AVIAN BREEDING HABITATS

IN HUDSON RIVER TIDAL MARSHES

Final Report

Prepared under contract with

The Hudson River Foundation
for Science and Environmental Research, Inc.
122 East 42nd Street, Suite 1901
New York, NY 10168
HRF Grant No. 024/86B/020

Prepared by

Bryan L. Swift
New York State Department of Environmental Conservation
Division of Fish and Wildlife
Wildlife Resources Center
Delmar, NY 12054

August 1989

PREFACE

The research contained in this report has been financed in part through research grants from the Hudson River Foundation for Science and Environmental Research, Inc., a New York not-for-profit corporation with its office located in New York City. The views expressed herein do not necessarily reflect the beliefs or opinions of the Foundation, which assumes no responsibility or liability for the contents or use of the information herein.

This report presents a synthesis of two years of study designed to analyze the use of Hudson River tidal marshes as breeding habitats by migratory birds. Results of the first year of study were presented in an earlier report to the Foundation (Swift 1987). This report includes results from both years of study and emphasizes the development and use of habitat models for predicting presence or absence of nesting species. The models can be used to identify potential habitats of species, to predict impacts of ecological changes, and to asses the importance of tidal marshes as avian breeding habitats.

Any comments or questions regarding this report should be directed to the author, at the following address: New York State Department of Environmental Conservation, Division of Fish and Wildlife, Wildlife Resources Center, Delmar, NY 12054.

ACKNOWLEDGMENTS

This project was financed in part through research grant No. 024/86B/020 from the Hudson River Foundation for Science and Environmental Research, Inc. Additional funding was provided by the New York State Division of Fish and Wildlife's Conservation Fund and the Hudson River National Estuarine Research Reserve.

Completion of this study would not have been possible without major efforts by Steve Orman and John Ozard, who assisted with breeding bird counts, habitat measurements, and data compilation and entry. My sincere thanks to both for their hard work and support throughout the project. I also thank Donna Dyer and Sue Sheridan for painstakingly typing this report. Many other staff in the Division of Fish and Wildlife assisted with nest-searching, water level measurement, and data analysis, and their efforts were greatly appreciated.

Certain information useful in project planning and interpretation of results was obtained through conversations with Robert Craig, Bill Eddleman, Jim Glahn, Erik Kiviat, Jim Rod, and Milton Weller. I thank Karl Parker, Milton Weller, and Brooke Meanley for their very helpful review comments on a draft of this report. Access to New York State Breeding Bird Atlas information was made possible by Janet Carroll, and the following individuals who discussed their "Atlas" work in tidal marshes with us: Dick Guthrie, William Cook, Jack Focht, Ed Treacy, Steve Chorvas, Frank Murphy and Seward Highley. The Laboratory of Ornithology at Cornell University provided tape recordings of bird calls used in this study.

Special permission for access to study area lands was obtained from, or with the assistance of: Ed Brady, Coxsackie, NY (West Flats); Betsy Blair, Hudson River National Estuarine Research Reserve, Annandale, NY (Stockport Marsh, Tivoli North Bay, and Iona Marsh); Jim Rod, National Audubon Society, Garrison, NY (Constitution Marsh); and Ken Krieser, Palisades Interstate Park Commission, Bear Mountain, NY (Iona Marsh). Thanks also to John Cronin of the Hudson River Fishermen's Association for making Castle Rock Field Station in Garrison a very comfortable "home away from home" on many occasions.

ABSTRACT

Field studies were conducted in 1986 and 1987 to document habitats used by breeding birds in six tidal freshwater marshes along the Hudson River in New York. Twenty-seven species were observed on study plots, but only 12 were considered probable nesting species in the tidal marsh environment. Marsh wren (Cistothorus palustris) was the most numerous species overall, followed by red-winged blackbird (Agelaius phoeniceus), swamp sparrow (Melospiza georgiana), Virginia rail (Rallus limicola), and yellow warbler (Dendroica petechia). Only two nonpasserine species, Virginia rail and least bittern (Ixobrychus exilis), made significant use of Hudson River tidal marshes for nesting. Despite the low diversity of nesting species, all study areas supported relatively dense populations of breeding birds. It was estimated that Hudson River tidal marshes may produce as many as 25,000 young birds annually.

Presence or absence and relative abundance of all marsh-nesting species were related to habitat variables using discriminant function analysis (DFA) and multiple regression. Significant correlations were detected for most species, and predictive models of habitat use were developed and evaluated for each. In most cases, 75-90% of all plots were correctly classified by the models as to the presence or absence of species. The models were evaluated using subsets of study plots as test cases, and most appeared useful for predictive purposes. Important habitat variables related to avian use of tidal marshes were availability of tall river bulrush-cattail cover, presence of purple loosestrife or woody vegetation, and depth of tidal flooding.

Cluster analyses of bird count data revealed that tidal marsh bird communities consisted of two relatively distinct assemblages of species, each associated with a preferred set of habitat conditions. A least bittern - marsh wren association was typically found in deepwater marsh areas, usually lacking in vegetation diversity, while an association of more terrestrial passerine species occurred in more shallowly flooded areas, characterized by a mixture of emergent and woody wetland vegetation.

Implications regarding the importance and management of tidal marshes as avian breeding habitats are discussed. Overall, it was concluded that Hudson River tidal marshes are probably most important as potential breeding areas for least bittern (a species of special concern in New York), as productive areas for wetland dependent bird communities to occur, and as foraging areas for species nesting in other habitats.

CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

INTRODUCTION

More than 1,000 ha of tidal marsh occur along the lower Hudson River, between Troy and New York City. These wetlands are predominantly tidal freshwater, characterized by near freshwater conditions, plant and animal communities dominated by freshwater species, and a daily lunar tidal fluctuation. The physical process of tidal flushing, combined with a freshwater marsh biota, makes this a dynamic and distinct estuarine community (Odum et al. 1984).

Tidal freshwater marshes are probably the most significant avian nesting habitats associated with the Hudson River, in terms of productivity, species composition, and areal extent. However, their importance as breeding habitats for migratory birds has received relatively little study in the eastern United States, where an estimated 164,000 ha of this community type occur (Odum et al. 1984). Estimates of breeding bird abundance in tidal marsh communities have been reported from Connecticut (Craig, in press), New Jersey (Hawkins and Leck 1977), and Maryland (Springer and Stewart 1948), but quantitative data on habitats used are generally lacking. In contrast, habitat use by breeding birds in nontidal marshes has been well documented (Provost 1947, Weller and Spatcher 1965, Weller 1979, Manci and Rusch 1988). However, observations from nontidal areas may not reflect conditions in tidal freshwater marshes.

In an effort to better understand the Hudson River ecosystem, the New York State Department of Environmental Conservation (NYSDEC) and the Hudson River Foundation jointly sponsored this study of avian breeding habitats in tidal marshes on the Hudson. Specific objectives of the study were: (1) to document bird species breeding in Hudson River tidal marshes; (2) to relate the spatial distributions of marsh-nesting species to measurable habitat variables; and (3) to develop models for predicting distribution and abundance of nesting species in tidal marshes throughout the Hudson River estuary. Development of avian habitat models has been reported for various species and ecological communities (Martinka 1972, Raphael 1981, Rice et al. 1981, U.S. Fish and Wildlife Service 1981, Whitmore 1981, Morrison et al. 1987). Such models can be used to identify potential habitats of species, to determine possible impacts of ecological changes, and to assess the importance of certain community types as avian breeding habitats.

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). The six study areas (and abbreviations used in this report) were: West Flats (WF); Stockport Marsh (SM); Hudson North Bay (HB); Tivoli North Bay (TB); Constitution Marsh (CM); and Iona Marsh (IM). These areas were selected to include a representative range of habitat variables that occur in Hudson River tidal marshes, and which typically influence marsh-nesting bird communities (Weller 1978). The six sites included four "railroad cove" marshes and two shallow bays that opened more broadly to the Hudson River. Detailed descriptions of the study areas were provided in an earlier report (Swift 1987).

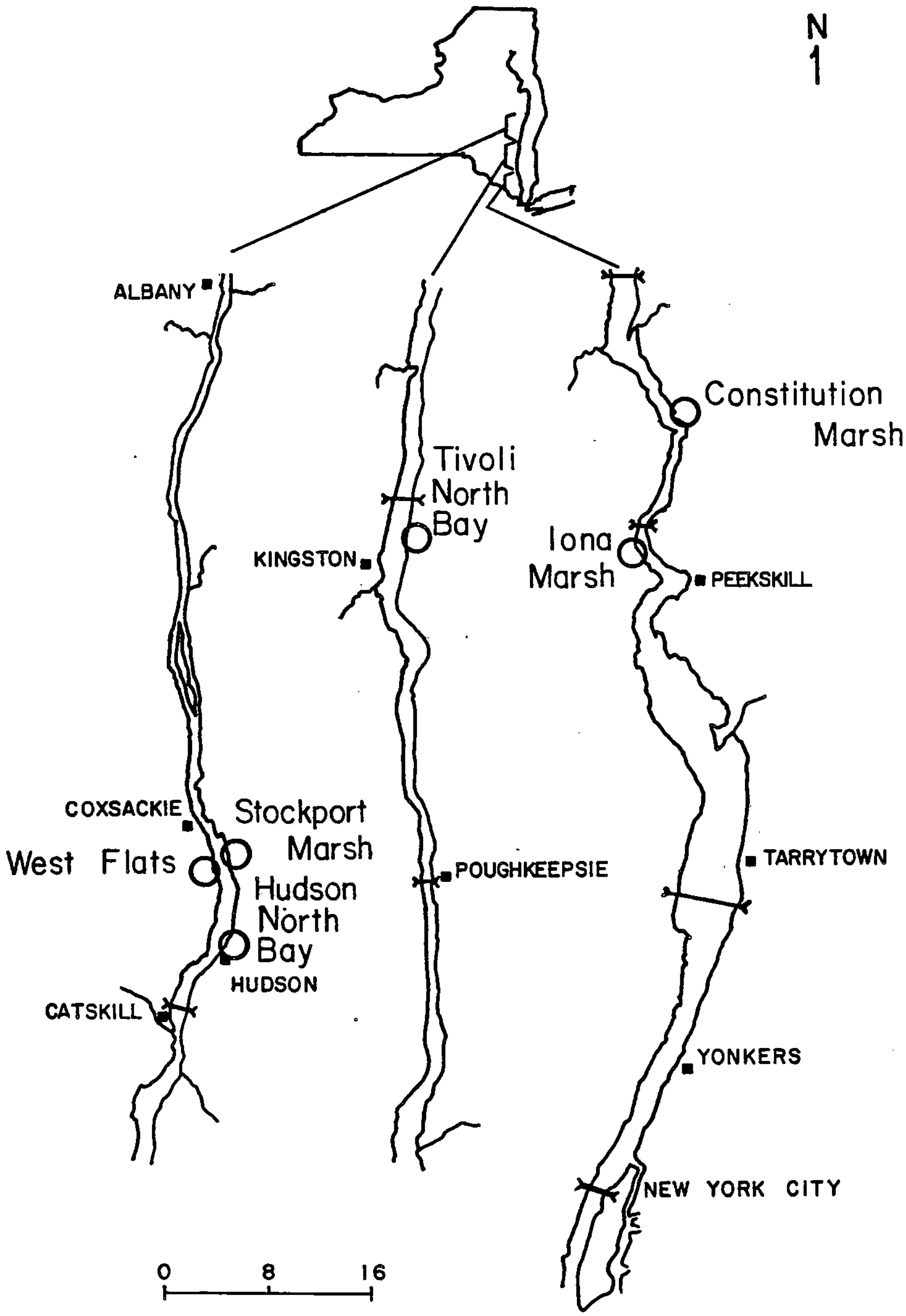

Figure 1. Locations of tidal marsh study areas along the Hudson River, New York.

All study areas contained large areas of emergent marsh, dominated by cattail (primarily Typha angustifolia). Other persistent emergents and woody plants, such as purple loosestrife (Lythrum salicaria), river bulrush (Scirpus fluviatilis), reed (Phragmites australis), willow (Salix spp.), swamp rose-mallow (Hibiscus palustris), and swamp rose (Rosa palustris), were conspicuous components of most study areas. Common nonpersistent 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). As a result of tidal influences, all study areas showed considerable interspersion of intertidal plant communities, ranging from "pre-marsh" (occurring near or below low tide level) through "senescent" marsh (occurring in the upper intertidal zone), as described by Kiviat (1978a). Nearly all lands adjacent to the marshes were forested, and subject to 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 Hudson River estuary is tidally influenced over its entire 250 km reach south of Troy. Water levels in the marshes fluctuate as much as 1.5 m during each tidal cycle, and peak high tide levels vary as much as 0.9 m over the year (Busby and Darmer 1970, Stedfast 1982). Tidal flow in the river is often substantially greater than the freshwater inflow, which is generally highest during spring and lowest during late summer and early fall (Moran and Limburg 1986). Under average runoff conditions, salt intrusion (5 ppt) reaches somewhere between Peekskill and Poughkeepsie (Fig. 1) during late summer. Consequently, the four northernmost study areas were truly tidal freshwater wetlands, while Iona Marsh, and to a lesser extent Constitution Marsh, were occasionally brackish.

METHODS

Breeding Bird Counts

Data on breeding bird populations were collected on 169 circular plots distributed among the six study areas. Each plot was 0.28 ha (30-m radius) in size. Plot centers were located randomly within each marsh and were separated by at least 60 m. In 1986, breeding birds were counted four times on 119 of these plots. In 1987, five counts were made on 50 of the same plots and on 50 new plots within five of the study areas (Table 1). Most repeat locations were selected nonrandomly in 1987 to include plots where nonpasserines had been observed in 1986.

All counts were conducted between 4 May and 20 June, during early morning (05:00-10:00 h DST) and evening periods (16:30-20:30 h), at times with no measurable precipitation or strong winds (greater than approximately 25 km/h). Each count consisted of an approximate 10-min visit to a plot center, during which all nonpasserine birds seen or heard and all male passerines heard singing within 30 m were identified to species and counted. During each plot visit, calls of selected nonpasserine species were broadcast from the plot center, using portable cassette recorders. This was done to increase detection of secretive species (after Glahn 1974, Johnson et

Table 1. Number and distribution of study plots in Hudson River tidal marshes.

	Year(s) Sampled			
Study Area	1986 only	1986 and 1987	1987 only	Total
West Flats	10	10	10	30
Stockport Marsh	20	-	-	20
Hudson North Bay	10	10	10	30
Tivoli North Bay	9	10	10	29
Constitution Marsh	10	10	10	30
Iona Marsh	10	10	10	30
Total	69	50	50	169

al. 1981, Marion et al. 1981, and Johnson and Dinsmore 1986b). A standardized sequence of calls and silent listening periods was used for each round of counts (Table 2). Maximum sound pressure 1 m from the source was approximately 90 db.

Study areas were visited in random order within each round of counts, 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 counts on half of the plots. Sampling schedules were designed to distribute possible effects of date, time of day, and observer bias equally among all areas.

Nest searches were conducted wherever repeated observations of nonpasserines were recorded within a 100-m^2 area on a plot. Each search consisted of 2-6 people hand-combing the vegetation along parallel routes (3-5 m apart) for up to 45 min. Approximately 20 locations were searched each year.

Habitat Measurements

Vegetation characteristics and physical habitat features were measured on all plots in order to define 13 avian habitat variables (Table 3). Variables included percent cover by 10 vegetation types that were identified by their structurally dominant plant species (Table 4). Percent of plot area covered by each type was estimated using a point-count technique along 30-m transects originating from the center of each plot. At 3-m intervals along each transect, vegetation type was identified and recorded. Plots sampled in 1986 had 4 perpendicular transects (a total of 40 points), while those sampled in 1987 had 6 transects intersecting at 60 degree angles (a total of 60 points). Orientation of the transects was determined by selecting a random compass bearing for each plot. Counts of each vegetation type were converted to percent cover for each plot. All vegetation cover measurements were made between July and early September. Stem counts of dominant emergent plant species were made on 1.0-m^2 square quadrats in selected cover types in 1986 (see Swift 1987).

Distances to the nearest creek channel (CHANDIST) and nearest natural upland (LANDDIST) were determined from each plot center. Channels were specifically defined as any intertidal or subtidal area within the marsh, lacking emergent vegetation, 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. Distances up to 60 m were usually measured in the field, while greater distances were estimated from aerial photographs obtained from the U.S.D.A. Agricultural Stabilization and Conservation Service. Distance to human-made uplands (e.g., railroad embankment) was included in the first year of study, but was found to be of little value in modeling avian habitats (Swift 1987).

Data on peak high tide levels were recorded throughout the 1987 field season using modified crest-stage recorders (Buchanan and Somers 1968). Two recorders were installed in each of the five marshes studied in 1987, and tide levels were extrapolated for the other area (Stockport Marsh) based on

Table 2. Playback sequence of tape-recorded calls used during breeding bird counts in Hudson River tidal marshes.[a]

	Round of Counts				
Year	1	2	3	4	5
1986	GRHE	LEBI	LEBI	LEBI	--
	LEBI	AMBI	AMBI	VIRA1	
	AMBI	VIRA1	VIRA1	LEBI	
	VIRA1	SORA1	SORA1	VIRA3	
	SORA1	VIRA2	LEBI	LEBI	
	COGA	SORA2	VIRA3	VIRA1	
	LEBI	LEBI	LEBI	LEBI	
	AMBI	AMBI	AMBI	VIRA3	
	VIRA1	VIRA1	VIRA1	LEBI	
	SORA1	SORA1	SORA1	-	
1987	VIRA3	LEBI	VIRA3	LEBI	LEBI
	SORA3	VIRA3	SORA3	LEBI	LEBI
	VIRA1	SORA3	LEBI	VIRA1	VIRA1
	SORA1	AMBI	VIRA3	LEBI	LEBI
	VIRA3	VIRA1	SORA1	SORA3	VIRA3
	SORA3	SORA1	LEBI	LEBI	LEBI
	VIRA1	LEBI	VIRA3	VIRA1	VIRA1
	SORA1	VIRA3	SORA3	LEBI	LEBI
	VIRA3	SORA3	LEBI	VIRA3	VIRA3
	-	AMBI	VIRA3	LEBI	LEBI

[a] Sequence on tape was from top of list to bottom for each round of counts. During the first round in 1986, calls were played for 30 s, with a 30-s silent listening period; in all other rounds, call periods were approximately 45 s, with 15-s silent intervals. Codes in table refer to specific calls, as follows: GRHE - green-backed heron "squak"; LEBI - least bittern "cooing"; AMBI - American bittern "pumping"; VIRA1 - Virginia rail "kicker" call; VIRA2 - Virginia rail "kid-ick"; VIRA3 - Virginia rail "grunt"; SORA1 - sora "peeper"; SORA2 - sora "chee"; SORA3 - sora "whinny"; COGA - common moorhen "squak". Scientific names of species appear later in the text.

Table 3. Habitat variables related to avian distribution in Hudson River tidal marshes.

Variable Name	Description
DENSECAT	% cover by DENSECAT cover type[a] /100.
LOOSE	% cover by LOOSE cover type /100.
PHRAG	% cover by PHRAG cover type /100.
WOODY	% cover by WOODY cover type /100.
TALLBUL	% cover by TALLBUL cover type /100.
SPARSCAT	% cover by SPARSCAT cover type /100.
LOWBUL	% cover by LOWBUL cover type /100.
BROAD	% cover by BROAD cover type /100.
OPEN	% cover by OPEN cover type /100.
UPLAND	% cover by UPLAND cover type /100.
CHANDIST	Distance (in 100 m) to nearest creek channel.
LANDDIST	Distance (in 100 m) to nearest natural upland.
MAXTIDE	Depth (in m) of peak high tide in summer 1987.

[a] Operational definitions of cover types appear in Table 4.

Table 4. 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).

observations made in 1986. Maximum recorded tide levels were measured during most study area visits, and on two special occasions (20 July and 4 September 1987) when all gages were checked during a single tide phase. Elevations of individual plots were related to gage readings by measuring water depth at each plot center (to nearest cm) during a single high tide, and calibrating to adjust for rising and falling tide. This method assumed that the water surface was approximately "flat" across the marsh at the time of measurement. In combination, these data were used to estimate peak water depths (MAXTIDE) for all points.

In addition to the original set of habitat variables, a modified set of variables was developed. The modified variable set consisted of presence/absence data rather than percent cover for each vegetation type, along with CHANDIST and LANDDIST in their original form. The purpose of this was to determine whether data gathering requirements for predicting habitat use could be simplified. The conversion of habitat variables to binary form has been employed in many habitat suitability models developed by the U.S. Fish and Wildlife Service (1981) for their Habitat Evaluation Procedures. Consequently, variables in the modified set were referred to as "HEP-model" transformations, and "HEP-" was used as a prefix to their names. No other transformations were applied to the habitat data.

Data Analyses

Breeding bird counts from each plot were the principal measures of avian distribution and abundance in this study. Distributions of breeding species were quantified by their frequency of occurrence, i.e., the number (or %) of plots on which a species was present. Relative abundance of each bird species was simply the mean number of individuals counted per plot-visit during a given year. For plots sampled in both 1986 and 1987, the two annual means were averaged to produce an overall mean for habitat analyses. Avian population densities were estimated by directly relating count means to the plot area (0.28 ha), assuming that each bird counted indicated a breeding pair. Total number of breeding birds (TBBN) on a plot was the sum of relative abundances for all potential marsh-nesting species. Bird species richness (BSR) was the number of these species occurring on a plot annually. Variation in count data due to date of sampling, time of day, and observers, was analyzed using univariate analysis of variance (ANOVA) and Duncan's multiple range test (Snedecor and Cochran 1967).

Avian habitat relationships were analyzed using simple correlation, analysis of variance, multiple linear regression, and discriminant function analysis (DFA) (Snedecor and Cochran 1967, Johnston 1972). These analyses led to the development of multivariate habitat models for all marsh-nesting species. DFA was the primary means by which avian habitat models were developed and tested. DFA has been widely used in avian habitat analysis, especially for predicting presence or absence of species on a local scale (e.g., Martinka 1972, Rice et al. 1981, Sedgwick 1987). Multiple linear regressions can be used to predict relative abundances of bird species from habitat variables, but are more likely to produce unsatisfactory results (Morrison et al. 1987). All analyses were performed using SPSS/PC+ software (Norusis 1984, 1986).

As a first step, simple Pearson product-moment correlations (r) between relative abundances of bird species and individual habitat variables were determined. Simple correlations between TBBN, BSR, and individual habitat variables were also determined. Correlations among habitat variables were obtained to identify possible ecological interactions and to assess the potential for multicollinearity (i.e., redundancy of variables) in subsequent analyses.

Multiple linear regressions were used to relate relative abundances of bird species to the original set of habitat variables. Both ordinary least squares (OLS) (i.e., retaining all variables) and stepwise variable selection methods were used. Stepwise multiple regression was used to identify subsets of variables that accounted for the majority of explainable variation in bird count data, based on probability of the F-statistic associated with entry or removal of habitat variables. Student's t-test was used to determine significance levels for regression coefficients, while coefficients of multiple determination (R^2) and corresponding F-tests provided an overall evaluation of each model. Multicollinearity among habitat variables was controlled by excluding DENSECAT as an explanatory variable in OLS models and by setting an arbitrary "tolerance" level of 0.3 in all analyses (Norusis 1984); this excluded habitat variables whose variation could be explained (i.e., $R^2 \geq 0.70$) by other variables retained in any model.

Two-group DFA was used to distinguish plots with probable evidence of breeding (Group 1) from plots with no evidence of breeding (Group 0) for each nesting species. Results of these analyses were viewed as predictive models of habitat suitability or habitat use (i.e., expected presence or absence of a species). For most species, probable evidence of breeding was two or more observations on a plot in either year, while plots with only one observation per year were omitted from the analysis (after Buckland and Anderson 1985). This resulted in different sample sizes among species. For several less common species, a single observation in either year was accepted as probable evidence of breeding for habitat analyses. This use of the term "probable" to describe evidence of breeding differs from that of Andrle and Carroll (1988).

All DFAs assumed equal prior probabilities for group classifications. Discriminant functions were estimated using complete variable sets (with a 0.3 tolerance limit) and stepwise-selected variables. 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 presence or absence of a species for each plot. The number (or %) of plots correctly classified (predicted) was the primary criterion used to evaluate the habitat models.

The ability of each DFA model to predict habitat use by breeding birds was tested in two ways: (1) preliminary "TESTYEAR" models were derived using the 119 plots sampled in 1986 and used to predict habitat use on the 50 new plots sampled in 1987; and (2) preliminary "RANTEST" models were derived using a randomly selected group of approximately 119 (i.e., 70$\pm$ %) plots and used to predict habitat use on the remaining plots. Validation with an independent data set is an important part of habitat model development (Johnson 1981, Morrison et al. 1987). After comparing test plot classification results with those for plots used to derive a preliminary model, data from all plots were pooled to produce final models of habitat use for each species.

In addition to habitat analyses, bird community relationships were examined by correlating relative abundances of species, using mean annual count data from all plots. Plots sampled in both years were treated as two distinct cases in these analyses. Hierarchical cluster analysis of the count data was then performed to determine whether distinct assemblages of tidal marsh bird species could be identified. Plots were grouped on the basis of similarity of species abundances, using the method of average linkage between groups (Norusis 1986). Habitat characteristics associated with each group of plots were then compared using univariate ANOVA and DFA, as described above.

RESULTS AND DISCUSSION

Avian Abundance and Diversity

Approximately 2,900 observations of birds, comprising 27 species, were recorded during the two years of study (Table 5 and Appendix A). 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. Passerines were by far the most abundant group, comprising 87% of all birds counted. Species that occurred only in adjacent uplands or forested wetlands, such as red-bellied woodpecker (Centurus carolinus) and blue-gray gnatcatcher (Polioptila caerulea), were not included in final tabulations.

Estimated densities of marsh-nesting species were relatively high in all study areas (Table 6). Mean density of birds for all areas was approximately 400 pairs per 40 ha. On the basis of this estimate, tidal marshes along the Hudson (comprising more than 1,000 ha) would be expected to support more than 10,000 pairs of breeding birds. Assuming average production of 2-3 fledged young per nesting pair for most species (Nice 1957), the Hudson estuary may contribute some 25,000 new birds annually to fall populations.

Previous studies of tidal freshwater marshes reported lower densities of breeding birds; Springer and Stewart (1948) found 164 pairs per 100 a (164 pairs per 40 ha) in Maryland, and Hawkins and Leck (1977) counted 79 adult birds in 5 ha (316 pairs per 40 ha) in New Jersey. The relatively small plot size (0.28 ha) and long count period (10 min) may have contributed to higher density estimates in this study, possibly by as much as 50% (Granholm 1983). Higher densities in Hudson River marshes may also have been due to the predominance of marsh wren, a small passerine that often occurs in dense nesting concentrations (Leonard and Picman 1987). This species accounted for more than 35% of all observations (Table 6). On the other hand, avian abundance may have been underestimated in this study, since several nesting species did not establish territories until mid May, after one round of counts was completed. In addition, marsh wren and red-winged blackbird are polygynous species that commonly have two or more nesting females per territorial male (Meanley and Webb 1963, Leonard and Picman 1987). Overall,

Table 5. Summary of bird counts in Hudson River tidal marshes.[a]

Common Name	Scientific Name	Number of Plots	Number of Observations 1986	Number of Observations 1987
Mute swan	*Cygnus olor*	6	3	4
Canada goose	*Branta canadensis*	5	0	12
Mallard	*Anas platyrhynchos*	5	6	2
American black duck	*Anas rubripes*	4	3	1
Wood duck	*Aix sponsa*	7	5	6
Green-backed heron	*Butorides striatus*	5	5	1
American bittern	*Botaurus lentiginosus*	8	9	0
Least bittern	*Ixobrychus exilis*	48	26	47
Virginia rail	*Rallus limicola*	82	110	106
Sora	*Porzana carolina*	4	0	4
Spotted sandpiper	*Actitis macularia*	7	8	9
Common snipe	*Gallinago gallinago*	2	2	1
Belted kingfisher	*Ceryle alcyon*	2	2	0
Eastern kingbird	*Tyrannus tyrannus*	8	7	2
Willow flycatcher	*Empidonax traillii*	33	36	18
Gray catbird	*Dumetella carolinensis*	14	12	13
Marsh wren	*Cistothorus palustris*	127	526	519
Yellow warbler	*Dendroica petechia*	63	91	67
Common yellowthroat	*Geothlypis trichas*	55	35	80
Northern oriole	*Icterus galbula*	4	0	5
Red-winged blackbird	*Agelaius phoeniceus*	153	276	240
Common grackle	*Quiscalus quiscula*	9	9	12
American goldfinch	*Carduelis tristis*	44	23	41
Northern cardinal	*Cardinalis cardinalis*	1	0	1
Sharp-tailed sparrow	*Ammospiza caudacuta*	3	1	2
Swamp sparrow	*Melospiza georgiana*	120	166	208
Song sparrow	*Melospiza melodia*	81	58	98
Total		169	1,419	1,499

[a] Counts were made on 169 0.28-ha plots during the 2-year study; 4 counts were made on 119 plots in 1986, and 5 counts were made on 100 plots in 1987. Fifty of the same plots were sampled in both years. Counts did not include species observed only in uplands or forested wetlands or flying overhead.

Table 6. Estimated densities of breeding birds ($\bar{x} \pm$ SE pairs per 40 ha) in six Hudson River tidal marshes, 1986 and 1987 combined.

		Study Areas						
Species	Abbrev.[a]	WF	SM	HB	TB	CM	IM	ALL
Least bittern	LEBI	18.1 ± 4.6	10.7 ± 4.6	12.7 ± 3.5	11.1 ± 3.7	2.4 ± 1.4	3.1 ± 1.6	9.6 ± 1.4
Virginia rail	VIRA	30.1 ± 5.6	39.3 ± 10.0	30.2 ± 7.2	24.3 ± 6.7	35.4 ± 8.4	12.8 ± 4.8	28.1 ± 2.9
Eastern kingbird	EAKI	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	3.2 ± 1.6	2.4 ± 1.7	2.1 ± 1.5	1.3 ± 0.5
Willow flycatcher	WIFL	6.0 ± 2.3	7.1 ± 4.2	2.4 ± 1.7	10.4 ± 3.8	22.3 ± 5.4	0.0 ± 0.0	8.1 ± 1.5
Gray catbird	GRCA	4.2 ± 2.1	0.0 ± 0.0	5.4 ± 2.7	0.0 ± 0.0	11.6 ± 5.7	0.0 ± 0.0	3.8 ± 1.2
Marsh wren	LBMW	177.4 ± 19.3	219.6 ± 23.2	201.5 ± 20.8	212.4 ± 18.9	67.7 ± 13.2	48.7 ± 13.3	150.4 ± 9.1
Yellow warbler	YEWA	12.1 ± 6.2	23.2 ± 9.4	9.4 ± 3.9	20.3 ± 6.5	62.9 ± 9.9	16.8 ± 5.6	24.2 ± 3.2
Common yellowthroat	COYE	7.1 ± 2.9	1.8 ± 1.8	3.6 ± 1.8	12.9 ± 3.3	27.7 ± 7.8	37.4 ± 7.0	15.9 ± 2.3
Red-winged blackbird	RWBL	50.9 ± 8.6	85.7 ± 15.4	77.1 ± 5.6	70.8 ± 11.9	105.9 ± 9.1	89.5 ± 8.7	79.7 ± 4.1
American goldfinch	AMGO	7.3 ± 3.8	5.4 ± 2.9	9.0 ± 2.9	6.7 ± 3.1	8.1 ± 2.7	17.9 ± 4.9	9.3 ± 1.5
Swamp sparrow	SWSP	48.2 ± 8.2	53.6 ± 10.2	28.6 ± 7.6	69.0 ± 11.1	63.7 ± 10.7	63.9 ± 10.6	54.5 ± 4.1
Song sparrow	SOSP	25.4 ± 6.2	10.7 ± 4.6	21.3 ± 5.5	11.4 ± 3.2	35.0 ± 7.4	29.8 ± 6.5	23.0 ± 2.5
Total Number of Birds	TBBN	386.7 ± 32.3	457.1 ± 30.6	402.1 ± 27.2	452.4 ± 20.0	446.0 ± 32.2	322.1 ± 19.7	408.1 ± 11.7
Bird Species Richness	BSR	5.1 ± 0.4	4.3 ± 0.3	4.7 ± 0.3	5.0 ± 0.4	5.8 ± 0.4	4.9 ± 0.2	5.0 ± 0.2

[a] Species' abbreviations shown here are used in subsequent tables.

the results were 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, Mitsch and Gosselink 1986). Estimated avian densities also compared favorably with densities reported from nontidal freshwater wetlands (Weller and Fredrickson 1974, Brinson et al. 1981, Manci and Rusch 1988).

Despite the abundance of breeding birds in Hudson River tidal marshes, it appears that these areas are used for nesting by a relatively small number of species. Only 12 species were clearly indicated to be nesting within the marshes, and 7 or fewer species accounted for over 90% of the birds counted in each study area. An average of 5 species were observed on each plot (Table 6). Bird species composition of the study areas was in close agreement with that reported from other tidal marshes in the eastern United States (Springer and Stewart 1948; Hawkins and Leck 1977; Craig, in press); only king rail (Rallus elegans) and seaside sparrow (Ammodramus maritimus) would be added to a list of breeding species representative of Atlantic coast tidal marshes (Meanley 1985).

The low diversity of birds nesting in tidal marshlands contrasts sharply with reports from nontidal freshwater marshes (Saunders 1926, Provost 1947, Weller and Spatcher 1965, Weller 1979). Many marsh-nesting species commonly found in nontidal marshes 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, and common moorhen (Gallinula chloropus). All of the above 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 1988). 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 for breeding. Occurrence of certain marsh-nesting species that were not confirmed breeding in Hudson River tidal marshes is discussed in more detail later.

The number of bird species nesting in tidal marshes is not indicative of the diversity of species that occurs in these areas over an entire year (e.g., Kiviat 1978a, Odum et al. 1984). In addition to their role as nesting 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 this study did not assess habitat use by species nesting outside of the emergent marsh community, all observations of birds were recorded. Species regularly seen in the study areas during the breeding season included great blue heron (Ardea herodias), green-backed heron (Butorides striatus), wood duck (Aix sponsa), spotted sandpiper (Actitis macularia), common snipe (Gallinago gallinago), belted kingfisher (Ceryle alcyon), tree swallow (Iridoprocne bicolor), and common grackle (Quiscalus quiscula). Black duck, green-winged teal (Anas crecca), osprey (Pandion haliaetus), northern harrier, and greater yellowlegs (Tringa melanoleuca) were often present during their respective migration periods. Clearly, the importance of tidal marshes as feeding areas for non-resident breeding species and migrants warrants further investigation.

Overview of Habitat Analyses

Quantitative habitat analyses were completed for 12 species that nested in Hudson River tidal marshes. These were: least bittern, Virginia rail, eastern kingbird (*Tyrannus tyrannus*), willow flycatcher, gray catbird (*Dumetella carolinensis*), marsh wren, yellow warbler, common yellowthroat, red-winged blackbird, American goldfinch, swamp sparrow, and song sparrow. Habitat use by each of these species is discussed in detail following this general overview of habitat analyses that were performed. A summary of habitat measurements for the six study areas is presented in Table 7. This is followed by a summary of habitat data for plots with probable evidence of breeding by each species (Table 8).

Simple Correlations. - Simple correlations provided strong evidence of habitat selection by tidal marsh nesting birds. Every species except eastern kingbird was significantly correlated with at least 2 habitat variables (Table 9). Variables most often correlated with abundances of species were MAXTIDE (8 species), LOOSE and WOODY (7 species each), and TALLBUL (6 species).

Multiple Regressions. - Multiple linear regressions had mixed results, reflecting many of the same habitat relationships as simple correlations (Tables 10-11). Habitat models produced by multiple regression explained 5-65% of the variation in avian species' abundances, but are probably of limited value for most species because: (1) variation in species' abundances among study plots was generally very low; and (2) simply predicting presence or absence on that scale is adequate for most habitat evaluation and management needs. Possible exceptions would be the more numerous passerine species, such as marsh wren and swamp sparrow, which sometimes occurred in locally high densities.

Discriminant Analyses. - Discriminant analyses were very useful for developing models of avian habitat use, as reported by others (Martinka 1972, Rice et al. 1981, Whitmore 1981, Williams 1981, Sedgwick 1987). DFA models revealed a greater number of significant habitat relationships than did the regression models. Furthermore, at least one model for each species correctly classified its presence or absence on more than 70% of the study plots (Tables 12-14), and the complete set of final DFA models had an average classification success rate of approximately 80%. Many of the "errors" involved plots where species were predicted to be present but were not observed (Appendix B). This is to be expected since several reasons for a species' absence in suitable habitat can be identified: (1) the species' population level is inadequate to occupy all suitable habitat; (2) a species is excluded by interspecific competition; or (3) the sampling procedure failed to detect it (Johnson 1981).

Validation of the DFA models produced highly variable test results (Appendix B). For example, one preliminary model of swamp sparrow habitat correctly classified 86% of the plots used to derive the model, and had 97% success for the test plots. On the other hand, a song sparrow habitat model with 67% classification success correctly classified only 34% of the test plots. Overall, classification success was approximately 5-15% lower for test plots than for plots used to derive the models (e.g., 65-75% versus 80%). TESTYEAR models performed most poorly for least bittern, Virginia rail, and song sparrow, while excellent test results were obtained for eastern kingbird, gray catbird, marsh wren, yellow warbler, and common yellowthroat. Annual

Table 7. Summary of habitat measurements ($\bar{x} \pm$ SE) on study plots in six Hudson River tidal marshes.[a]

Habitat Variable	Study Area WF	SM	HB	TB	CM	IM	All
DENSECAT(%)	5.9 ± 2.2	13.6 ± 3.6	20.2 ± 5.1	51.1 ± 6.4	31.6 ± 4.3	47.9 ± 4.7	29.1 ± 2.3
LOOSE(%)	9.2 ± 2.3	12.9 ± 3.4	2.2 ± 0.8	21.7 ± 5.1	21.3 ± 4.2	0.0 ± 0.0	11.1 ± 1.4
PHRAG(%)	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	25.5 ± 4.7	4.6 ± 1.1
WOODY(%)	1.6 ± 0.7	2.4 ± 1.0	0.5 ± 0.2	2.0 ± 1.0	7.4 ± 1.9	0.2 ± 0.1	± 2.4 0.5
TALLBUL(%)	23.4 ± 4.3	7.0 ± 2.0	16.9 ± 4.3	0.5 ± 0.3	0.1 ± 0.1	0.3 ± 0.2	8.1 ± 1.3
SPARSCAT(%)	19.2 ± 2.7	22.6 ± 2.9	18.6 ± 3.4	12.4 ± 2.8	23.7 ± 3.2	9.9 ± 2.0	17.5 ± 1.2
LOWBUL(%)	18.0 ± 3.8	26.1 ± 5.6	21.3 ± 4.7	0.3 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	10.1 ± 1.5
BROAD(%)	12.8 ± 2.7	8.1 ± 2.0	9.5 ± 2.1	6.4 ± 2.8	6.3 ± 2.7	0.4 ± 0.2	7.2 ± 1.0
OPEN(%)	7.3 ± 2.0	0.1 ± 0.1	7.7 ± 2.3	5.5 ± 2.1	6.7 ± 1.7	14.1 ± 3.2	7.3 ± 0.9
UPLAND(%)	2.4 ± 1.1	7.1 ± 3.2	2.9 ± 1.2	0.0 ± 0.0	2.9 ± 1.7	1.8 ± 0.9	2.6 ± 0.6
CHANDIST(m)	45.5 ± 7.6	114.8 ± 10.2	37.9 ± 5.7	53.6 ± 9.0	38.0 ± 7.4	31.1 ± 5.8	49.8 ± 3.6
LANDDIST(m)	80.1 ± 11.3	54.4 ± 6.3	97.4 ± 13.6	356.8 ± 34.0	108.0 ± 16.5	93.5 ± 9.5	134.9 ± 10.8
MAXTIDE(cm)	73.0 ± 4.0	70.2 ± 2.3	69.4 ± 2.7	66.1 ± 3.7	52.8 ± 2.6	41.0 ± 2.3	61.5 ± 1.5

[a] Values in the table are in units 100 times larger than the values used in habitat analyses (see Table 3). This simple transformation was made for ease of interpretation.