON RIVER TIDAL MARSHES

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INTRODUCTION

The Hudson River flows approximately 500 km through eastern New York State, from the Adirondack Mountains to New York City. Below Troy, some 250 km above the mouth, the Hudson comprises one of the major riverine estuaries on the east coast of the United States. Historically, the Hudson River has been greatly influenced by man's activities, and avian habitats have undoubtedly been affected. However, very little quantitative information has been available regarding breeding bird communities associated with such river systems. Such data could be used to construct an historical picture of avian populations, or to predict effects on breeding birds of potential future changes in the estuary.

In this study, we analyzed present day breeding bird communities in tidal freshwater marshes in the Hudson River estuary. These wetlands are probably the most significant avian nesting habitats associated with the river, in terms of productivity, species composition, and areal extent. However, the importance of tidal river marshes as breeding habitats for migratory birds has received little study anywhere in the eastern United States, where an estimated 164,000 ha of this community type occurs (Springer and Stewart 1948; Hawkins and Leck 1977; Odum et al. 1984; Meanley 1985; Craig, in press). Specific objectives of our research included: (1) document bird species breeding in Hudson River tidal marshes; (2) relate the distribution and abundance of species to each other; and (3) relate observed avian communities to habitat characteristics. In this paper, we present our findings and suggest possible applications to future management of avian communities on the lower Hudson River. Other aspects of our work were reported elsewhere (Swift 1987, and in prep.; Swift et al., in press).

HISTORICAL PERSPECTIVE

Henry Hudson explored the Hudson River in 1609, and Dutch settlers arrived in 1624. For the next 200 years, settlement in the Hudson Valley remained sparse, and human influences on the river were negligible. During the 19th century, however, the population expanded, accompanied by major changes in land use, and establishing patterns of river use that continue today.

Use of the Hudson River as a transportation corridor has affected it in many ways. Development of the steamboat and steam locomotive, and the building of shoreline railroads in the mid 1800's, spurred intensive wood-cutting for fuel. Erosion of soil from logged slopes, and the placement of railroad fills across shallow bays and coves, combined to alter circulation and sedimentation patterns in the river. This resulted in the creation of many of the large emergent marshlands in existence today (Kiviat 1978).

Transportation service also brought many people to the river's edge for commercial, industrial, residential and recreational uses. Urban areas developed at the mouths of major tributaries, often at the expense of natural riverine wetlands, because of landfilling, dredging, and shoreline modification. Development of ports as far north as Albany and Troy also created a need for navigation channel dredging, beginning in 1900, and in many cases, dredge spoils were deposited in nearby wetland habitats (Malcolm Pirnie, Inc., 1983).

Agricultural expansion in the Hudson Valley during the 1800's also contributed to land-clearing and sediment deposition impacts noted above. At the same time, however, many of the Hudson River estates first appeared along the shoreline. These large landholdings were characterized by intensive grounds management, formal gardens and large mansions, but woodlands adjoining the river were usually left undisturbed. This helped establish a land use pattern, as well as an ethic, which has since protected the Hudson River from many potentially destructive developments.

Perhaps the greatest impact of man on the Hudson River ecosystem has been his use of the water resource itself. For decades, the river has received large volumes of wastewater discharged from a variety of point and non-point sources. Discharges of municipal sewage and toxic chemicals have proven to be major threats to the health and potential uses of the river. A general increase in Hudson River water quality has been evident in recent years (Moran and Limburg 1986), but levels of hazardous substances (most notably PCBs and cadmium) in the estuary are still excessive, and are the subject of at least two massive cleanup efforts (Horn et al. 1979; Schroeder and Barnes 1983; U.S. EPA 1981, 1986). Degradations in wetland habitat quality are likely, but potential impacts on only a few wildlife species have been investigated (Stone et al. 1980; U.S. EPA 1986; J. Rod, pers. comm.). The Hudson River is also exploited for power generation, with at least 5 major power plants using river water for cooling. Other activities, such as withdrawals for drinking water, proposed construction of an interstate highway on filled land, and operation of upstream flood control reservoirs, have raised questions regarding potential impacts on the ecosystem, and are the subject of continuing public debate (Limburg et al. 1986).

In spite of its history, a number of relatively large tidal marshlands exist on the lower Hudson River. We have no estimates of how much marshland existed on the river centuries ago, but efforts have been made to map their current distribution for environmental protection purposes (NYSDEC 1980). At present, we estimate that there are probably more than 1,000 ha of tidal freshwater marsh on the Hudson River (Swift, unpubl.). Although processes during the last 150 years have been responsible for creating some of this area, concomitant losses have occurred due to dredging and filling activities.

With so much human activity on the Hudson River, it is surprising that so little ecological work has been done on the ecosystem. Prior to the 1960's, only one study of avian habitats was reported (Foley and Taber 1951), and site-specific breeding records were scarce. Since then, considerable effort has been made to better understand and manage the Hudson River estuary, but emphasis has been on its fisheries (Limburg et al. 1986, Boyle 1979). Consequently, this study represented one of the first efforts made to develop a quantitative data base on avian habitats associated with the lower Hudson River.

STUDY AREAS

Field studies were conducted in six tidal marshes on the Hudson River, ranging from 30-200 ha in size, and located between Albany and Peekskill, New York (Fig. 1). Study areas were selected to provide a representative range of habitat variables that occur in Hudson River tidal marshes (Kiviat 1978, Odum et al. 1984), and which typically influence marsh-nesting bird communities. The six sites included four "railroad cove" marshes and two shallow bays that opened more broadly to the Hudson River. Detailed descriptions of the six areas were provided in an earlier report (Swift 1987).

All study areas were predominantly classified as persistent or nonpersistent emergent marshes, interspersed with smaller areas of intertidal and subtidal communities (see Cowardin et al. 1979 for descriptions of wetland types). These wetlands showed considerable interspersion of successional vegetation types, ranging from "pre-marsh" (occurring near or below low tide level) through "senescent" marsh (occurring in the upper intertidal zone), as described by Kiviat (1978). Extensive stands of "mature" and "senescent" marsh, dominated by cattail (primarily *Typha angustifolia*), were present in all areas. Other persistent emergents and woody plants, such as river bulrush (*Scirpus fluviatilis*), purple loosestrife (*Lythrum salicaria*), reed (*Phragmites australis*), willow (*Salix* spp.), swamp rose-mallow (*Hibiscus palustris*), and swamp rose (*Rosa palustris*), were conspicuous components of several study areas. Common non-persistent emergents included arrowheads (*Sagittaria* spp.), wild rice (*Zizania aquatica*), arrow arum (*Peltandra virginica*), sweet flag (*Acorus calamus*), jewelweed (*Impatiens biflora*), pickerelweed (*Pontederia cordata*), clearweed (*Pilea pumila*), smartweeds (*Polygonum* spp.), and spatterdock (*Nuphar advena*). All of the marshes were generally bordered by undeveloped forestland (or river channel), and experienced relatively little human disturbance. Three study areas were located within the Hudson River National Estuarine Research Reserve (U.S. Dept. of Commerce and NYSDEC 1982).

The lower Hudson River is tidally influenced over its entire 250 km reach. During each tidal cycle, water levels fluctuate as much as 1.5 m, and peak high tide levels may vary as much as 0.9 m over the year (Busby and Darmer 1970, Stedfast 1982). Average freshwater inflow to the estuary is approximately 550 m^3/s, with highest flows occurring in spring, and lowest flows occurring in late summer or early fall. However, mean tidal flow in the river is often substantially greater than freshwater inflow (Moran and Limburg 1986). Under an average runoff regime, salinity intrusion (5 ppt) reaches somewhere between Peekskill and Newburgh during late summer. Consequently, the two southernmost study areas were occasionally brackish, while all others were truly freshwater tidal marshes.

METHODS

Breeding Bird Counts

Data on bird populations were collected during two breeding seasons on 169 circular 0.28-ha plots (30-m radius) among the six study areas. Plot centers were located randomly within each marsh and were separated by at least 60 m. Breeding birds were counted on these plots between 4 May and 20 June during early morning and evening periods (05:00-10:00 h and 16:30-21:00 h DST respectively), at times with no measurable precipitation or strong winds (greater than approximately 25 km/h). In 1986, we made four counts on 119 plots, and in 1987, we made five counts at 50 repeat locations and on 50 new plots within the same study areas. Most repeat locations were selected non-randomly in 1987 to include plots where non-passerines were observed in 1986.

Each count consisted of an approximate 10-min observation period from the plot center, during which all non-passerine birds and all singing male passerines observed on a plot were identified to species and counted. During each plot visit, observations of non-passerine species, especially bitterns and rails, were elicited by playback of tape-recorded calls using portable cassette recorders (after Johnson et al. 1981, Marion et al. 1981, Johnson and Dinsmore 1986). The order of visiting study areas was selected at random for each round of counting, and the order of plot visitation was varied by selecting alternating starting points and routes. During most study area visits, two observers were used, each responsible for conducting counts on half of the plots. Additional information on census methods was reported elsewhere (Swift 1987, and in prep.)

Habitat Measurements

Data on various aspects of vegetation and hydrology were collected from all plots in order to construct a total of 13 habitat variables. These included 10 vegetation cover types, defined on the basis of structurally dominant species of vegetation (Table 1). Percent of plot area covered by each type was estimated using a point-count technique along 4 or 6 30-m transects originating from the center point of each plot (Swift, in prep.). All vegetation cover measurements were made between July and early September. Distances to the nearest creek channel (CHANDIST) and to the nearest natural upland (LANDDIST) were determined from each plot center point. We defined "channels" as any area of open water or non-vegetated mud flat within the marsh, greater than 2 m across, and extending uninterrupted to the Hudson River. Natural uplands were defined as any contiguous area of dry land or forested wetland situated above mean high tide, with apparently natural contours. Peak high tide levels (MAXTIDE) during the 1987 breeding season were estimated for each study area using modified crest-stage recorders (Buchanan and Somers 1968). Elevations of individual plots were related to gage readings by measuring water depth at each plot center during a single high tide.

Data Analysis

All data recorded during standardized counts on plots were used to estimate relative abundances of breeding birds. Relative abundance of each species was simply the mean number of unique individuals counted per visit in a given year. For plots sampled in 1986 and 1987, the two annual means were averaged to produce an overall mean for habitat analyses. Population densities were estimated by directly relating these count means to the plot area (0.28 ha). Total number of breeding birds on a plot was the sum of relative abundances for all species considered possible marsh-nesting species. Bird species richness was the number of marsh-nesting species occurring on a plot annually.

We examined possible species' associations and interactions by determining simple Pearson product-moment correlations between observed relative abundances of species, using mean annual count data from all plots. Plots sampled in both years were treated as two distinct cases. Hierarchical cluster analysis of the count data was then performed to determine whether distinct assemblages of tidal marsh bird species could be identified. Cases (plots) were clustered using the method of average linkage between groups (Norusis 1986). Habitat characteristics associated with each species group were compared using univariate analysis of variance (ANOVA) and discriminant function analysis (DFA) (Snedecor and Cochran 1967, Johnston 1972, Norusis 1986). All DFA's assumed equal prior probabilities for group classifications. Discriminant functions were estimated using full variable sets and stepwise variable selection methods. Stepwise variable selection was performed by minimizing the value of Wilk's lambda. Upon completion of each DFA, a classification results summary was produced, comparing actual and predicted group classifications for each plot. All analyses were performed using SPSS/PC+ software (Norusis 1984, 1986).

RESULTS AND DISCUSSION

Avian Populations in Tidal River Marshes

Approximately 2,900 observations of birds, comprising 26 species, were recorded during the two years of field work (Table 2). Overall, the most commonly observed species were Marsh Wren (Cistothorus palustris), Red-winged Blackbird (Agelaius phoeniceus), Swamp Sparrow (Melospiza georgiana), Virginia Rail (Rallus limicola), Yellow Warbler (Dendroica petechia), Song Sparrow (Melospiza melodia), Common Yellowthroat (Geothlypis trichas), Least Bittern (Ixobrychus exilis), American Goldfinch (Carduelis tristis) and Willow Flycatcher (Empidonax traillii). These 10 species accounted for 95% of all observations.

Our census results, especially species composition, were in agreement with those reported from other tidal river marshes in the northeastern U.S. (Springer and Stewart 1948; Hawkins and Leck 1977; Meanley 1985; Craig, in press). However, many non-passerines commonly found in non-tidal marshes (Saunders 1926, Provost 1947, Weller and Spatcher 1965, Weller 1979) were notably absent or uncommon during this study. These included Pied-billed Grebe (Podilymbus podiceps), Mallard (Anas platyrhynchos), Black Duck (Anas rubripes), Blue-winged Teal (Anas discors), American Bittern (Botaurus lentiginosus), Sora (Porzana carolina), King Rail (Rallus elegans) and Common Moorhen (Gallinula chloropus), all of which have been reported as possible nesting species in the Hudson Valley region of New York (Foley and Taber 1951; Bull 1974; U.S. Dept. of Commerce and NYSDEC 1982; Andrle and Carroll, in press). Northern Harrier (Circus cyaneus) and Black Tern (Chlidonias niger) also nest in large inland marshes in New York, but are not known to use tidal freshwater marshes.

Estimated densities of marsh nesting species were relatively high in all study areas (Table 3). Mean density of birds for all areas was approximately 400 pairs per 40 ha. This compares favorably with densities reported from non-tidal freshwater wetlands (Weller and Fredrickson 1974, Brinson et al. 1981, Manci and Rusch 1988). Previous studies of tidal marshes reported densities of 164 and 116 breeding pairs per 40 ha (Springer and Stewart 1948, and Hawkins and Leck 1977, respectively). Higher densities in this study may be attributed in part to the predominance of Marsh Wren, a small passerine that often occurs in dense nesting concentrations (Leonard and Picman 1987). On the other hand, our estimates of avian abundance may be low, since several species did not arrive on breeding grounds until mid-May, after one round of counting was completed. Nonetheless, our results seem consistent with observations that tidal freshwater wetlands are highly productive biological communities (Weinstein 1977, Odum and Heywood 1978, Whigham et al. 1978, Odum et al. 1984).

Despite high densities of birds breeding in Hudson River marshes, it appears that these areas provide suitable nesting habitat for relatively few species, as noted earlier. While as many as 25 species may occur in these wetlands during a breeding season, 7 or fewer nesting species accounted for over 90% of our observations in each study area. Overall, an average of 5 species were counted on each plot (Table 3). We believe that the number of bird species nesting in tidal river marshes is probably limited by two factors. Twice daily tidal flooding in the lower Hudson River excludes most species that nest on or near the ground, since water levels often rise more than 0.5 m above the marsh surface. As a result, resident breeding birds include only those which can construct their nests above high tide levels in emergent or woody wetland vegetation, and which do not require permanent open water. A second limitation to avian diversity in tidal river marshes is the lack of well developed shrub and canopy layers. Structural diversity of vegetation, especially in the vertical profile, is directly related to the number of breeding bird species in most ecosystems (MacArthur and MacArthur 1961, Weller and Fredrickson 1974, Weller 1978, Swift et al. 1984). In general, tidal river marshes represent a structurally simple, and unstable, environment for breeding birds. Consequently, nesting bird species richness in tidal marshes is much less than may be inferred from lists of species observed in such areas over the entire year (e.g., Kiviat 1978, Odum et al. 1984).

In addition to their role as breeding habitats, Hudson River tidal marshes serve as foraging areas for a variety of species nesting in adjacent habitats or visiting the marshes during migration. Although our study methods were not designed to assess habitat use by species nesting outside of the emergent marsh community, observations of these were recorded during the study. Non-breeding species regularly seen in the study areas included Great Blue Heron (Ardea herodias), Green-backed Heron (Butorides striatus), Wood Duck (Aix sponsa), Spotted Sandpiper (Actitis macularia), Common Snipe (Gallinago gallinago), Greater Yellowlegs (Tringa melanoleuca), Belted Kingfisher (Ceryle alcyon), Tree Swallow (Iridoprocne bicolor), and Common Grackle (Quiscalus quiscula). Clearly, the importance of tidal river marshes as feeding areas for non-resident breeding species and migrant birds warrants further investigation.

In similar studies of Connecticut River marshes, Craig (in press) concluded that no species historically present had expanded their breeding distribution, and about 40% of the original 22 breeding species had less extensive distributions or become locally extinct. He suggested that the influence of man was related to all species declines, and was also a factor in the introduction of three species as breeders, i.e., Mute Swan (Cygnus olor), Canada Goose (Branta canadensis), and Mallard. Although comparable historic data are not available, these trends may also be characteristic of Hudson River marshes. In fact, Mute Swan and Canada Goose were confirmed nesting in the two southernmost study areas, and may be increasing northward in the Hudson Valley.

Avian Communities in Tidal River Marshes

Bird species breeding in Hudson River marshes were apparently not distributed independently of one another. Simple correlations (Table 4) and cluster analysis of the census data suggested that two relatively distinct avian sub-communities (associations of species) occurred in Hudson River tidal marshes. In the cluster analysis, 2 of 219 plots were separated out first, followed by a split of the remaining plots into two major groups (n=126 and 91, respectively). Further analysis produced a fourth group containing only 1 member, at which point the analysis was terminated. Based on similarity of species composition, the two smallest groups (3 plots) were pooled with the largest. Differences in relative abundances of 10 species were significantly different among the two resulting groups, as were differences in total number of breeding birds and number of nesting species (Table 5).

One group of plots (Group 2) was dominated by Marsh Wren, and characterized by the presence of Least Bittern at many locations. Red-winged Blackbird, Swamp Sparrow, Virginia Rail, and Song Sparrow accounted for most of the other birds counted on Group 2 plots (Table 5). The other group of plots (Group 1) had significantly fewer Least Bitterns and Marsh Wrens, while nearly all other passerine species were more abundant (Table 5). These plots were dominated by Red-winged Blackbird, Marsh Wren, and Swamp Sparrow, but were also characterized by the occurrence of Willow Flycatcher, Gray Catbird, Yellow Warbler, Common Yellowthroat, American Goldfinch and Song Sparrow. Of the species included in this analysis, only Virginia Rail and Sora were not clearly associated with either of the two groups.

While many plots included species representative of both sub-communities, the data suggested that a significant spatial separation of the two was occurring, at least on a very local scale. Such segregation may be caused by exclusion of one species by another through behavioral interactions or resource competition (Ricklefs 1979), or by species' preferences for different habitats. The first mechanism seems plausible since Marsh Wren distribution has been shown to be affected by aggressive interactions with Red-winged Blackbirds, Swamp Sparrows, and Song Sparrows; in fact, Marsh Wren nest locations and feeding areas are often spatially segregated from other co-occurring passerines (Leonard and Picman 1986). Cluster analysis of habitat data from the plots indicated that a continuum of habitat conditions (rather than two discrete types) was available, further suggesting that species' interactions were operating. However, no other data on spatial or behavioral relationships among bird species were collected in this study.

Habitat Relations to Avian Communities

Although species' interactions apparently influenced avian distribution in Hudson River tidal marshes, habitat conditions probably played a greater role in determining overall community structure. Habitat characteristics differed significantly among the two groups in 8 of 13 univariate analyses (Table 6), and were used in a discriminant function (Table 7) which correctly classified 84% of the plots into their assigned groups. As suggested earlier, depth of flooding and availability of structurally diverse vegetation appear to be the most important factors affecting habitat use by nesting birds. These relationships generally reflected habitat associations of the member species, as reported by Swift (in prep.).

The Least Bittern and Marsh wren sub-community was typically found in relatively deep-flooding sites, containing dense stands of cattail and cattail-river bulrush mix (TALLBUL). Such areas are usually classified as "mature" tidal marsh communities, an intermediate stage in tidal freshwater marsh succession (Kiviat 1978). Unlike most other species, Least Bittern and Marsh wren are capable of constructing nests as much as 2.0 m above the ground surface in stands of pure cattail, confirmed by nests that we observed. In most study areas, Group 2 plots were often located in the marsh interior, relatively far from adjacent natural uplands. Most other species may have been excluded from these sites by relatively deep flooding or lack of suitable nesting substrates. This distribution pattern suggests that studies of wetland bird communities should include sampling of interior areas, in addition to counts made from adjacent upland edges.

The avian sub-community dominated by passerine species less restricted to marsh habitats was typically found in "senescent" tidal marsh communities, a later stage in marsh succession, as described by

Kiviat (1978). Habitats favored by these bird species were characterized by presence of purple loosestrife, reed, or woody vegetation. These cover types often occur on sites that experience relatively shallow tidal flooding (Swift 1987), and tend to increase diversity of nesting substrates used by passerine birds. In fact, we found nests of all the following species supported by purple loosestrife stems: Virginia Rail, Yellow Warbler, Red-winged Blackbird, American Goldfinch, and Swamp Sparrow. Group 1 plots often occurred in close proximity to natural upland edges, indicating that shoreline zones tended to have the greatest number of nesting species. Areas adjoining man-made fills (e.g., railroad embankments) did not exhibit this same "edge effect", apparently because they lacked the shallow transition zone (created by deposition of sediments from uplands) that favors avian community richness.

Habitat associations of the two avian sub-communities suggest that a fairly predictable response to marsh succession or other changes in habitat conditions occurs in tidal river marshes. "Pre-marsh", consisting of submerged or floating aquatics, and "young" marsh, dominated by non-persistent broad-leaved emergent plants (Kiviat 1978), provide no suitable nesting habitat for avian species (Springer and Stewart 1948; Swift, in prep.). Despite relatively deep flooding, river bulrush, wild rice, smartweeds, and sweet flag, may invade these sites, establishing a "transition" marsh community. Initially, such areas provide only sparse, non-persistent cover, so nesting habitat use remains negligible. However, once stands of cattail become established (even with flooding up to 1.0 m deep), the "mature" marsh community is recognized, which provides the first suitable habitat for marsh-nesting species. Nesting in these areas is probably pioneered by Marsh Wren and Least Bittern. Gradually, deposition of sediments and dead plant material reduces water depths, increasing habitat suitability for near-ground nesting species, especially Virginia Rail and Red-winged Blackbird (Table 8). The higher marsh surface also facilitates invasion of cattail stands by purple loosestrife, reed, and woody vegetation, gradually allowing establishment of the more "terrestrial" sub-community of passerines. Swamp Sparrows, and possibly Song Sparrow, are among the first to respond to these changes, followed by Common Yellowthroat on the higher sites and Willow Flycatcher where woody shrubs appear. Once woody vegetation above 2 m tall is established (usually Salix spp.), or near marsh-woodland edges, one can also expect to find Yellow Warbler, Eastern Kingbird (near open water), and Gray Catbird. Eventually, the emergent marsh community may be totally replaced by shrub swamp or forested wetland, inhabited by a host of other bird species characteristic of moist floodplain woodlands. In the Hudson Valley, these include Red-bellied Woodpecker (Centurus carolinus), Veery (Catharus fuscescens), Blue-gray Gnatcatcher (Polioptila caerulea), American Redstart (Setophaga ruticilla), Northern Oriole (Icterus galbula), and Rose-breasted Grosbeak (Pheucticus ludovicianus) (Swift, unpubl.).

As natural succession procedes, habitat suitability for pioneer nesting species is reduced, perhaps suddenly, through vegetative changes or interactions with other species. The rate at which this replacement of avian communities occurs is unknown; it is undoubtedly variable among tidal river systems, and may be greatly accelerated by the introduction of exotic plants, such as purple loosestrife and reed. Consequently, the Least Bittern - Marsh Wren sub-community appears to be somewhat vulnerable to habitat loss through succession. This may be of some concern since the Least Bittern is considered rare, uncertain, or declining in many regions of the United States (Tate 1986, NYSDEC 1987, USFWS 1987). While Marsh Wrens seem able to exist in very small pockets of suitable habitat, Least Bitterns may require at least 5 ha of suitable habitat (Brown and Dinsmore 1986). Historically, suitable habitats for this species may have been perpetuated by exposure to river currents, tidal flushing, or continual marsh accretion into the river channel. Today, many natural marshes on the river have been replaced by sheltered coves which favor the "senescent" marsh community. The continued availability of suitable nesting areas for Least Bittern in the Hudson estuary may depend on habitat manipulation to maintain or establish "mature" marsh habitats.

The apparent succession of avian communities in response to habitat changes in tidal river marshes suggests some other implications for the future. Potential impacts of man on the Hudson are many and varied, including continued use of the river for waste disposal, water supplies, navigation, and recreation. Most important to the existence of Hudson River breeding bird communities are (1) the amounts of wetland creation and loss that occur due to human activities, (2) potential effects of pollutants already or potentially discharged into the river, and (3) the projected rise in sea level (estimated at 70-200 cm by the year 2100; Bigford 1987). In New York State, public concern about the first two problems has resulted in extensive management efforts to address them, including strict regulatory programs. In contrast, the potential effects of rising sea levels on tidal marsh communities has yet to be addressed in the context of natural succession and habitat availability (Bigford 1987). Needed are inventories of existing and potential habitats for marsh-nesting birds, projections of tidal wetland response to sea level rise, and long term goals for bird species' distribution and abundance. These would form the basis for effective management of Hudson River tidal marshes for breeding birds.

CONCLUSION

Tidal marshes on the Hudson River support dense populations of breeding birds, but are characterized by a relatively small number of nesting species. This appears to be typical of tidal river systems on the east coast of the United States. Least Bittern and Virginia Rail are the only non-passerines that make extensive use of tidal river marshes for nesting. On the other hand, most passerines typically found in inland marshes also make use of similar habitats in the Hudson estuary.

Collectively, the nesting species of riverine tidal marshes comprise two relatively distinct avian sub-communities, which are somewhat spatially segregated, despite a continuum of available habitats. While habitat conditions are the primary determinants of avian distribution, species interactions (primarily between Marsh Wrens and other passerines) may also be operating. Our findings suggest that the effects of habitat alterations can be evaluated in terms of a predictable community level response, in addition to the responses of individual species.

On the basis of this study, it may be possible to suggest some historical changes in the composition and distribution of breeding bird communities associated with Hudson River marshes, as was done for the Connecticut River (Craig, in press). More important, however, is the potential application of our results to future management of the ecosystem. Impact assessments, mitigation strategies, and management plans should be based on knowledge of the avian species and communities affected, and their expected responses to habitat change. Hopefully, this study has helped fulfill this need, since there are opportunities to use this information in management of riverine estuaries throughout the eastern United States.

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Table 1. Definitions of cover types identified in Hudson River tidal marshes.[a]

DENSECAT	- Dense cover comprised of nearly pure stands of cattail (Typha glauca or T. angustifolia), generally _ 1.5 m tall, usually with standing dead stems from the previous year; included swamp rose-mallow (Hibiscus palustris) in some areas.
LOOSE	- Dense cover with purple loosestrife (Lythrum salicaria) comprising a conspicuous component, generally _ 1.5 m tall, lacking woody vegetation, and often including a considerable amount of cattail.
PHRAG	- Dense cover with reed (Phragmites australis) a conspicuous component.
WOODY	- Wetland sites with shrubs or solitary trees comprising a conspicuous component, generally _ 6 m tall; common woody species included alders (Alnus spp.), dogwoods (Cornus spp.), willow (Salix spp.), swamp rose (Rosa palustris), and red maple (Acer rubrum).
TALLBUL	- Dense cattail cover with river bulrush (Scirpus fluviatilis) a conspicuous component, generally _ 1.5 m tall; usually contained little or no broad-leaved emergent vegetation.
SPARSCAT	- Sparse cover generally _ 1.5 m tall, with cattail a conspicuous component; considerable amounts of river bulrush or broad-leaved emergents were often present.
LOWBUL	- Sparse to dense stands of river bulrush, _ 1.5 m in height, with no cattail present; often interspersed with broad-leaved emergent plant species.
BROAD	- Areas dominated by broad-leaved emergents, low sedges, grasses, or annuals, with little or no river bulrush or cattail.
OPEN	- Intertidal or subtidal areas lacking any emergent wetland vegetation (e.g., mud flats, open water, or mats of dead vegetation).
UPLAND	- Any areas above mean high tide, regardless of vegetative cover; included typical upland forest and fields, railroad fills, and forested wetlands.

a A cover type had to be at least 2 m x 2 m in size to be recognized at a transect point; smaller areas were classified according to surrounding cover type(s).

Table 2. Summary of bird counts in Hudson River tidal marshes[a].

Common Name	Scientific Name	1986	1987
Mute Swan	*Cygnus olor*	3	4
Canada Goose	*Branta canadensis*	0	12
Mallard	*Anas platyrhynchos*	6	2
American Black Duck	*Anas rubripes*	3	1
Wood Duck	*Aix sponsa*	5	6
Green-backed Heron	*Butorides striatus*	5	1
American Bittern	*Botaurus lentiginosus*	9	0
Least Bittern	*Ixobrychus exilis*	26	47
Virginia Rail	*Rallus limicola*	110	106
Sora	*Porzana carolina*	0	4
Spotted Sandpiper	*Actitis macularia*	8	9
Common Snipe	*Gallinago gallinago*	2	1
Belted Kingfisher	*Ceryle alcyon*	2	0
Eastern Kingbird	*Tyrannus tyrannus*	7	2
Willow Flycatcher	*Empidonax traillii*	36	18
Gray Catbird	*Dumetella carolinensis*	12	13
Marsh Wren	*Cistothorus palustris*	526	519
Yellow Warbler	*Dendroica petechia*	91	67
Common Yellowthroat	*Geothlypis trichas*	35	80
Northern Oriole	*Icterus galbula*	0	5
Red-winged Blackbird	*Agelaius phoeniceus*	276	240
Common Grackle	*Quiscalus quiscula*	9	12
American Goldfinch	*Carduelis tristis*	23	41
Northern Cardinal	*Cardinalis cardinalis*	0	1
Swamp Sparrow	*Melospiza georgiana*	166	208
Song Sparrow	*Melospiza melodia*	58	98
Total		1,418	1,497

[a] Counts were conducted 4 times on 119 plots (0.28 ha) in 1986, and 5 times on 100 plots in 1987; 50 plots were sampled in both years.