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Habitat Use by Salt Marsh Birds and Response to Open Marsh Water Management

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Abstract.—We examined the numerical responses of salt marsh birds in Massachusetts to modified open marsh water management (OMWM), a habitat alteration technique to control salt marsh mosquitoes without destroying habitat quality for pool-using birds. This management had little overall effect on bird populations in two 3-ha plots monitored for three yearss after manipulation. Shorebirds increased at first, probably owing to use of spoil resulting from construction activities but then decreased to pre-alteration numbers. Other pool-using birds (herons, terns and kingfishers) were not affected by management and consistently used control plots with extensive natural pool systems. Numbers of some marsh- and upland-nesting birds declined temporarily but returned to pre-alteration levels by the end of the study. Results indicate that open water marsh management, as modified in Massachusetts, has little immediate adverse or beneficial effect on salt marsh birds in marshes that have been previously ditched.

Key words.—Mosquito control, open marsh water management, bird abundance, shorebirds, herons, salt marshes, Massachusetts, New England, habitat alterations, salt marsh pools, grid-ditching.

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In the past, attempts to control nuisance salt marsh mosquitoes (mainly *Aedes sollicitans*) have involved draining extensive areas of marsh by grid-ditching. This technique has not been used selectively and has caused decreases in other salt marsh organisms (Urner 1935, Headlee 1939, Bourn and Cottam 1950, Daiber 1974, Shisler and Jobbins 1975), while not always effectively controlling mosquitoes (Hruby et al. 1985). Open marsh water management (OMWM) allows access by predatory fish to temporary pools containing mosquito larvae, thus controlling them (Ferrigno and Jobbins 1968, Provost 1977). The original OMWM system, as used in New Jersey and Delaware, USA, involved the creation of pools of various depths that serve as refuges for fish and as foraging sites for many salt marsh birds (Urner 1935, Bradbury 1938, Bourn and Cottam 1950, Teal and Teal 1969, Burger et al. 1982, Clarke et al. 1984). In this study, modifing OMWM for New England conditions (Hrubý et al. 1985), we altered existing ditches to create fish refuges.

In a one-year study in Massachusetts, Clarke et al. (1984) found that salt marshes with well-maintained ditches and few pools have lower numbers of shorebirds, herons, terns and aerial insectivores than do marshes with poorly-maintained ditches and extensive pools. Because of OMWM's potential for ecologically sound and effective mosquito control, Clarke et al. (1984) called for a field test of OMWM, which had not then been attempted in New England. In this paper, we examine the effects of open marsh water management on various bird groups and contrast changes in bird numbers on experimental and control plots. We also re-examine the use of ditched and unditched plots by birds, in light of three additional years' data.

STUDY AREA AND METHODS

Study Areas

Five 3-ha study plots (300 X 100 m) were established in the salt marshes of Rowley, Essex County, Massachusetts, USA (Fig. 1). The control plots (C1, C2, and C3) were near coastal bays and were domi-

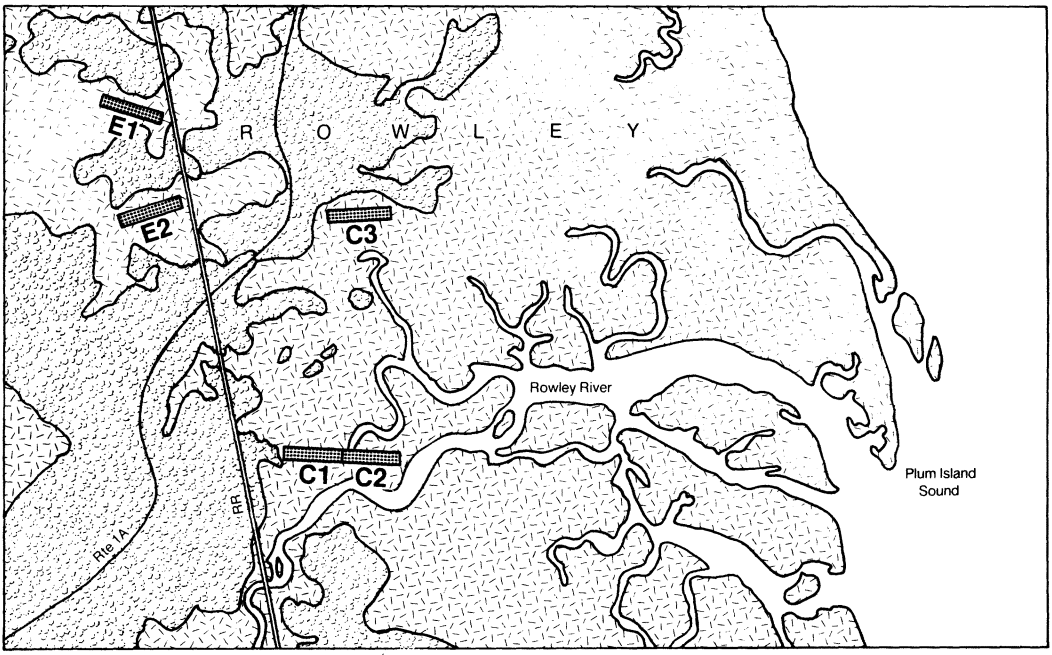

Figure 1. Location of study plots in coastal salt marshes of northeastern Massachusetts. Blank areas indicate open water, hatched areas indicate salt marsh, while the remaining colored area along Route 1A is upland vegetation. Each plot is 300m long and 50m wide.

nated by salt hay (*Spartina patens*), cordgrass (*Spartina alterniflora,* short form), and spike grass (*Distichlis spicata*). Plots E1 and E2 were backwater marshes (Clarke et al. 1984) adjacent to upland habitat. Salt hay and cordgrass predominated but cattail (*Typha angustifolia*), bulrush (*Scirpus* spp.) and various herbaceous plants were also present along the upland edges (See Clarke et al. 1984 for more detailed descriptions of vegetation.). All plots had been ditched before 1940, but because of poor ditch maintenance, ditches on Plots C1, C2 and E1 had become clogged and pool systems had re-formed (Fig. 2). In contrast, Plots C3 and E2 had well-maintained ditch systems and few pools.

OMWM was performed on Plots E1 and E2 in early June 1983. Old ditches were deepened to 1m and widened to 0.5 m to serve as reservoirs for larvae-eating minnows, and shallower (0.3m deep) radial ditches connected reservoirs to suspected mosquito breeding areas (Hruby et al. 1985). No new pools were created.

Bird Censusing

We censused birds by recording all birds seen within plot boundaries. The observer walked slowly (ca. 21m/min) along a predetermined census route 30 m inside each plot boundary and recorded the location of all birds seen (as described by Clarke et al. 1984). Birds were recorded only if they were foraging on or above the plot or were resting on the plot. The observer also recorded the activity (feeding, resting or involved in territory defense) and location (pool, vegetation, air, or other—ditch, creek, or spoil) of all birds censused so that we could better relate the effects of OMWM to the foraging behavior of each bird group.

All five plots were censused on each visit and the order of censusing was varied as much as possible. We censused at all times of day because preliminary analysis showed that time of day had no effect on bird numbers. We censused during all stages of the tidal cycle, and only stopped censusing during heavy rain. Different observers did field work each year (J. A. Clarke in 1982, R. A. Lent in 1983, R. M. Marshall in 1984, and T. Brush in 1985); but because of the open nature of our plots and the ease of seeing birds, we assumed that observer-related biases were minimal. Because any observer-related bias should be expressed equally on all plots, we assumed that any such bias that did exist would not affect comparisons between plots. Censuses were conducted from late June through early September in 1982 (26 censuses), 1983 (35 censuses), 1984 (15 censuses), and 1985 (21 censuses).

Data Analysis

To analyze the effects of OMWM we compared bird numbers before and after alterations on the experimental plots and over a similar period on the control plots. We also compared within-year differences in bird numbers between altered and unaltered plots to see if OMWM affected relative ranking of plots by birds. The Kruskal-Wallis non-parametric test (Zar 1974) was used to determine if overall differences in bird abundance occurred among years or among plots. Box plots (Tukey 1977, McGill et al. 1978) were used in pairwise comparisons if the Kruskal-Wallis result was significant. Nonparametric statistics were used because data were not normally distributed and we had many zero counts (Hurlbert 1984).

Bird species were placed initially into 12 groups, based on foraging behavior, diet, nesting site, and

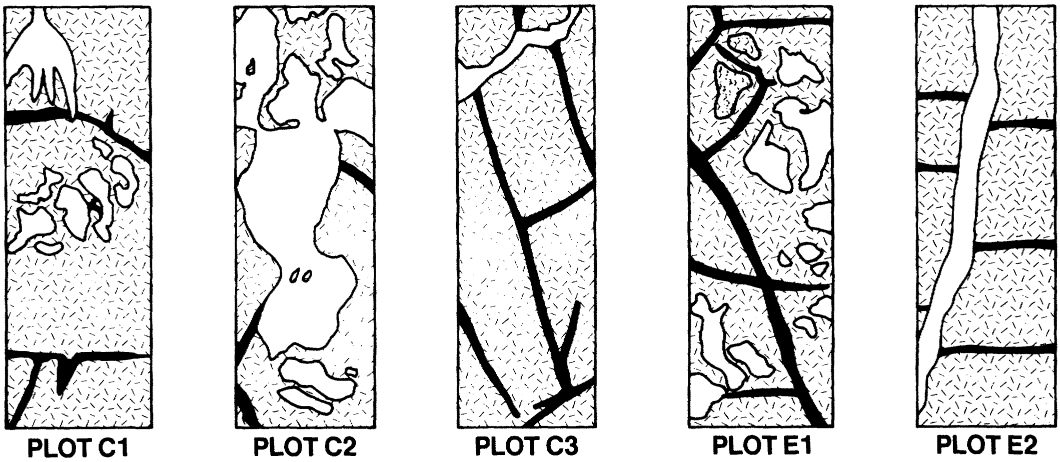

Figure. 2. Schematic illustration of ditches and pools on 3-hectare study plots located in northeastern Massachusetts, before alteration. Solid dark bars indicate ditches, and blank areas indicate natural creeks and pools. Other symbols as in Figure 1. See Hruby et al. (1985) for appearance of Plots E1 and E2 after alteration.

taxonomy. Five groups (raptors, gulls, waterfowl, rails, and cormorants) were ignored because of small sample sizes, and analyses were limited to the remaining seven groups. These groups included herons (species usually foraging in water, including both Ardeidae and Threskiornithidae), shorebirds (species usually foraging on mudflats or in shallow water, Charadriidae and Scolopacidae), aerial insectivores (species seeking prey in the air, Hirundinidae, Tyrannidae, and Apodidae), marsh passerines (species actually or potentially nesting in the marsh, mainly Fringillidae), upland passerines/insectivores (species foraging in the marsh but nesting in adjacent uplands, mainly Corvidae, Mimidae, Emberizidae [Parulinae], and Fringillidae), upland granivores/omnivores (blackbirds and starlings, mainly Emberizidae [Icterinae] and Sturnidae), and terns and kingfishers (including species scanning pools from air; Laridae [Sterninae] and Alcedinidae) See the Appendix for common and scientific names of the species.

RESULTS

Overall, OMWM had little effect on plot use by birds in the different groups (Table 1). Interplot differences in bird abundance were generally greater than interyear differences, with exceptions discussed below. OMWM temporarily affected plot use by members of some groups (see below), but by the end of the study numbers had returned to pre-alteration levels. Relative use of the experimental plots was affected little by OMWM. Pool-using groups (herons, shorebirds, and terns and kingfishers) were generally most abundant on Plot C2, which had the largest pool system, whereas marsh- and upland nesting groups made greatest use of one of the backwater plots (E1 or E2), regardless of alteration (Tables 2 and 3).

Herons showed yearly differences in numbers only on Plot C2 and were not affected by OMWM (Tables 1 and 2). Plot C2, a control plot with many pools, was used significantly more than other plots by herons in 1982, 1984 and 1985 (Table 2).

Aerial insectivores showed little yearly variation and were not affected by OMWM. Plot C1, a control plot with some pools, was used more than Plots E1 and E2 in 1983 (Table 2).

Terns and kingfishers, like species in most other groups, showed annual variation on Plot C2, and they were not affected by OMWM. Plot C2 was used more

Table 1. Effect of Open Marsh Water Management on abundance of birds in various groups. Plots are listed if abundance of birds in a particular group on that plot varied significantly among years[1].

	OMWM	Control
Not affected		
Herons and ibis	—	—
Aerial insectivores	—	—
Terns and kingfishers	—	—
Upland granivores/omnivores	—	—
Upland passerines/insectivores	E1	—
Declining, then recovering		
Marsh passerines	E1,E2	C1,C2,C3
Increasing, then declining		
Shorebirds	E2	

[1]Significant at $p < 0.05$ level using Box plots.

than all other plots in all years except 1984 (Table 2).

Table 2. Median number (per census) of birds in different foraging groups on control and experimental plots and statistical significance of differences[1].

Year	Plot[2] C1	C2	C3	E1	E2	K-W[3]
Herons						
1982	1	2	0	0	0	63.6*
1983	0	1	0	0	0	45.8*
1984	0	2	0	0	0	33.2*
1985	1	1	0	0	0	47.0*
K-W[4]	5.0	8.0	—	0	—	
Shorebirds						
1982	3	12	0	3	0[b]	74.8*
1983	6	10	0	7	4[a]	63.2*
1984	10	11	0	0	1	33.2*
1985	5	17	0	11	0[b]	75.0*
K-W[4]	8.0	4.3	2.7	5.1	53.4*	
Aerial insectivores						
1982	5	3	2	1	1	12.3
1983	5	2	5	1	1	31.2*
1984	3	0	1	2	0	5.2
1985	4	3	1	1	0	19.7
K-W[4]	3.6	15.1	7.7	8.6	4.2	
Marsh passerines						
1982	0[c]	0[c]	0[b]	1[b]	3[b]	55.6*
1983	1[b]	1[b]	1[a]	0[b]	3	90.1*
1984	0[c]	0[c]	0[b]	0[b]	5	34.9*
1985	3[a]	3[a]	1[a]	3[a]	6[a]	49.8*
K-W[4]	40.3*	35.3*	27.5*	60.7*	32.6*	
Upland passerines						
1982	0	0	0	1	0	29.8*
1983	0	0	0	1	0	33.7*
1984	0	0	0	2	0	43.0*
1985	0	0	0	2	1	36.2*
K-W[4]	1.9	11.3	9.0	22.7*	15.1	
Upland granivores/omnivores						
1982	0	0	1	1	4	35.6*
1983	0	0	1	4	1	47.5*
1984	0	0	2	4	6	32.0*
1985	0	0	0	2	2	14.5
K-W[4]	3.4	3.3	8.2	4.2	12.8	
Terns and kingfisher						
1982	0	3	0	0	0	89.6*
1983	0	2	0	0	0	136.8*
1984	0	0	0	0	0	25.5*
1985	0	2	0	0	0	75.5*
K-W[4]	3.1	14.4	—	2.7	3.6	

[1]p < 0.001 (shown by *) for Kruskal-Wallis statistic due to the large number of comparisons. If the Kruskal-Wallis statistic was significant, Box plots determined differences between all pairs of years.

[2]Alphabetic superscripts indicate medians which were significantly different from those with other superscripts (within each plot).

[3]Among plots comparison.

[4]Among years comparison.

Table 3. Summary of plot use by bird groups, 1982 through 1985. Values show the number of times a group was most abundant on that plot. Each year was analyzed separately because of the possible effects of OMWM or other factors.

	Plot[1] C1	C2	C3	E1	E2
Pool-dependent groups					
Herons	1	3	0	0	0
Shorebirds	1	2	0	0	0
Terns and kingfisher	0	3	0	0	0
Summarys					
Before OMWM (1982)	0	3	0	0	0
After OMWM (1983-5)	2	5	0	0	0
Other groups					
Aerial insectivores	1	0	0	0	0
Marsh passerines	0	0	0	0	4
Upland passerines	0	0	0	4	1
Upland granivores	0	0	0	1	1
Summary					
Before OMWM (1982)	0	0	0	1	1
After OMWM (1983-5)	1	0	0	4	5
Summary for all groups					
Before (1982)	0	3	0	1	1
After (1983-1985)	3	5	0	4	5

[1]Pool coverage: C1=8%, C2=50%, C3=<1%, E1=6%, E2=<1%.

Upland granivores/omnivores also showed little annual variation and were not affected by OMWM. This group made greater use of the experimental plots than the control plots, especially in 1984 and 1985 (Table 2).

Numbers of upland passerines varied significantly on one of the experimental plots, but not in a way which suggests that they were affected by OMWM (Table 2). Upland passerines consistently were most abundant on Plot E1 (an OMWM plot with existing pools).

Marsh passerines temporarily decreased in response to OMWM, but their numbers also varied on a more widespread basis, across all plots. Marsh passerines were generally most abundant on all plots in 1985, with a secondary peak in 1983 on the control plots (Table 2). In contrast to their abundance on the control plots in 1983, marsh passerines were absent from Plot E1 in 1983, the first year after alteration. They began to recover in 1984, and by 1985 they exceeded pre-alteration numbers on Plot E1. On Plot E2, changes in marsh-passerine abundance are difficult to distinguish from those occurring on control plots. There was no decline in 1983 or 1984 on this plot, and marsh passerines used Plot E2 significantly more than all other plots in every year.

Shorebirds immediately responded to OMWM alterations by increasing on Plot E2, the heavily-ditched OMWM plot (Table 2). Shorebird numbers on Plot E2 were higher immediately after OMWM (1983) than before OMWM (1982). By the end of the study (1985), numbers were back to pre-alteration levels on Plot E2. Shorebird numbers on Plot E1 were not affected by OMWM and remained at their high pre-alteration levels. Relative use of study plots was dependent on pool abundance. Shorebirds made greatest use of Plot C2 in all years except 1984, when they made greatest use of Plot C1. Shorebirds made least use of Plots C3 (control ditched plot) and E2 (OMWM ditched plot). These plots consistently had the lowest numbers of shorebirds, except for the temporary increase on plot E2 because of OMWM.

In this context, foraging behavior refers to locations chosen by foraging or resting birds within study plots. Because in >95% of all observations birds were foraging, patterns of habitat use can be interpreted as foraging locations. Because we were interested in identifying the major features of the salt marsh, which were used by the different groups, we lumped observations from all plots.

Groups showed three major patterns of habitat use. Herons and ibis, shorebirds, and terns and kingfishers all foraged predominantly in pools (Fig. 3). Many of the shorebirds were observed foraging in shallow water or on mudflats at the edges of pools, while herons and terns mainly foraged in deeper water. Shorebirds and herons foraged to a lesser extent in "other" locations, mainly creek or ditch edges. Marsh passerines, upland passerines/insectivores and upland granivores/omnivores all were observed >90% of the time in vegetation, whereas aerial insectivores foraged in the air >85% of the time.

DISCUSSION

Contrary to results of earlier studies (Ferrigno 1970, Shisler and Schultze 1976,

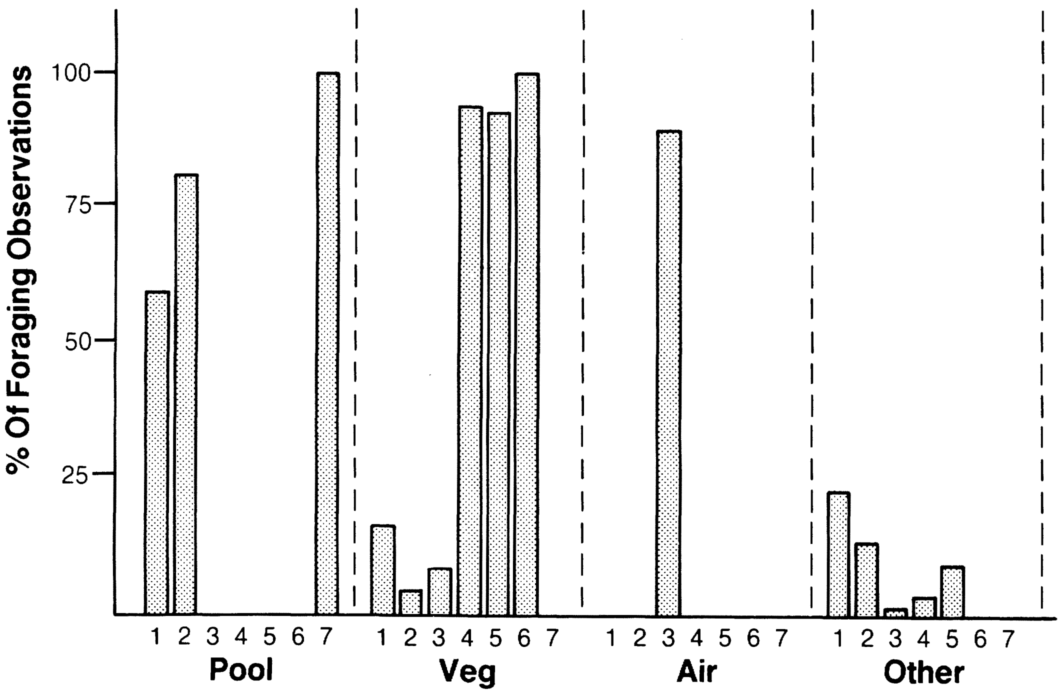

Figure 3. Foraging locations used by members of seven bird groups in five salt marsh plots in northeastern Massachusetts. 1=Herons and ibis (n=91 foraging observations), 2=Shorebirds (n=768), 3=Aerial insectivores (n=669), 4=Marsh passerines (n=473), 5=Upland passerines (n=305), 6=Upland granivores/omnivores (n=4034), 7=Terns and kingfisher (n=97). Pool=foraging in or at immediate edge of natural pools, Veg=foraging in marsh vegetation, Air=foraging in air above marsh, and Other=combined observations in ditches, creeks or spoil piles.

Burger and Shisler 1978), OMWM had little effect on the abundance of avian groups on our two experimental plots. Most pool-using groups (herons, shorebirds and terns) consistently used plots with pools, regardless of habitat alteration. This result is not surprising because the modified OMWM we employed did not actually create any pools, at least in the short term, that were suitable for these groups. The OMWM reservoirs and radials employed here were narrower and deeper than most pools used by foraging herons and terns (Brush, unpub. data). The edges of OMWM "pools" were probably unsuitable for shorebirds because they are steep-sided and there is no exposed or nearly-exposed mud, the microhabitat used by most shorebirds on Plots C1, C2 and E1. The short-term increase in shorebird numbers on the formerly ditched OMWM plot (E2) was probably due to the thin layer of exposed spoil left after construction of OMWM reservoirs and radials. As the spoil was covered by regrowing vegetation, shorebirds on Plot E2 decreased to pre-alteration numbers.

The effect of OMWM on other groups was either negative in the short term (marsh passerines) or non-existent (upland passerines, upland granivores/omnivores and aerial insectivores). Two factors may have contributed to the temporary decline in numbers of marsh passerines on Plot E1: 1) the removal or covering of marsh vegetation, which was their primary foraging location (Fig. 3), and 2) the presence of machinery on the marsh during early June, in the early breeding season. Both interpretations are supported by the resurgence of marsh passerines on Plot E1 in 1984 and 1985 (Table 2).

OMWM, as modified in this study, appears to neither greatly enhance nor greatly reduce habitat quality for groups of birds using the marsh for breeding or foraging. Several studies in New Jersey (Burger et al. 1977, Burger and Shisler 1978, 1979) found OMWM to have little effect on colonially-nesting species, but ours is one of the few studies to consider the effects of OMWM on all birds using salt marshes in the summer (Burger et al. 1982). Our data confirm both the value of pools and the negative effects of grid-ditching observed by Clarke et al. (1984) in New England and by many studies in the Mid-Atlantic states (Ferrigno and Jobbins 1968, Daiber 1974). The plot with the greatest coverage by pools (Plot C1) had the greatest numbers of pool-using birds, and plots with extensive, well-maintained grid-ditch systems had few pools and few pool-using birds. The data, collected within three years after alteration, suggest that OMWM is an improvement over traditional grid-ditching as a method of controlling salt marsh mosquitoes. However, the method as modified in New England (Hruby et al. 1985) may not be suitable as a habitat restoration technique. We are hopeful that pools will naturally reform due to the high water levels maintained on our study plots, but we also suggest that marsh managers consider the creation of wider pools with sloping sides, which will provide foraging sites for birds as well as refuges for small marsh fishes.

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APPENDIX

Sixty-one bird species seen during the study are grouped on the basis of foraging behavior, diet and breeding location.

Herons and Ibis: American Bittern (*Botaurus lentiginosus*), Great Blue Heron (*Ardea herodias*), Great Egret (*Casmerodius albus*), Snowy egret (*Egretta thula*), Little Blue Heron (*Egretta caerulea*), Tricolored heron (*Egretta tricolor*), Green-backed Heron (*Butorides striatus*), Black-crowned Night-Heron (*Nycticorax nycticorax*), Yellow-crowned Night-Heron (*Nycticorax violaceus*), Glossy Ibis (*Plegadis falcinellus*).

Shorebirds: Black-bellied Plover (*Pluvialis squatarola*), Semipalmated Plover (*Charadrius semipalmatus*), Killdeer (*Charadrius vociferus*), Greater yellowlegs (*Tringa melanoleuca*), Lesser Yellowlegs (*Tringa flavipes*), Solitary Sandpiper (Tringa solitaria), Spotted Sandpiper (*Actitis macularia*), Ruddy Turnstone (*Arenaria interpres*), Semipalmated Sandpiper (*Calidris pusilla*), Least Sandpiper (*Calidris minutilla*), White-rumped Sandpiper (*Calidris fuscicollis*), Pectoral Sandpiper (*Calidris melanotos*), Curlew Sandpiper (*Calidris ferruginea*), Stilt Sandpiper (*Calidris himantopus*), Ruff (*Ehilomachus pusnax*), Short-billed Dowitcher (*Limnodromus griseus*).

Aerial Insectivores: Eastern Phoebe (*Sayornis phoebe*), Eastern Kingbird (*Tyrannus tyrannus*), Chimney Swift (*Chaetura pelagica*), Purple Martin (*Progne subis*), Tree Swallow (*Tachycineta bicolor*), Northern Rough-winged Swallow (*Stelgidopteryx serripennis*), Bank Swallow (*Riparia riparia*), Cliff Swallow (*Hirundo pyrrhonota*), Barn Swallow (*Hirundo rustica*).

Marsh Passerines: Marsh Wren (*Cistothorus palustris*), Savannah Sparrow (*Passerculus sandwichensis*), Sharp-tailed Sparrow (*Ammodramus caudacutus*), Seaside Sparrow (*Ammodramus maritimus*), Swamp Sparrow (*Melospiza georgiana*).

Upland Passerines/Insectivores: Northern Flicker (*Colaptes auratus*), American Crow (*Corvus brachyrhynchos*), American Robin (*Turdus migratorius*), Northern Mockingbird (*Mimus polyglottos*), Brown Thrasher (*Torostoma rufum*), Cedar Waxwing (*Bombycilla cedrorum*), Yellow Warbler (*Dendroica petechia*), Common Yellowthroat (*Geothlypis trichas*), Song Sparrow (*Melospiza melodia*), Eastern Meadowlark (*Sturnella magna*), American Goldfinch (*Carduelis tristis*).

Upland Granivores/Ommivores: Mourning Dove (*Zenaida macroura*), European Starling (*Sturnus vulgaris*), Bobolink (*Dolichonyx oryzivorus*), Red-winged Blackbird (*Agelaius phoeniceus*), Common Grackle (*Quisculus quiscula*), Brown-headed Cowbird (*Molothrus ater*), House Sparrow (*Passer domesticus*).

Terns and Kingfisher: Belted Kingfisher (*Ceryle alcyon*), Common Tern (*Sterna hirundo*), Least Tern (*Sterna antillarum*).