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AVIAN USE OF PURPLE LOOSESTRIFE DOMINATED HABITAT RELATIVE TO OTHER VEGETATION TYPES IN A LAKE HURON WETLAND COMPLEX

MICHAEL B. WHITT,[1,3,4] HAROLD H. PRINCE,[1] AND ROBERT R. COX, JR.[2]

ABSTRACT.—Purple loosestrife (*Lythrum salicaria*), native to Eurasia, is an introduced perennial plant in North American wetlands that displaces other wetland plants. Although not well studied, purple loosestrife is widely believed to have little value as habitat for birds. To examine the value of purple loosestrife as avian breeding habitat, we conducted early, mid-, and late season bird surveys during two years (1994 and 1995) at 258 18-m (0.1 ha) fixed-radius plots in coastal wetlands of Saginaw Bay, Lake Huron. We found that loosestrife-dominated habitats had higher avian densities, but lower avian diversities than other vegetation types. The six most commonly observed bird species in all habitats combined were Sedge Wren (*Cistothorus platensis*), Marsh Wren (*C. palustris*), Yellow Warbler (*Dendroica petechia*), Common Yellowthroat (*Geothylpis trichas*), Swamp Sparrow (*Melospiza georgiana*), and Red-winged Blackbird (*Agelaius phoeniceus*). Swamp Sparrow densities were highest and Marsh Wren densities were lowest in loosestrife dominated habitats. We observed ten breeding species in loosestrife dominated habitats. We conclude that avian use of loosestrife warrants further quantitative investigation because avian use may be higher than is commonly believed. *Received 27 May 1998, accepted 26 Aug. 1998.*

Purple loosestrife (*Lythrum salicaria*) is an exotic, broad-leaved, herbaceous perennial that is common in North American freshwater wetland habitats north of 35° N latitude (Thompson 1989). Loosestrife is native to Eurasia where it occurs in freshwater marshes, open stream margins, and alluvial floodplains; it invades similar habitats in North America (Thompson 1989). Common plant associates of loosestrife in North American wetland habitats such as cattails (*Typha* spp.), reed canary grass (*Phalaris arundinacea*), sedges (*Carex* spp.), and rushes (*Juncus* spp.) closely resemble its associates in Eurasian wetlands (Thompson et al. 1987). Loosestrife out competes and partially or completely replaces native emergent vegetation (Thompson 1989). Loosestrife often pioneers in disturbed areas such as drainage ditches (Wilcox 1995) and displaces moist-soil species such as smartweeds (*Polygonum* spp.) and millets (*Panicum* spp.) on mudflats (Thompson et al. 1987). Species of wetland plants become distributed along a wetland gradient and are good indicators of long-term hydrology and other abiotic factors (Keddy and Reznicek 1985). Wetland vegetation types generally grade from forested wetland to shrub-scrub, to wet meadow, to strand (or mudflat), to emergent marsh, and finally, to open water (Cowardin et al. 1979, Keddy and Reznicek 1985). Loosestrife occupies zones near the strand including emergent and wet meadow zones.

Avian use of loosestrife is not well studied (Thompson et al. 1987). Prince and Flegel (1995) found no records in the literature of loosestrife as avian food or nesting habitat in Lake Huron wetlands. In New York wetlands, Rawinski and Malecki (1984) observed that Marsh Wrens (*Cistothorus palustris*) preferred cattail for nesting, whereas Red-winged Blackbirds (*Agelaius phoeniceus*) preferred loosestrife for nesting. Rawinski and Malecki (1984) also noted that Black-crowned Night-herons (*Nycticorax nycticorax*) roosted in loosestrife, and Pied-billed Grebes (*Podilymbus podiceps*) nested in one- and two-year-old emergent loosestrife stands. Kiviat (1996) found 15 American Goldfinch (*Carduelis tristis*) nests in loosestrife during a 23-year study of birds in the Hudson Valley. Swift and coworkers (1988) observed Least Bitterns (*Ixobrychus exilis*) and other birds in Hudson River wetlands that consisted of cattail, river bulrush (*Scirpus fluviatilis*), loosestrife, and common reed (*Phragmites australis*).

[1] Michigan State Univ., Dept. of Fisheries and Wildlife, East Lansing, MI 48824.
[2] Northern Prairie Wildlife Research Center, 8711 37th Street SE, Jamestown, ND 58401.
[3] Present address: Svoboda Ecological Resources, 2477 Shadywood Road, Excelsior, MN 55331; E-mail: michael_whitt@hotmail.com
[4] Corresponding author.

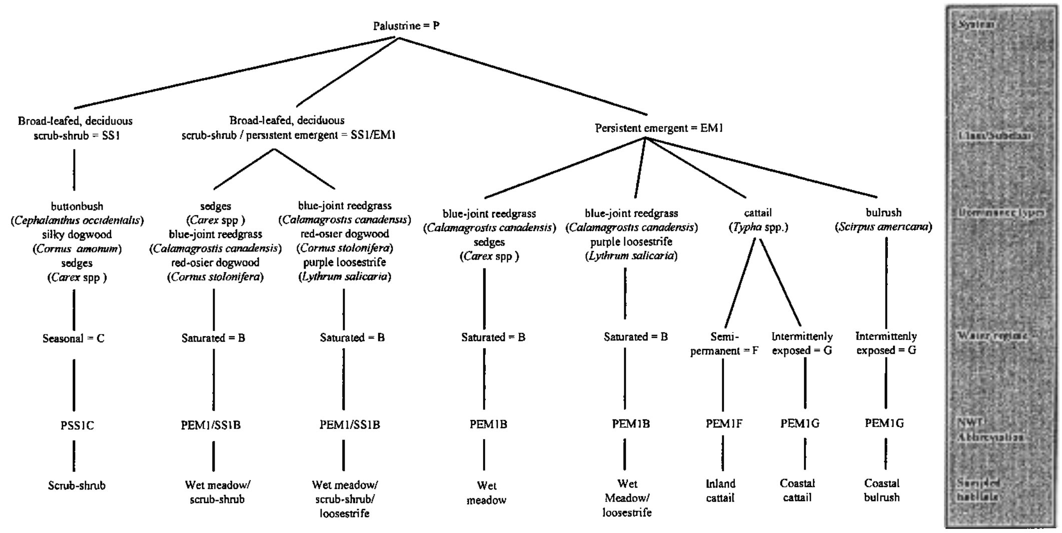

FIG. 1. Characteristics of surveyed vegetation types in Saginaw Bay wetlands, 1994–1995, based on National Wetlands Inventory (Cowardin et al. 1979) classification system. PSS1C = Palustrine, broad-leafed deciduous scrub-shrub, and seasonally flooded; PEM1/SS1B = Palustrine, persistent emergent/broad-leafed deciduous scrub-shrub, and saturated; PEM1B = Palustrine, persistent emergent, and saturated; PEM1F = Palustrine, persistent emergent, and semi-permanently flooded; PEM1G = Palustrine, persistent emergent, and intermittently exposed (Cowardin et al. 1979).

Minnesota established the first statewide loosestrife control program in 1987 with the goal of broadening public awareness, conducting inventories, developing control methods, and initiating control work (Skinner et al. 1994). Minnesota has spent $US 1.75 million since the beginning of the program (Skinner, pers. comm.). Other state and federal agencies also have spent considerable money and effort to control loosestrife, in part, because wildlife values of this plant are widely regarded to be limited. Methods of control have included use of chemicals, water manipulation, mowing, tillage, planting robust mudflat species such as Japanese millet (Thompson 1989), and, most recently, biological control using insects (Malecki et al. 1993).

Our objective was to compare avian use of vegetation zones dominated by loosestrife with other wetland zones where loosestrife was absent or not dominant. Comparison of avian breeding species richness, density, and diversity is a necessary first step to assess the value of loosestrife-dominated habitats to birds, and ultimately to evaluate costs and benefits of loosestrife control.

METHODS

We conducted field work during 1994 and 1995 in Bay, Tuscola, and Huron counties adjacent to Saginaw Bay, Lake Huron, Michigan. Saginaw Bay comprises the majority of remaining wetland habitat on Lake Huron because unsuitable shore morphology (e.g., cliffs) prohibited wetland formation, and development pressures (mostly agricultural) eliminated presettlement wetland habitats (Prince and Flegel 1995). Although this area has experienced a 50% overall wetland loss (Dahl 1990), 70% of inland wetlands and 99% of lakeplain prairies have been drained and converted to other uses (Comer 1996). Most existing Saginaw Bay wetlands are disturbed by adjacent urban and agricultural development, diking, and exotic flora and fauna.

We surveyed birds on 18-m fixed-radius plots in eight vegetation types based on hydrology and plant form and structure: scrub-shrub, wet meadow/scrub-shrub, wet meadow/scrub-shrub/loosestrife, wet meadow, wet meadow/loosestrife, inland cattail, coastal cattail, and coastal bulrush (*Scirpus* spp.). Our habitat classifications were based on Cowardin and coworkers (1979); dominant plants had greater than 30% cover (Fig. 1). We used a split class (e.g., broad-leafed deciduous scrub-shrub/persistent emergent; National Wetlands Inventory) to classify two vegetation types because scattered shrubs of at least 30% cover were present. We separated cattail sites into coastal and inland because hydrologies differed; coastal sites were

TABLE 1. Mean cover (Robel) height (cm) ± SE and mean water depth (cm) ± SE by period and vegetation type in Saginaw Bay wetlands, 1994–1995.

	Period 1		Period		Period 3	
Year and site[a]	Cover height	Water depth	Cover height	Water depth	Cover height	Water depth
1994 SS	27.8 ± 4.3	27.5 ± 0.9	55.0 ± 5.9	12.1 ± 3.2	75.7 ± 8.1	25.4 ± 2.9
1995 SS	35.8 ± 3.4	24.4 ± 0.8	68.8 ± 4.3	14.4 ± 0.7	74.6 ± 5.5	1.9 ± 0.6
1994 WM/SS	—[b]	—	62.8 ± 4.2	saturated	56.7 ± 3.5	saturated
1995 WM/SS	24.4 ± 4.1	0.2 ± 0.2	67.8 ± 7.8	saturated	100.8 ± 8.7	saturated
1994 WM/SS/LS	—	—	107.5 ± 11.0	saturated	101.1 ± 3.9	saturated
1995 WM/SS/LS	30.0 ± 8.5	saturated	48.9 ± 4.2	saturated	87.8 ± 9.5	0.5 ± 1.7
1994 WM/LS	—	—	84.4 ± 8.8	saturated	106.7 ± 8.2	2.2 ± 0.4
1995 WM/LS	38.9 ± 4.8	saturated	63.3 ± 3.3	saturated	87.8 ± 6.4	saturated
1994 WM	—	—	81.7 ± 5.1	0.3 ± 0.2	83.9 ± 2.6	1.8 ± 0.8
1995 WM	30.6 ± 2.6	saturated	61.1 ± 4.3	saturated	68.3 ± 6.7	saturated
1994 IC	80.0 ± 3.2	29.9 ± 2.0	70.7 ± 4.1	21.0 ± 1.7	110.6 ± 7.2	26.4 ± 1.4
1995 IC	41.4 ± 6.6	17.1 ± 3.4	52.4 ± 9.0	13.3 ± 2.5	94.8 ± 6.4	7.7 ± 1.9
1994 CC	—	—	71.2 ± 7.5	22.0 ± 2.6	144.3 ± 8.2	31.6 ± 2.4
1995 CC	60.3 ± 4.7	9.1 ± 1.4	82.2 ± 6.3	12.5 ± 1.5	127.9 ± 8.3	22.2 ± 1.7
1994 CB	—	—	11.3 ± 3.4	33.5 ± 1.4	34.7 ± 5.5	36.8 ± 1.2
1995 CB	—	—	8.9 ± 2.7	23.7 ± 0.8	33.2 ± 3.6	30.1 ± 1.1

[a] Vegetation types: SS = scrub-shrub, WM/SS = wet meadow/scrub-shrub, WM/SS/LS = wet meadow/scrub-shrub/loosestrife, WM/LS = wet meadow/loosestrife, WM = wet meadow, IC = inland cattail, CC = coastal cattail, CB = coastal bulrush.
[b] Dashes (—) indicate insufficient or lack of data.

intermittently exposed, whereas inland sites were semipermanently flooded by groundwater and precipitation.

Sampling periods were divided into an early season during the second and third weeks of May, a midseason during the first and second weeks of June, and a late season during the last week of June and first week of July. We conducted surveys between sunrise and 10:00 EST. Surveys were not conducted if sustained winds exceeded 24 km/h or during heavy rain.

We selected plots using the following protocol: first, an azimuth was determined that traversed the habitat. The center of the first plot was placed at least 18 m from the outer boundary of the vegetation on that azimuth. The center of the next plot was 70 m from the first plot on the same azimuth. This procedure was continued until observers surveyed three or more plots or reached a different vegetation type. If fewer than 3 plots were established on the first azimuth, we established a second azimuth, approximately perpendicular to the first azimuth, that traversed the vegetation type and permitted plot placement at least 70 m from other plots. Plots were set on this azimuth in the same manner as on the first azimuth. Plots were placed in different locations at the same site among time periods to avoid resampling the same plots and recounting the same nests. Coastal bulrush plots were not surveyed during the first periods of each year because they lacked structure; new vegetative growth was not yet established and the previous year's growth was eliminated by ice action. Neither did we survey three vegetation types (wet meadow/scrub-shrub/loosestrife, wet meadow, wet meadow/loosestrife) during the first period of 1994. We surveyed 258 plots in 8 wetland habitats.

Observers waited 5 min for normal bird activity to resume after arriving at a survey plot. We recorded all birds seen or heard on plots during a 7-min observation period. We recorded flying birds if their flight originated or terminated within the plot and we tallied individual birds only once. We played tape-recorded calls (Peterson 1990) of five secretive species [American Bittern (*Botaurus lentiginosus*), Least Bittern, King Rail (*Rallus elegans*), Virginia Rail (*R. limicola*), and Sora (*Porzana carolina*)] during the last 3 min using portable cassette recorders (Johnson et al. 1981, Marion et al. 1981, Johnson and Dinsmore 1986). We played calls for 25–30 sec followed by 10 sec of silence. We measured water depth and vertical cover 4 m from the plot center at 0°, 120°, and 240° (Table 1). Observers measured vertical cover to the nearest 10 cm using a 2-m Robel pole placed at plot center and viewed while maintaining eye level 1 m above the water surface or ground level and looking back toward plot center (Higgins et al. 1994). Workers returned to plots later that day and searched the innermost 13-m radius (0.05 ha) portion for nests. A bird species was designated as breeding when nests or flightless young were observed in one or more periods or when adults were observed in two of three periods (Brown and Dinsmore 1986). A nest verified breeding status when eggs, young, or strong evidence of use such as egg shell fragments, down, or fecal sacs were present. We considered predated nests as breeding evidence when prey species could be determined. We also tallied species as breeding if they were observed within the sampled vegetation type but outside of plot boundaries on two of three visits.

We tallied breeding species richness (i.e., number of breeding species) for each vegetation type. We calculated avian diversities for each plot using the Shannon-

TABLE 2. Distribution of breeding birds by vegetation type in Saginaw Bay wetlands, 1994–1995. Breeding status based on observation of adults on at least two of three visits, or a nest or flightless young on at least one visit.

Species	SS[a]	WM/SS[a]	WM/SS/LS[a]	WM/LS[a]	WM[a]	IC[a]	CC[a]	CB[a]
Pied-billed Grebe[b]							X	X
American Bittern				X		X		
Least Bittern						X	X	
Canada Goose						X	X	
Wood Duck[b]	X							
American Black Duck	X							
Mallard	X	X	X	X	X	X		
Blue-winged Teal			X		X			
Redhead[b]						X		
Northern Harrier[b]		X						
Ring-necked Pheasant		X			X			
Virginia Rail	X		X	X		X	X	
Sora	X					X	X	
Common Moorhen/American Coot[c]						X	X	X
Forster's Tern[b]							X	
Black Tern[b]						X	X	
Northern Flicker	X							
Eastern Wood-pewee	X							
Willow Flycatcher		X						
Great Crested Flycatcher	X							
Eastern Kingbird	X				X			
Tree Swallow	X	X						
Sedge Wren		X	X		X			
Marsh Wren						X	X	
Gray Catbird	X	X						
Yellow Warbler	X	X	X					
Common Yellowthroat	X	X	X		X	X	X	
Rose-breasted Grosbeak	X							
Savannah Sparrow		X			X			
Song Sparrow	X	X						
Swamp Sparrow	X	X	X	X	X	X	X	
Bobolink		X						
Red-winged Blackbird	X		X	X	X	X	X	
Yellow-headed Blackbird							X	
Brewer's Blackbird	X							
Brown-headed Cowbird	X	X						
Baltimore Oriole	X							
American Goldfinch		X	X					
Total	20	15	9	5	9	13	13	2

[a] Vegetation types: SS = scrub-shrub, WM/SS = wet meadow/scrub-shrub, WM/SS/LS = wet meadow/scrub-shrub/loosestrife, WM/LS = wet meadow/loosestrife, WM = wet meadow, IC = coastal cattail, CB = coastal bulrush.
[b] Species observed within the sampled vegetation type but not on plots.
[c] American Coot and Common Moorhen were grouped together because these species were most often observed by call only and their calls are difficult to distinguish.

Weiner diversity index. Density was the number of birds (both sexes) observed on a plot multiplied by 10 to obtain density per hectare.

We used ANOVA (PROC GLM; SAS 1990; SAS 6.12 for Windows) to assess fixed effects of vegetation, period, year, and their interactions on avian density and diversity. Residuals were normally distributed, but variances were not homogeneous because we never observed some species in one or more habitats (resulting in means and variances of zero). However, the overall F-statistic from ANOVA is robust to violations in assumptions of homogeneous variances (Sokal and Rohlf 1981). Early-period observations were eliminated from all analyses because of missing data. We considered plots as the experimental units because we decided *a priori* to restrict our inference to Saginaw Bay wetlands. We used $\alpha = 0.05$ for all statistical comparisons. We initially analyzed fully specified models (all main effects and interactions included). We fitted each model using a backward, stepwise procedure by eliminating non-significant ($P > 0.05$) effects, beginning with highest-order interactions. Thus, our final models included only significant effects or interactions, and main effects or interactions contained in significant higher-order interactions. We used Fisher's protected least significant difference test to isolate differences among least-square means (LSMEANS, SAS 1990) for significant effects in the ANOVA (Milliken and Johnson 1984). We compared density and diversity of birds in loosestrife-dominated vegetation types (wet meadow/scrub-shrub/loosestrife and wet meadow/loosestrife) to those in other vegetation types using orthogonal contrasts (PROC GLM; SAS 1990), and estimated least-square means using estimate statements (PROC GLM; SAS 1990). We developed similar models for abundance of the six most commonly observed bird species: Sedge Wren (*Cistothorus platensis*), Marsh Wren, Yellow Warbler (*Dendroica petechia*), Common Yellowthroat (*Geothlypis trichas*), Swamp Sparrow (*Melospiza georgiana*), and Red-winged Blackbird.

Standard errors reported are for least-square means (SAS 1990). Because multiple comparison of means with heterogenous variances may be misleading (Sokal and Rohlf 1981), we further examined comparisons of non-zero means to means of zero using confidence intervals. For each mean of zero, we constructed a 90% upper confidence limit after assigning the highest standard deviation associated with any mean in the model. We then compared 90% lower confidence intervals for nonzero means to 90% upper confidence intervals for zero means; we considered failure of these intervals to overlap as statistically significant. Resulting confidence intervals for zero means are likely overestimated, yielding a conservative comparison. We note in tables instances where confidence interval comparisons did not corroborate multiple comparisons using Fisher's least significant difference test.

RESULTS

As the season progressed water depths at coastal sites (coastal cattail and coastal bulrush) increased and those at inland sites decreased while vertical cover generally increased at all sites (Table 1). We surveyed 258 plots and observed 39 breeding bird species in Saginaw Bay wetland habitats (Table 2). Six breeding species were observed in the sampled vegetation type, but not on survey plots: Pied-billed Grebe, Wood Duck (*Aix sponsa*), Redhead (*Aythya americana*), Northern Harrier (*Circus cyaneus*), Forster's Tern (*Sterna forsteri*), and Black Tern (*Chlidonias niger*). We also observed 10 species breeding in loosestrife dominated habitats (Table 2).

Marsh Wren ($n = 20$), Swamp Sparrow ($n = 16$), and Red-winged Blackbird ($n = 21$) were the most commonly observed nests on all plots (Table 3). We observed Mallard, Blue-winged Teal (*Anas discors*), Virginia Rail, and Red-winged Blackbird nests while traversing between plots in loosestrife-dominated vegetation zones, but not on the plots.

Avian density and diversity.—Our final model indicated that avian density differed only in relation to vegetation (ANOVA: $F = 14.45$, df = 7, 181, $P < 0.001$; Table 4). Avian density was higher (orthogonal contrast: $F = 8.87$, df = 1, 181, $P = 0.003$) in loosestrife-dominated vegetation types [46.9 ± 3.8 (SE) birds/ha] than in other vegetation types (34.7 ± 1.6). Avian diversity also differed only in relation to vegetation (ANOVA: $F = 12.76$, df = 7, 181, $P < 0.001$; Table 4). Avian diversity was lower (orthogonal contrast: $F = 4.74$, df = 1, 181, $P = 0.03$) in loosestrife-dominated vegetation types (0.42 ± 0.08) than in other vegetation types (0.60 ± 0.03). Effects of year, period, and all interactions were not significant ($P > 0.05$ for all tests) for both avian density and diversity. Scrub-shrub contained the highest bird species diversity and wet meadow/loosestrife and coastal bulrush the lowest (Table 4).

Species abundance.—The vegetation × period × year interaction was significant (ANOVA: $F = 2.34$, df = 7, 157, $P = 0.03$) in our initial Sedge Wren model. Thus, vegetation related differences in Sedge Wren abundance were not consistent among periods and years (Table 5). Within periods and years, Sedge Wren abundance did not differ (orthogonal contrasts: $P > 0.05$ for all tests) between loosestrife dominated vegetation types and other vegetation types.

Marsh Wren abundance differed among vegetation types (ANOVA: $F = 30.72$, df = 7, 181, $P < 0.001$; Table 5). Marsh Wren abundance was lower (orthogonal contrast: $F = 10.73$, df = 1, 181, $P = 0.001$) in loosestrife-dominated vegetation types (0 ± 1.8) than in other vegetation types (6.2 ± 0.7). Yellow Warbler abundance differed among vegetation types, but differences were not consistent between mid- and late periods (ANOVA: vegetation × period interaction, $F = 2.08$, df = 7, 173, $P = 0.048$; Table 5). The interaction was due to significantly higher ($P < 0.001$) numbers of Yellow Warblers observed in late period scrub-shrub compared

TABLE 3. Number of nests and percent of plots within vegetation types where nests of the three most commonly observed bird species were found in Saginaw Bay wetlands, 1994–1995.

Vegetation type[a]	Marsh Wren	Swamp Sparrow	Red-winged Blackbird	Total plots[b]
SS	0	4 (9%)	13 (30%)	43
WM/SS	0	2 (6%)	0	31
WM/SS/LS	0	2 (12%)	0	16
WM/LS	0	4 (27%)	0	15
WM	0	1 (4%)	3 (11%)	27
IC	8 (23%)	3 (8%)	5 (14%)	35
CC	12 (17%)	0	0	71
CB	0	0	0	20
Total nests	20	16	21	—

[a] Vegetation types: SS = scrub-shrub, WM/SS = wet meadow/scrub-shrub, WM/SS/LS = wet meadow/scrub-shrub/loosestrife, WM/LS = wet meadow/loosestrife, WM = wet meadow, IC = inland cattail, CC = coastal cattail, CB = coastal bulrush.
[b] Includes early, mid-, and late season surveys.

with mid-period scrub-shrub (Table 5). Yellow Warbler abundance did not differ (orthogonal contrast: $P > 0.05$ for both tests) between loosestrife-dominated and other vegetation types in either period. Common Yellowthroat abundance differed among vegetation types (ANOVA: $F = 6.04$, df = 7, 181, $P < 0.001$; Table 5). Common Yellowthroat abundance did not differ (orthogonal contrast: $F = 1.20$, df = 1, 181, $P > 0.05$) between loosestrife-dominated and other vegetation types.

Swamp Sparrow abundance differed among vegetation types (ANOVA: $F = 39.03$, df = 7, 180, $P < 0.0001$; Table 5) and between periods (ANOVA: $F = 6.88$, df = 1, 180, $P = 0.009$). Swamp Sparrow abundance was higher during the late period (19.1 ± 1.1 birds/ha) compared with the mid-period (15.2 ± 1.1 birds/ha). Swamp Sparrow abundance was higher (orthogonal contrast: $F = 133.06$, df = 1, 180, $P < 0.001$) in loosestrife-dominated vegetation types (36.0 ± 2.0) than in other vegetation types (10.8 ± 0.8). Swamp Sparrows accounted for 95% and 65% of the overall avian density at wet meadow/loosestrife and wet meadow/scrub-shrub/loosestrife plots, respectively. Abundance of Red-winged Blackbird differed among vegetation types, but differences were not consistent between mid- and late periods (ANOVA: vegetation × period interaction, $F = 2.14$, df = 7, 173, $P = 0.04$; Table 5). The interaction was due to significantly higher ($P < 0.001$) numbers of Red-winged Blackbirds observed in mid-period scrub-shrub compared with late period scrub-shrub (Table 5). Red-winged Blackbird abundance did not differ (orthogonal contrasts: $P > 0.05$ for both tests) between loosestrife dominated and other vegetation types in either period.

DISCUSSION

Weller and Spatcher (1965), Kantrud and Stewart (1984), and Burger (1985) concluded that plant form and structure, rather than taxonomic composition, play key roles in habitat selection by marsh-nesting birds. The structure of loosestrife consists of stout, wood-like persistent growth and herbaceous new growth, similar to shrubs. Overall, species richness in loosestrife was slightly lower than that in other vegetation types except coastal bulrush (Table 2). Scrub-shrub habitat contained the highest breeding species richness and diversity, but these values may be explained in part by the location of scrub-shrub as an ecotone between forest and emergent wetland. Several scrub-shrub breeding birds were not wetland-dependent species but instead birds of forest edge and gaps such as Northern Flicker (*Colaptes auratus*; Moore 1995), Eastern Wood-pewee (*Contopus virens*; McCarty 1996), Great Crested Flycatcher (*Myiarchus crinitus*; Lanyon 1997), and Brown-headed Cowbird (*Molothrus ater*; Lowther 1993).

Swamp Sparrow nests were most abundant in vegetation types where loosestrife was dominant (Table 3). Reinert and Golet (1986) determined that breeding Swamp Sparrows principally required shallow standing water, low (<1.5 m) dense cover, and elevated song-posts, similar to our loosestrife-dominated sites. Swamp Sparrows constructed nests using fine-stemmed sedges and grasses anchored

TABLE 4. Mean avian density (no./ha) ± SE, avian diversity (Shannon-Weaver) ± SE, and number of second and third period plots by (*n*) vegetation type in Saginaw Bay wetlands, 1994–1995.

Vegetation type[a]	*n*[b]	Density[c]	Diversity[c]
SS	30	51.33 ± 3.4 A	1.05 ± 0.08 A
WM/SS	19	38.95 ± 4.3 BC	0.63 ± 0.10 B
WM/SS/LS	13	44.62 ± 5.2 ABC	0.59 ± 0.12 B
WM/LS	12	49.17 ± 5.4 AB	0.22 ± 0.12 C
WM	21	39.52 ± 4.1 BC	0.62 ± 0.09 B
IC	23	41.74 ± 3.9 ABC	0.74 ± 0.09 B
CC	51	36.27 ± 2.6 C	0.56 ± 0.06 B
CB	20	0.5 ± 4.2 D	0 C

[a] Vegetation types: SS = scrub-shrub, WM/SS = wet meadow/scrub-shrub, WM/SS/LS = wet meadow/scrub-shrub/loosestrife, WM/LS = wet meadow/loosestrife, WM = wet meadow, IC = inland cattail, CC = coastal cattail, CB = coastal bulrush.
[b] Excludes early period surveys because of missing data.
[c] Means within columns followed by the same letter do not differ ($P > 0.05$) as determined by ANOVA and Fisher's least significant difference.

in persistent loosestrife stalks. We also observed Mallard, Blue-winged Teal, Virginia Rail, and Red-winged Blackbird nests at our loosestrife-dominated sites, and found American Bittern, Sedge Wren, Yellow Warbler, Common Yellowthroat, and American Goldfinch breeding based on our criteria. Pied-billed Grebe (Rawinski and Malecki 1984), Least Bittern (Swift et al. 1988), Red-winged Blackbird (Rawinski and Malecki 1984), and American Goldfinch (Kiviat 1996) were observed nesting in loosestrife habitats previous to this study.

Rawinski and Malecki (1984) observed that Marsh Wrens preferred cattail habitats, but Red-winged Blackbirds preferred loosestrife habitats. We also found that nesting Marsh Wrens used cattail habitats, but we observed Red-winged Blackbird nests most frequently in scrub-shrub zones (Table 5). Inconsistencies in vegetation type, period, and year effects (i.e., significant three-way interaction) on Sedge Wren abundance may reflect this species' variable breeding site selection (Table 5). Burns (1982) observed that Sedge Wrens show little site fidelity; this characteristic may be due to the ephemeral nature of wet meadow habitats (Kroodsma and Verner 1978). We believe that Sedge Wren abundance may decline as loosestrife increases in wet meadow canopies. We observed greater areal cover of loosestrife at the wet meadow/loosestrife site compared with the wet meadow/scrub-shrub/loosestrife site and Sedge Wren abundance was significantly higher in two of four sampling periods at the site with less loosestrife (Table 5).

The avian diversity in loosestrife dominated habitats was lower on average than that of other wetland habitats that we surveyed, indicating uneven distributions of fewer species. We found higher avian densities in loosestrife-dominated habitats compared to other vegetation types, although Swamp Sparrows comprised the majority of overall density in loosestrife habitats. Swamp Sparrows accounted for 59% of the overall wet meadow density. Swamp Sparrow densities reported in other studies ranged up to 8.78 individuals/ha (Mowbray 1997) and are considerably lower than our densities in several vegetation types. We observed a significant increase in Swamp Sparrow density between mid- and late periods, which may be explained, in part, by the addition of juveniles from early nests (Peck and James 1987, Beaver 1991, Mowbray 1997). Swamp Sparrows prefer open wetlands of sedges, grasses (i.e., wet meadow), and cattail during the breeding season (Beaver 1991, Mowbray 1997). Principally, loosestrife occurs in the wet meadow, strand, and emergent portions of a typical wetland profile, which are the areas where Swamp Sparrows reach their highest abundance (Beaver 1991, Mowbray 1997).

Nesting female and young Swamp Sparrows satisfy their high protein requirements by consuming invertebrates. Wetherbee (1968) determined that 88% of Swamp Sparrow diets during spring and early summer consisted of insects. Arroll (1995) found that aquatic invertebrate abundance in loosestrife in central Washington was similar to that in cattail and bulrush. Arroll (1995) found only

TABLE 5. Mean density (no./ha) ± SE of the six most commonly observed bird species by vegetation type in Saginaw Bay wetlands, 1994–1995.

	Sedge Wren				
	1994		1995		
Vegetation type[a]	Period 2[b]	Period 3[b]	Period 2[b]	Period 3[b]	Marsh Wren[b]
SS	0 C	0 C	0 B	0 B	0 C
WM/SS	6.7 ± 1.6 B	3.0 ± 1.6 BC	0 B	10.0 ± 1.9 A	0 C
WM/SS/LS	10.0 ± 1.9 AB	0 C	6.7 ± 2.2 A[d]	3.3 ± 2.2 B	0 C
WM/LS	0 C	6.7 ± 2.2 B[c]	0 B	0 B	0 C
WM	13.3 ± 2.2 A	13.3 ± 1.6 A	3.3 ± 1.6 AB	3.3 ± 1.6 B	0.5 ± 1.9 C
IC	0 C	0 C	0 B	0 B	15 .6 ± 1.8 B
CC	0 C	0 C	0 B	0 B	20.6 ± 1.2 A
CB	0 C	0 C	0 B	0 B	0.5 ± 2.0 C

[a] Vegetation types: SS = scrub-shrub, WM/SS = wet meadow/scrub-shrub, WM/SS/LS = wet meadow/scrub-shrub/loosestrife, WM/LS = wet meadow/loosestrife, WM = wet meadow, IC = inland cattail, CC = coastal cattail, CB = coastal bulrush.
[b] Means within columns followed by the same letter do not differ ($P > 0.05$) as determined by ANOVA and Fisher's least significant difference.
[c] Fisher's least significant difference multiple comparisons were not corroborated by 90% confidence interval comparisons with WM/SS/LS and IC (see METHODS).
[d] Fisher's least significant difference multiple comparison were not corroborated by 90% confidence interval comparisons with WM/SS and WM/LS (see METHODS).
[e] Fisher's least significant difference multiple comparison were not corroborated by 90% confidence interval comparisons with WM/LS (see METHODS).
[f] Fisher's least significant difference multiple comparisons were not corroborated by 90% confidence interval comparison with WM/SS, WM/LS, and CB (see METHODS).
[g] Fisher's least significant difference multiple comparisons were not corroborated by 90% confidence interval comparison with WM/SS, WM/LS, and CB (see METHODS).

nine statistically significant results in 111 individual comparisons of aquatic invertebrates associated with macrophyte stems (using stem vacuum), sediment (using sediment core), and the water column (using activity traps). Of the four statistically different comparisons involving loosestrife, two showed higher Diptera and Ostracoda abundance in cattail compared with loosestrife, and two showed higher Copepod abundance in loosestrife compared with cattail (Arroll 1995). Thus, invertebrate food items during the breeding season do not appear limiting in loosestrife habitat, although quantitative data from the Northeast are needed.

Loosestrife is an anathema to wetland managers because it often replaces seed-producing mudflat species managed to attract waterfowl. Water level manipulations such as early season drawdowns encourage loosestrife establishment (Thompson 1989). Loosestrife forms dense stands that are difficult for some bird species to negotiate and this may be especially true for larger birds such as waterfowl or species that walk on the ground such as bitterns and rails. Our study demonstrates that loosestrife may provide suitable habitat for some passerines.

Many researchers have observed that habitat diversity leads to faunal diversity in wetlands (Weller and Spatcher 1965, Weller and Fredrickson 1974, Weller 1978, Kantrud and Stewart 1984, Burger 1985). The highest avian density, diversity, and productivity in marshes occurs where emergent vegetation is interspersed 1:1 with open water (Weller and Spatcher 1965, Weller and Fredrickson 1974, Fredrickson and Reid 1988). Wetland managers manipulate vegetative interspersion in marshes using artificial drawdowns, muskrat management, and other means (Fredrickson and Reid 1988). Kaminski and Prince (1981) observed increased waterfowl density and diversity coincident with increased abundance, biomass, and diversity of macroinvertebrates in manipulated emergent wetland habitat. Our loosestrife sites contained few openings. We suspect that manipulated loosestrife habitat (to create interspersion) could result in higher bird diversity.

Loosestrife was widespread in Saginaw Bay coastal wetlands and dominated canopies at several sites. Although diversity was low, loosestrife provided nesting and brood rearing habitat to birds in Saginaw Bay wetlands where alternative habitat choices were available. Some species, such as Marsh Wren, may be disadvantaged as loosestrife displaces other plant forms (e.g., cattail and bulrush). Swamp Sparrows may prefer loosestrife habitat where

TABLE 5. Extended.

Yellow Warbler		Common Yellowthroat[b]	Swamp Sparrow[b]	Red-winged Blackbird	
Period 2[b]	Period 3[b]			Period 2[b]	Period 3[b]
9.3 ± 1.0 A	14.7 ± 1.0 A	2.7 ± 0.6 B[e]	11.3 ± 1.8 C	17.3 ± 1.8 A	6.0 ± 1.8 A[g]
3.3 ± 1.3 B	2.0 ± 1.2 B	5.3 ± 0.8 A	21.5 ± 2.3 B	0 C	0 B
2.8 ± 1.4 B	1.7 ± 1.6 B	1.5 ± 1.0 BC	27.8 ± 2.8 B	7.1 ± 2.7 B[f]	1.7 ± 2.9 AB
0 B	0 B	0 C	44.2 ± 2.9 A	0 C	0 B
0 B	0 B	1.4 ± 0.8 BC	21.2 ± 2.2 B	6.7 ± 2.4 B[f]	4.2 ± 2.0 AB
0.7 ± 1.0 B	0 B	0 C	9.6 ± 2.1 C	5.7 ± 1.9 BC	4.4 ± 2.4 AB
0 B	0 B	0.2 ± 0.5 C	1.5 ± 1.4 D	1.8 ± 1.4 BC	1.2 ± 1.4 B
0 B	0 B	0 C	0 D	0 C	0 B

nest-building materials (fine-stemmed grasses and sedges) are available. We conclude that avian use of loosestrife warrants further quantitative investigation because avian use may be higher than is commonly believed.

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