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AVIAN USE OF PURPLE LOOSESTRIFE (*Lythrum salicaria*)
IN SOUTHERN MICHIGAN WETLAND COMPLEXES

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AVIAN USE OF PURPLE LOOSESTRIFE (*Lythrum salicaria*) IN SOUTHERN MICHIGAN WETLAND COMPLEXES

By

Jason Dennis Hill

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ABSTRACT

AVIAN USE OF PURPLE LOOSESTRIFE (*Lythrum salicaria*) IN SOUTHRN MICHIGAN WETLAND COMPLEXES

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Purple loosestrife (*Lythrum salicaria*), a broad-leaved perennial native to Eurasia, is considered to have significantly altered native wetland flora and fauna since its introduction to North America in the 1800's and subsequent expansion. Detailed quantitative botanical descriptions of species composition and structure of wetlands containing purple loosestrife along with documentation of avian use is limited. We evaluated the impact of purple loosestrife on avian diversity and abundance by conducting early, mid, and late breeding bird surveys for three years (1997-1999) at sites containing purple loosestrife matched with a comparative reference site. Breeding birds were counted in 464 (0.1ha) circular survey plots. All plots were searched for nests and vegetation structure and plant species composition within census plots was measured. Mean vegetation diversity across purple loosestrife sites was not significantly different when compared with reference sites. Forty-one avian species used sites containing purple loosestrife at varying densities. Nests of 15 species were located. The relative recent invasion of the past 20 years of purple loosestrife in Michigan appears to be attracting a complex of avian species not previously documented.

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INTRODUCTION

Purple loosestrife (*Lythrum salicaria*), a broad-leaved perennial, native to Eurasia, was introduced to North America during the early 1800's (Thompson et al. 1987). Introduction from seeds transported in ship ballast and imported wool are believed to be the main sources of purple loosestrife stock in the northeastern United States (Thompson et al. 1987). Early records indicate that horticulturists and beekeepers also introduced purple loosestrife to be planted in gardens and cultivated sites (Thompson et al. 1987). Purple loosestrife occurs north of the 35th parallel and is currently established throughout most of the eastern U.S. and north into Canada (Stucky 1980, Thompson et al. 1987). It commonly occupies moist soil zones along roadside ditches, low wet meadows, marshes, and along edges of rivers and ponds (Shamsi and Whitehead 1974, Stucky 1980). In Michigan, purple loosestrife has been established since the mid to late 1980's in coastal wetlands, southern Michigan watersheds, and management floodings where traditional wetland management techniques for waterfowl have enabled the proliferation of purple loosestrife.

Purple loosestrife has been discounted as a wildlife food source and is believed to alter wetland vegetation structure, reducing its value as potential habitat (Thompson et al. 1987). It has also been proposed that purple loosestrife lacks natural predators in N. America, enabling it to outcompete native flora, thus reducing native plant diversity (Anderson 1995). Thompson et al. (1987) state that if optimal conditions are present, loosestrife has the potential to displace native moist soil annuals, resulting in a "virtual monotype" of purple loosestrife. The consensus among resource managers is that purple loosestrife has a detrimental impact on native wetland flora and fauna (Fernald 1940, Anderson 1995, Thompson et al. 1987, Thompson 1991, Rawinski and Malecki 1984).

A review of the published literature on purple loosestrife by Anderson (1995) indicates a wealth of contradictory and inconclusive evidence concerning the ecological and economic effects of purple loosestrife on N. American wetlands. Likewise, few quantitative studies exist that support the widely accepted yet untested hypothesis that purple loosestrife has deleterious effects on native wetland ecosystems (Hager and McCoy 1998). Determining significant relationships between purple loosestrife and native wetland flora and fauna is important in assessing the ecological and/or economic impacts of wetland management and biological control efforts.

Detailed quantitative botanical descriptions of the species composition and structure of wetlands containing purple loosestrife are few and limited in scope. During a study of purple loosestrife on the Bar River, Canada, Treberg and Husband (1998) reported that species richness was not significantly different in stands with or without purple loosestrife. Similar results, indicating a lack of correlation between loosestrife abundance and species richness, were reported by Anderson (1991). Rawinski and Malecki (1984) found no apparent trends in the relationship between purple loosestrife and cattail densities at the Montezuma National Wildlife Refuge in central New York. Further information concerning native plant species is needed to determine changes in community structure, rare species, and diversity associated with wetlands dominated by purple loosestrife.

Avian use of purple loosestrife has not progressed beyond the descriptive stages. Beyond observational studies, marginal amounts of quantitative data exist regarding avian use of purple loosestrife (Hager and McCoy 1998). Rawinski and Malecki (1984) provide evidence of purple loosestrife use by nesting Red-winged Blackbirds (*Agelaius phoeniceus*) in areas of high loosestrife density. Accordingly, a roosting colony of Black-crowned Night Herons (*Nycticorax nycticorax*) and nests of Pied-billed Grebes (*Podilymbus podiceps*) were also discovered in loosestrife stands (Rawinski and Malecki 1984). High densities of breeding Swamp Sparrows (*Melospiza georgiana*) were found using wet meadow/loosestrife and wet meadow/loosestrife/scrub-shrub habitats contrasted with significantly lower densities in wet meadow habitats in coastal wetlands of the Saginaw Bay, Michigan (Whitt et al. 1999). Whitt et al. (1999) also reported the use of purple loosestrife by the American Bittern (*Botaurus lentiginosus*), Mallard (*Anas platyrhynchos*), Virginia Rail (*Rallus limicola*), and Red-winged Blackbird. Kiviat (1996) found 15 American Goldfinch nests anchored in tall, robust clumps of purple loosestrife during a 23-year study in the Hudson Valley.

The purpose of this study was to determine if: (1) wetlands dominated by purple loosestrife have reduced plant taxa richness and diversity; (2) purple loosestrife alters the vegetation structure of wetlands and thus reduces nesting substrate available to breeding birds; and (3) there is a reduction in breeding bird density, richness, or diversity found on wetlands dominated by purple loosestrife.

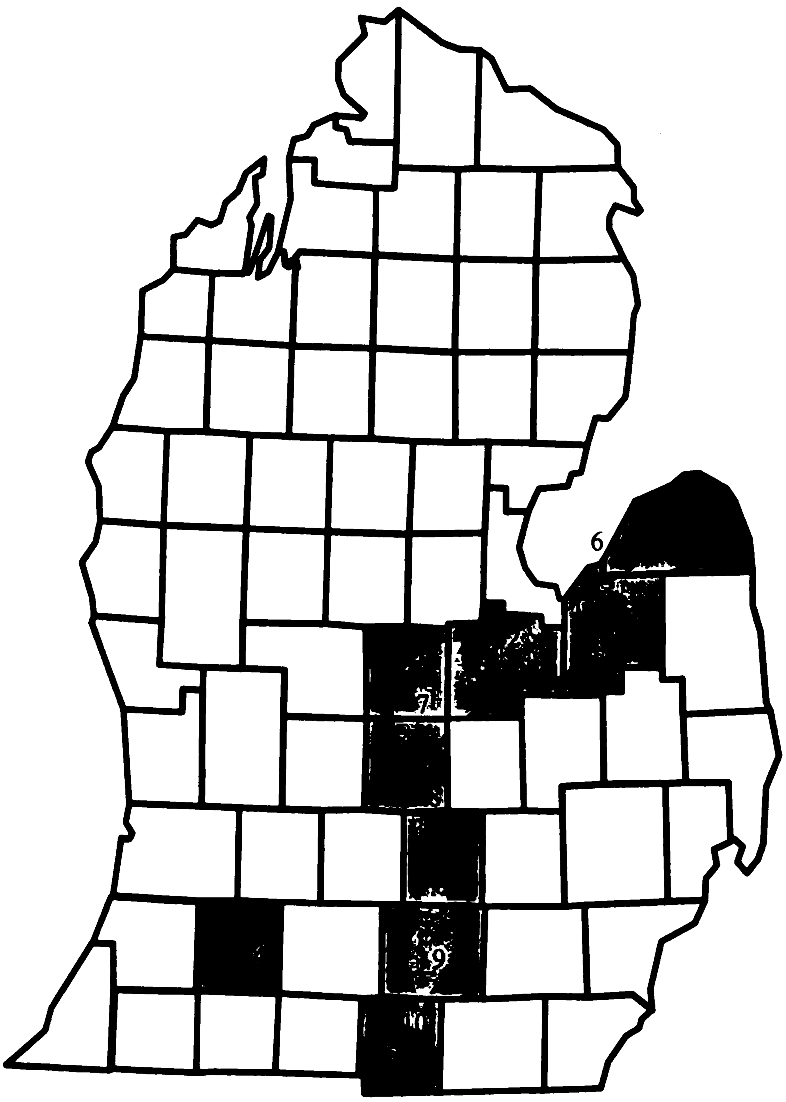
METHODS

Site Selection

Ten study sites located in the southern Lower Peninsula of Michigan were chosen on the basis of overall area, hydrogeomorphic characteristics, and dominance of purple loosestrife (Figure 1). Study sites sampled range from isolated inland marshes and wet meadows to riverine systems and coastal wetlands. Emergent and emergent/scrub-shrub zones were sampled at each site (Cowardin et al. 1979). Five sites, where emergent vegetation dominated by purple loosestrife (> 30% aerial cover) covered an area greater than 25 ha, were paired with five equal sized reference sites. Paired reference sites (lacking purple loosestrife) were chosen on the basis of their proximity and hydrogeomorphic similarities to purple loosestrife dominated sites.

Purple loosestrife Sites

Quanicassee State Game Area: This site is located in Tuscola County (T.14.N. R.7.E. sec.30), just north of M-25, approximately 16 Km east of Bay City, Michigan (Figure 1). Many vegetation zones including inland marsh, wet prairie, and scrub-shrub occur within this diked Saginaw Bay Lake Plain wetland (Albert 1995). Surveys were conducted in the same wet prairie zones sampled in 1994 and 1995 by Whitt et al. (1999). Plant taxa such as purple loosestrife, sedge (*Carex* spp.), blue-joint grass (*Calamagrosits canadensis*), and water smartweed (*Polygonum amphibium*) dominated.



Purple Loosestirfe	**Reference**
1 -Quanicassee	6 -Maisou Island
2 -Shiawassee	7 -Maple River
3 -Lake Lansing	8 -Rose Lake
4 -Morrow Lake	9 -Portage
5 -Boot Lake	10 -Somerset

Fig. 1. Location of study sites surveyed in Michigan.

Lake Lansing: This site is located in Ingham County (T.4.N. R.1.W. sec.2), just north of Lake Dr., approximately 0.2 Km west of the Lake Lansing public boat launch, within Lake Lansing Park North (Figure 1). This emergent wetland, visible from the road, has a wooden boardwalk and is readily accessible to the public. Purple loosestrife, sedge, and reed-canary grass (*Phalaris arundinacea*) are dominant plant taxa found at this site. It is believed that the introduction of purple loosestrife to this site was caused by an adjacent dike failure in 1981 that contained dredge spoils from Lake Lansing.

Boot Lake: This site is located in Hillsdale County (T.7.S. R.3.W. sec.1), north of Boot Lake on M-99, approximately 5 Km east of Hillsdale, Michigan (Figure 1). This emergent/scrub-shrub wetland is hydrologically connected to Boot Lake via a culvert running under M-99. The wetland is bordered by M-99 on the south and forested upland elsewhere. Dominant vegetation found at this site includes purple loosestrife, sedge, and spike rush (*Eleocharis* spp.).

Shiawassee State Game Area: This site, a managed green tree reservoir created by damming the Shiawassee River in the early 1950's, is located in Saginaw County (T.10.N. R.3.E. sec.2 and 3; T.11.N. R.3.E. sec.3), approximately 0.8 Km east of the Bad River boat launch at the end of St. Charles Rd. (Figure 1). Extensive flooding of the green tree reservoir is thought to have caused the conversion of forested zones in the 1980's into emergent/scrub-shrub vegetation dominated by purple loosestrife. Sampling was conducted in emergent/scrub-shrub zones along the Shiawassee River channels that meander through the impoundment. Dominant wetland plants found at this site include purple loosestrife, rice-cut grass (*Leersia oryzoides*), arrow arum (*Peltandra virginica*), and reed-canary grass.

Morrow Lake: This site is located in Kalamazoo County (T.2.S. R.10.W. sec.24), just west of 35th Street, 0.2 Km north of I-94, adjacent to the Kalamazoo River (Figure 1). This site is hydrologically connected to the Kalamazoo River and was created by the construction of the STS Hydropower dam near Kalamazoo City. Purple loosestrife, arrow arum, and reed-canary grass were the dominant taxa sampled within the emergent herbaceous wetland zones bordering the Kalamazoo River.

Reference Sites

Maisou and Middle Grounds Islands: This site is located on the Wildfowl Bay State Game Area in Huron County (T.17.N. R.7.E.), approximately 10 Km north of Sebewaing, Michigan (Figure 1). This site is hydrologically influenced by the water level of the Saginaw Bay of Lake Huron. Wet meadow zones of this reference site were sampled to contrast the impact of purple loosestrife at Quanicassee SGA. Dominant plant taxa include sedge and blue-joint grass.

Rose Lake State Game Area: This site is located in Clinton County (T.5.N. R.1.W. sec.14), just east of Upton Rd., approximately 0.8 Km north of Clark Rd., on the southern end of Corey Marsh (Figure 1). Dominant plant taxa found in this emergent wetland depression include reed-canary grass, great bur reed (*Sparganium eurycarpum*), sedge, and narrow-leaved cattail (*Typha angustifolia*).

Somerset State Game Area: This site is located on the southern most end of Lombard Lake at the Somerset SGA, in Hillsdale County (T.5.S. R.1.W. sec.22 and 23) (Figure 1). The emergent/scrub-shrub wetland zones that were sampled are part of the Somerset wildlife refuge, which is inaccessible to the public. Water levels at this site were the deepest where emergent and wet meadow vegetation formed a floating mat. Dominant plant taxa include spike rush and sedge.

Maple River State Game Area: This site is located approximately 15 Km north of St. Johns, Michigan, on I-27, in Gratiot County (T.9.N. R.2.W. sec. 28) (Figure 1). Wet meadow and cattail (*Typha* spp.) zones were sampled within Management Unit B. Water control structures dictate water levels within this diked wetland adjacent to the Maple River. Narrow-leaved cattail, reed-canary grass and sedge are dominant plant taxa found in this managed flooding.

Portage Marsh: This reference wetland found within Waterloo Recreation Area is located just east of Waterloo-Munith Rd., approximately 2 Km northwest of Reithmiller Rd., in Jackson County (T.1.S. R.2.E. sec.21, 22, 27, 28) (Figure 1). This wetland is part of the Portage Lake Swamp wetland complex, located northeast of Portage Lake. Dominant plant taxa found in this wet meadow/emergent wetland include sedge, reed-canary grass, and blue-joint grass.

Vegetation Structure and Composition

Vegetation was sampled on 18m (0.1 ha) fixed radius avian survey plots at each study site in 1998 and 1999 to characterize the composition and structure of wetlands dominated by purple loosestrife and reference wetlands. Survey plots were systematically located within each wetland (Figure 2). Each plot center was marked during the morning survey and all plots were revisited in the afternoon to sample vegetation. Four 50cm x 50cm ($0.25m^2$) quadrats were positioned 9m from the center of each avian survey plot at an azimuth of 0°, 90°, 180°, and 270°. Within each quadrat, ocular estimates of percent cover of herbaceous and woody vegetation were recorded on a taxon (species and genera) basis using the canopy coverage method containing the six cover classes of Daubenmire (1959). Species of the genera *Carex* and *Eleocharis* were grouped into their respective genera and treated similarly across study sites for comparison. Individual living stems were counted by taxon to determine density. A Robel Pole (2m in height) was used to provide visual obstruction measurements (VOM) taken at a standard height of 1m and at a distance of 4m at each quadrat (Robel et al. 1970). Facing outward from the plot center, the height at which 100 percent of the pole was obstructed was recorded to the nearest decimeter. Maximum vegetative height (cm) of live plant species was also recorded at the same position as visual obstruction measurements. Water levels were measured at the center of each quadrat to the nearest cm.

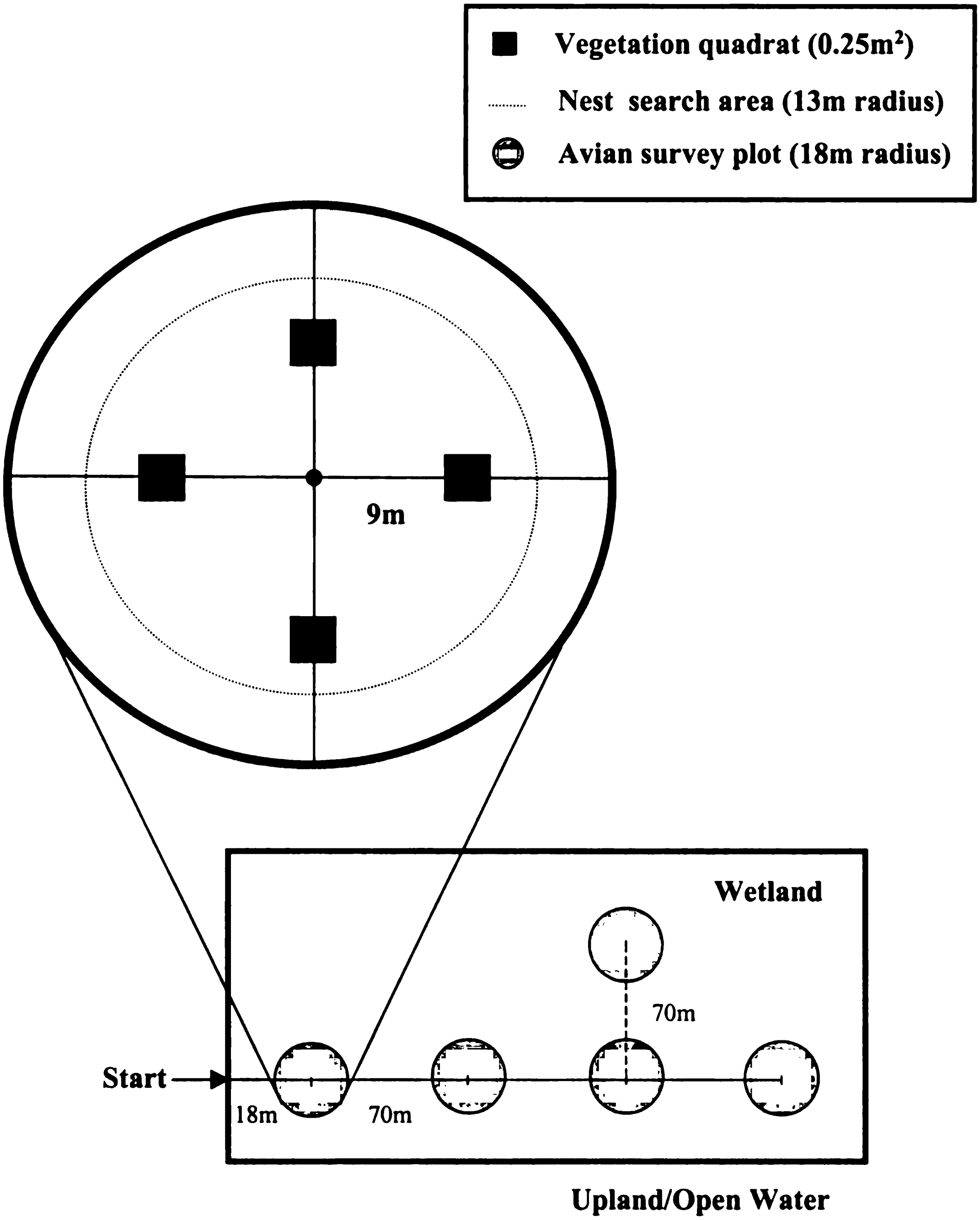


Fig. 2. Sampling protocol used for placement of 0.1 ha (18m radius) avian survey plots, 0.05 ha (13m radius) nest search areas, and 0.25m^2 vegetation quadrats within study sites.

Breeding Bird Surveys

Breeding bird surveys were conducted during three 2-week time periods for the 1997, 1998, and 1999 breeding seasons (Brewer et al. 1991). Quanicassee, Lake Lansing, and Shiawassee were the only study sites surveyed in 1997. Early season surveys began the second week of May while mid and late season surveys began the first and fourth weeks of June, respectively. A fixed-radius circular plot method was used to collect survey data between sunrise and 10:00 am (Brown and Dinsmore 1986, Reynolds et al. 1980).

The first circular plot of the survey was centered 18m from open water or upland vegetation and a pre-determined azimuth was used to traverse the stand of vegetation (Figure 2). The next plot was then centered 70m from the first plot following the original azimuth chosen to traverse the stand. Additional plots were located using the same method. If open water or upland vegetation was encountered, a new azimuth perpendicular to the last was implemented (Whitt et al. 1999). Four plots were chosen as a minimum number to be surveyed within a single stand of vegetation (Morrison 1981). The total number of plots surveyed at each site varied according to the area of the stand and weather conditions encountered (Table 1).

Once a plot was located, the survey began after a 5-minute wait period. Bird species were then recorded by sight and/or by call within the 18m plot for the next 7 minutes. All species within the plot were recorded to the nearest meter. Individual birds were recorded once and flying birds were recorded if flight originated or ended within the plot. Birds observed flying through a survey plot were also noted.

Recordings of secretive bird species such as the American Bittern, Least Bittern (*Ixobrychus exilis*), Yellow Rail (*Coturnicops noveboracensis*), Virginia Rail, and Sora

(*Porzana carolina*) were played the last two minutes of the observation period (Marion et al. 1981, Johnson and Dinsmore 1986). Sightings and calls for all birds, including secretive species, were recorded for a total of 7 minutes during each survey. Once all count periods were completed, each plot was revisited to conduct vegetation sampling and nest searches.

Table 1. Number of avian survey plots and vegetation quadrats sampled at each study site during the 1997-1999 breeding seasons.

		Period			Total	
Habitat	**Study Site**	**Early**	**Mid**	**Late**	**Survey Plots**	**Vegetation Quadrats**
Purple loosestrife	Quanicassee	22 (7)*	24 (8)*	22 (9)*	68 (24)*	176
	Lake Lansing	17 (5)*	19 (7)*	18 (6)*	54 (18)*	144
	Boot Lake	12	12	12	36	144
	Shiawassee	21 (6)*	24 (8)*	21 (5)*	66 (19)*	188
	Morrow Lake	12	12	11	35	140
Reference	Maisou Island	16	16	16	48	192
	Rose Lake	11	12	12	35	140
	Somerset	12	12	12	36	144
	Maple River	14	16	16	46	184
	Portage	8	16	16	40	160
	Total	**145 (18)***	**163 (23)***	**156 (20)***	**464 (61)***	**1612**

* Parentheses indicate the number of avian survey plots sampled in 1997.

Nest Searches

Nest searches were conducted on individual survey plots (0.1ha) following the completion of the morning survey. Nests were searched for by using a 13m (0.05 ha) fixed radius within the original 18m radius avian survey plot (Brown and Dinsmore 1986). The entire 0.05 ha area was searched by using 1.5m concentric circles, starting from the outermost circle inward. Active nests were identified by species and recorded in respect to location within a plot, vertical height above ground or water, and status. Active nests are those that included eggs, nestlings, or strong evidence of use including the presence of fledglings or family groups (Craig and Beal 1992). A species was considered breeding if an active nest, flightless young, or adults were observed during 2 out of 3 sampling periods (Brown and Dinsmore 1986). Vegetation height, water depth, vertical cover (VOM), canopy cover (measured with a spherical densiometer) (Lemmon 1959), nesting substrate, and nest material were recorded for each nest located.

Muskrat (*Ondatra zibethicus*) houses were located using the same protocol as that used for nest searches. While searching in 1.5m concentric circles for avian nests on 13m (0.05 ha) plots, the location of muskrat houses was recorded to the nearest meter. Plant material and substrate used for construction were also identified and recorded for each muskrat house.

Analysis

Importance values were calculated for each plant taxa observed within 0.25m^2 vegetation quadrats. These values are based on the sum of relative frequency, relative density, and relative dominance (percent cover) (Curtis 1959, Cain and Castro 1959). Importance values (maximum importance value =300) were averaged by survey plot at each study site.

Avian densities were calculated for each species on a survey plot basis and averaged across study site and habitat type (purple loosestrife or reference). Density was calculated by dividing the count of each species at a survey plot by 0.1 ha to obtain a density per hectare. Avian species observed and/or heard within a plot, excluding "flythrough" species, were used to determine density.

Vegetation and avian diversities were calculated using the Shannon Index of diversity (Shannon and Weaver 1949). The index (H′), which accounts for both the number of taxa and evenness (uniformity) of the distribution, was calculated as follows:

$$H' = -\sum_{n=1}^{S} (p_n) \ln(p_n)$$

where p_n denotes the proportion of the sample belonging to the n-th taxon and S is the total number of taxa in the sample (Shannon and Weaver 1949, Longuet-Higgins 1971). Species grouped into genera were included when computing diversity.

Density and diversity values were compared by study site, habitat type, year, period, and associated interactions using the Statistical Analysis Software (SAS v.6.12, SAS 1990) system. The general linear model (GLM) and mixed procedures were used to perform an analysis of variance (ANOVA) for unbalanced data. Density and diversity values, including associated standard errors, were estimated using least-square means statements (SAS 1990). Orthogonal contrasts were used to determine differences in least-square means between study sites. A lack of individual species observations at one or more study site violated the assumption of homogeneous variances in our models. However, the robustness of the ANOVA F-statistic permits such violations. Differences with $P < 0.05$ were considered significant.

RESULTS

General Site Characteristics

Mean water depth across survey plots did not significantly differ between purple loosestrife sites (Mixed Procedure, F=0.52, P=0.4709) when compared to reference sites (Table 2). Boot Lake and Morrow Lake were the deepest purple loosestrife study sites and did not significantly differ by mean water depth (orthogonal contrast: F=0.39, P=0.5310). The Somerset reference site, where measurements were taken through a floating mat of vegetation, had the deepest mean water depth (45cm ± 1.0), relative to other study sites. Annual variations in water depth indicate a significantly wetter year in 1998 (12.8cm ± 0.4) when compared to 1999 (9.4cm ± 0.4) (F=34.59, P=0.0001). Mean water levels increased as the breeding season progressed in 1998 (year x period interaction, F=7.36, P=0.0007). Although mean water depths differed among periods in 1999, a clear seasonal trend was not apparent.

Mean maximum vegetation height did not significantly differ between reference sites when compared to purple loosestrife sites (Mixed Procedure, F= 0.21, P=0.6488) (Table 2). Maple River (166cm ± 3.2) and Morrow Lake (157cm ± 3.7) had the greatest mean vegetation height of reference and purple loosestrife sites, respectively. Conversely, Quanicassee and Maisou had the lowest mean vegetation heights and did not significantly differ from one another (orthogonal contrast: F= 1.09, P=0.2967). A significant increase in mean vegetation height occurred from early to late sampling periods for both 1998 and 1999 (year x period interaction, F=12.21, P=0.0001). Mean vegetation height was

Table 2. Mean water depth ± SE (cm), vegetation height ± SE (cm), and vertical cover height ± SE (cm) by study site during the 1998 and 1999 breeding seasons.

			Max Height			Vertical Cover (VOM)[a]		
			Period			Period		
Habitat	**Study Site**	**Water Depth**	**Early**	**Mid**	**Late**	**Early**	**Mid**	**Late**
Purple loosestrife	Quanicassee	1 ± 0.9	77 ± 4.2	111 ± 4.0	130 ± 4.5	99 ± 4.1	108 ± 4.0	109 ± 4.4
	Lake Lansing	2 ± 1.0	79 ± 4.7	125 ± 4.7	150 ± 4.7	73 ± 4.6	124 ± 4.6	137 ± 4.6
	Boot Lake	18 ± 1.0	90 ± 4.7	118 ± 4.7	142 ± 4.7	93 ± 4.6	114 ± 4.6	131 ± 4.6
	Shiawassee	1 ± 0.8	60 ± 4.2	120 ± 4.0	162 ± 4.0	100 ± 4.1	136 ± 4.0	138 ± 4.0
	Morrow Lake	17 ± 1.0	107 ± 4.7	164 ± 4.7	204 ± 4.9	121 ± 4.6	147 ± 4.6	150 ± 4.8
Reference	Maisou Island	2 ± 0.8	79 ± 4.0	105 ± 4.0	117 ± 4.0	69 ± 4.0	83 ± 4.0	81 ± 4.0
	Rose Lake	8 ± 1.0	89 ± 4.9	131 ± 4.7	157 ± 4.7	64 ± 4.8	110 ± 4.6	129 ± 4.6
	Somerset[b]	45 ± 1.0	114 ± 4.7	113 ± 4.7	132 ± 4.7	88 ± 4.6	87 ± 4.6	100 ± 4.6
	Maple River	14 ± 0.9	103 ± 4.3	178 ± 4.0	211 ± 4.0	84 ± 4.3	127 ± 4.0	134 ± 4.0
	Portage	2 ± 0.9	93 ± 5.7	148 ± 4.0	153 ± 4.0	86 ± 5.7	114 ± 4.0	114 ± 4.0
Purple loosestrife:		**8 ± 6.3**	**82 ± 10.0**	**127 ± 10.0**	**158 ± 10.0**	**97 ± 6.4**	**125 ± 6.4**	**133 ± 6.4**
Reference:		**14 ± 6.3**	**96 ± 10.0**	**136 ± 10.0**	**154 ± 10.0**	**78 ± 6.4**	**105 ± 6.4**	**111 ± 6.4**

[a] Measured to the nearest decimeter using a Robel (1970) pole.

[b] Measured water depth through a floating mat of vegetation to solid substrate.

significantly higher in 1998 (129.7cm ± 1.2) when compared to 1999 (121.5cm ± 1.1) (F=20.58, P=0.0001).

Vertical cover (VOM), measured to the nearest decimeter, was significantly greater on average across purple loosestrife sites when compared to reference sites across all time periods sampled (Mixed Procedure, F=5.74, P=0.0167) (Table 2). Morrow Lake and Shiawassee (sites containing the most percent aerial coverage and stem density of purple loosestrife) had the greatest mean vertical cover values, respectively. Contrary to mean vegetation height, mean vertical cover was significantly greater in 1999 (116.0 ± 1.1) than in 1998 (100.42 ± 1.1) (F=98.28, P=0.0001), with a significant increase as the season progressed for both years (year x period interaction, F=6.05, P=0.0024).

Dominance of purple loosestrife varied among purple loosestrife sites (Figure 3). Quanicassee and Lake Lansing had the lowest mean aerial cover and stem density of purple loosestrife and were not significantly different from each other (orthogonal contrast: F=0.62, P=0.4308 and F=0.75, P=0.3870). All other sites were significantly different from each other using orthogonal contrasts between sites for both percent cover and density. Boot Lake had moderate cover (45.3%) and density (18.9 stems/m^2) values, relative to other purple loosestrife sites while Shiawassee and Morrow Lake had the highest cover and density values for purple loosestrife (Figure 3).

Although a significant increase in mean stem density of purple loosestrife was observed from 1998 to 1999 (F=28.63, P=0.0001), mean percent cover of purple loosestrife did not change between years (F=1.30, P=0.2549) (Table 3). There was a significant seasonal increase in percent cover of purple loosestrife for 1998 and 1999

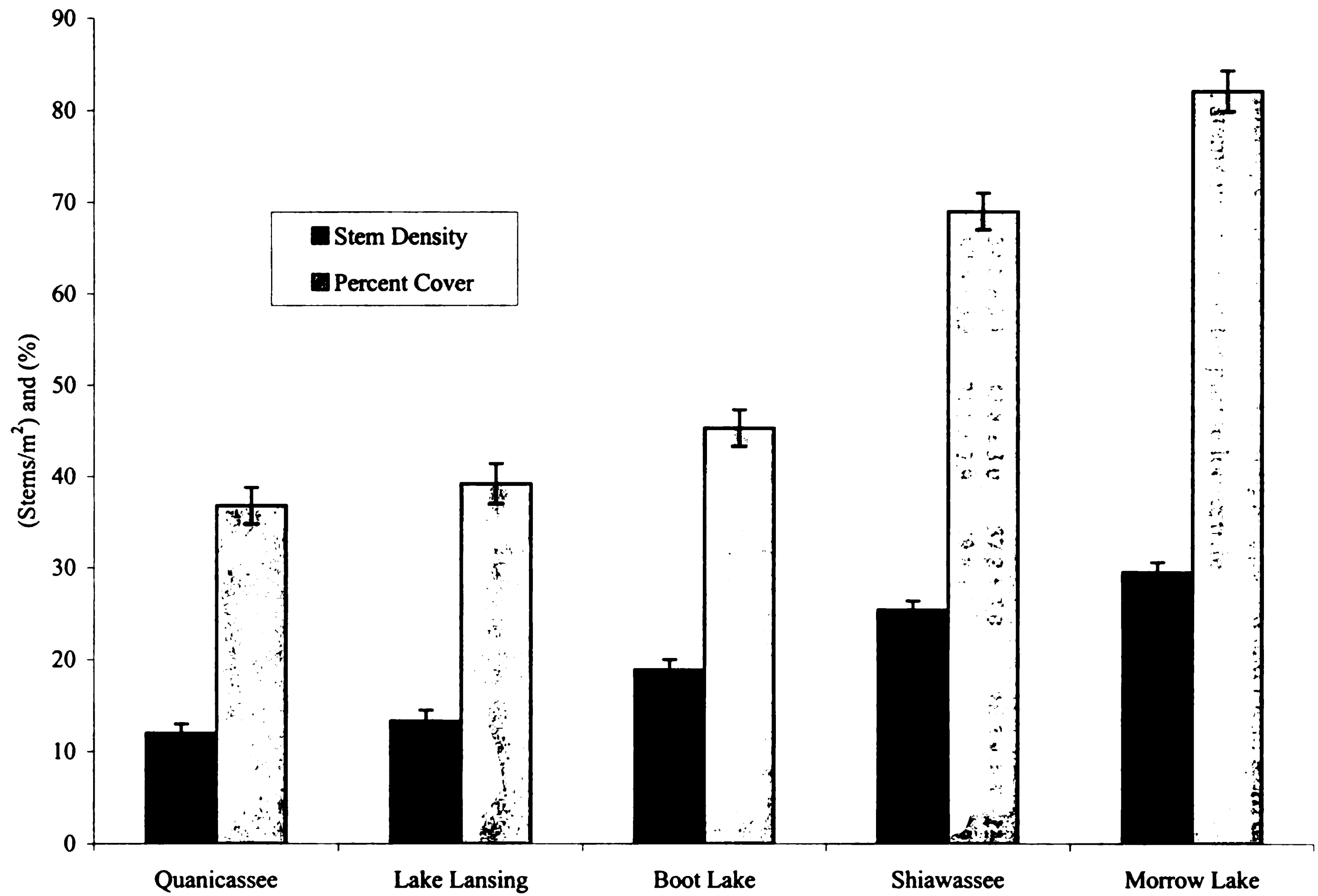


Fig. 3. Mean stem density (no. stems/m^2) and mean percent cover ($\pm$ SE) of purple loosestrife by study site in 1998 and1999.

(F=98.64, P=0.0001) (Table 3). Purple loosestrife density did not significantly differ by period (F=1.35, P=0.2596) and year x period interactions (F=0.06, P=0.9396).

Table 3. Mean percent cover ± SE by sampling period and mean stem density ± SE (no. stems/m^2) by year for purple loosestrife.

	Percent Cover			Stem Density	
Study Site	**Early**	**Mid**	**Late**	**1998**	**1999**
Quanicassee	15.7 ± 3.2	40.1 ± 2.7	53.5 ± 3.1	10.7 ± 1.4	13.6 ± 1.5
Lake Lansing	15.5 ± 3.8	44.6 ± 3.2	50.9 ± 3.2	13.6 ± 1.6	13.3 ± 1.6
Boot Lake	34.6 ± 3.1	43.8 ± 3.0	57.2 ± 3.0	16.3 ± 1.5	21.6 ± 1.5
Shiawassee	52.6 ± 3.2	71.5 ± 2.9	79.8 ± 2.8	22.8 ± 1.4	28.5 ± 1.4
Morrow Lake	70.5 ± 3.3	86.4 ± 3.2	89.5 ± 3.3	24.1 ± 1.5	35.8 ± 1.6
Mean:	**37.8 ± 1.5**	**57.3 ± 1.3**	**66.2 ± 1.4**	**17.5 ± 0.7**	**22.5 ± 0.7**

Vegetation Structure and Composition

Importance values were calculated for each plant taxon found in 0.25m^2 quadrats at each study site. Species with an importance value greater than 30 (out of a maximum of 300) were considered dominant at a study site. Three to five dominant species were found at each purple loosestrife survey site, with a cumulative total of nine species identified (Table 4). Purple loosestrife had the greatest importance value relative to other dominants at all purple loosestrife sites, except Quanicassee, where sedge and blue-joint grass had higher importance values. Two to five species were dominant on reference sites for a cumulative total of six species identified (Table 5). An invasive species, reed-canary grass, had the highest mean importance value across reference sites, but was not significantly higher than sedge and narrow-leaved cattail.

Table 4. Importance values of plant species sampled on 792 quadrats ($0.25m^2$) positioned within avian survey plots at purple loosestrife study sites during the 1998 and 1999 breeding seasons.

	Importance Value (IV)[b]					
Species[a]	**Quanicassee**	**Lake Lansing**	**Boot Lake**	**Shiawassee**	**Morrow Lake**	**Mean IV (± SE)**
Lythrum salicaria	70	66	79	144	210	115.2 ± 11.6
Carex spp.	113	56	74	10	—	64.2 ± 13.0
Phalaris arundinacea	11	62	7	59	74	43.0 ± 11.6
Calamagrostis canadensis	76	—	9	—	—	42.9 ± 18.3
Eleocharis spp.	22	—	39	—	—	31.3 ± 18.3
Leersia oryzoides	5	—	5	70	—	27.0 ± 15.0
Peltandra virginica	—	4	8	39	48	25.3 ± 13.0
Polygonum amphibium	33	6	8	18	—	16.4 ± 13.0
Rumex orbiculatus	4	5	5	38	—	13.2 ± 13.0

[a] Species with importance values over 30 at any purple loosestrife site are listed. A complete plant species list can be referenced in Appendix A.

[b] Maximum Importance value = 300.

Dashes (—) indicate that a species was not observed within sampling quadrats.

Table 5. Importance values of plant species sampled on 820 quadrats ($0.25m^2$) positioned within avian survey plots at reference study sites during the 1998 and 1999 breeding seasons.

	Importance Value (IV)[b]					
Species[a]	**Maisou Island**	**Rose Lake**	**Somerset**	**Maple River**	**Portage**	**Mean IV (± SE)**
Phalaris arundinacea	—	81	11	206	35	84.3 ± 13.0
Carex spp.	117	51	56	54	100	76.8 ± 11.6
Typha angustifolia	6	44	27	149	—	72.0 ± 13.0
Eleocharis spp.	—	43	77	—	—	61.5 ± 18.3
Calamagrostis canadensis	117	—	11	—	38	55.5 ± 15.0
Sparganium eurycarpum	—	56	3	12	14	25.1 ± 13.0

[a] Species with importance values over 30 at any reference site are listed. A complete plant species list can be referenced in Appendix A.

[b] Maximum Importance value = 300.

Dashes (—) indicate that a species was not observed within sampling quadrats.

Vegetation Diversity and Richness

Mean vegetation diversity did not significantly differ between purple loosestrife and reference sites when averaged on a study site basis (Mixed Procedure, F=0.02, P=0.8810) (Table 6). Likewise, when averaged on an avian survey plot basis, mean diversity was

Table 6. Mean vegetation diversity (Shannon and Weaver 1949) ± SE, mean taxa richness ± SE, and total taxa richness based on individual quadrats (0.25 m^2) by study site for the 1998-99 breeding seasons combined.

Habitat	Study Site	n[a]	Diversity[b]	Richness[c]	Total Richness
Purple loosestrife	Quanicassee	44	1.62 ± 0.13 D	4.5 ± 0.3 E	44
	Lake Lansing	36	2.94 ± 0.09 A	10.0 ± 0.4 C	36
	Boot Lake	36	2.49 ± 0.10 BC	11.1 ± 0.4 B	36
	Shiawassee	47	1.74 ± 0.14 D	3.9 ± 0.3 EF	47
	Morrow Lake	35	1.28 ± 0.12 DE	3.0 ± 0.4 F	35
Reference	Maisou Island	48	1.50 ± 0.01 DE	5.6 ± 0.3 D	48
	Rose Lake	35	2.18 ± 0.03 C	6.3 ± 0.4 D	35
	Somerset	36	2.22 ± 0.05 C	12.5 ± 0.4 A	36
	Maple River	46	1.22 ± 0.05 E	2.4 ± 0.3 F	46
	Portage	40	2.65 ± 0.28 AB	11.1 ± 0.4 B	40
Purple loosestrife[d]:		**198 (5)**	**2.01 ± 0.28**	**6.5 ± 1.8**	**63**
Reference[d]:		**205 (5)**	**1.95 ± 0.28**	**7.6 ± 1.8**	**72**

[a] Number of 0.1ha avian survey plots sampled throughout the 1998 and 1999 breeding seasons. Four 0.25 m^2 Daubenmire (1959) frames were sampled per survey plot.

[b] Diversity index values followed by the same letter do not significantly differ (P>0.05) as determined by ANOVA (orthogonal contrast).

[c] Mean richness per 0.1 ha avian survey plot. Means followed by the same letter do not significantly differ (P>0.05) as determined by ANOVA (orthogonal contrast).

[d] Mean diversity and richness over all reference sites and those dominated by purple loosestrife.

not significantly different between purple loosestrife and reference sites (Mixed Procedure, F=0.29, P=0.5891). Lake Lansing had the greatest mean diversity index value relative to other study sites. Portage was the most diverse and taxa rich (having a mean of 11.1 taxa per survey plot) of all reference study sites. Boot Lake was ranked the third most diverse site having mean richness values similar to both Lake Lansing and Portage. The lowest mean diversity values were observed at Morrow Lake and Maple River.

Total plant taxon richness was also determined on a study sites basis (Table 6). A total of 63 and 72 plant taxa were sampled at purple loosestrife and reference sites, respectively. Of these taxa, 52 were found common to both purple loosestrife and reference sites. Mean richness did not significantly differ between reference and purple loosestrife sites (Mixed Procedure, F=0.17, P=0.6760). However, mean richness occurring at reference sites was greater by approximately one taxon per avian survey plot (Table 6). Shiawassee and Morrow Lake (sites with the greatest density and percent cover of purple loosestrife) had the lowest mean taxa richness found at purple loosestrife sites. Cattail and wet meadow vegetation zones sampled at Maple River had the lowest mean taxa richness relative to other study sites.

Breeding Bird Surveys

A total of 50 avian species (41 species at purple loosestrife sites and 40 at reference sites) were observed on or flying through survey plots during the 1997, 1998, and 1999 breeding seasons (Table 7). Of these, 31 species were observed at both purple loosestrife and reference study sites. Ten species were observed only in purple loosestrife sites and nine were seen solely in reference sites. According to the breeding bird criteria of Brown and Dinsmore (1986), 29 species were considered actively breeding. Of the 29 noted breeding species, 21 were found at study sites containing purple loosestrife, and 24 were found at reference sites (Table 7).

Table 7. Avian species found (using 0.1 ha, 18m fixed radius survey plots) on purple loosestrife study sites only, reference study sites only, and those species observed using both habitat types.

	Habitat Type	
Common (Purple loosestrife and Reference)	**Purple loosestrife**	**Reference**
American Bittern[c]	Pied-billed Grebe	Least Bittern
Great Blue Heron[a]	Great Egret	Blue-winged Teal[b]
Canada Goose[b]	Green Heron	Redhead
Wood Duck[c]	Ring-billed Gull[a]	Common Tern[b]
Mallard[c]	Forster's Tern	Black Tern[b]
Virginia Rail[c]	Northern Flicker	Downy Woodpecker
Sora[c]	Alder Flycatcher	Eastern Kingbird[b]
American Coot	American Robin[a]	Marsh Wren[b]
Sandhill Crane	Northern Cardinal	Yellow-headed Blackbird
Killdeer[b]	White-crowned Sparrow	
Herring Gull[a]		
Mourning Dove[a]		
Chimney Swift		
Ruby-throated Hummingbird		
Belted Kingfisher[b]		
Willow Flycatcher[c]		
Tree Swallow[c]		
Cliff Swallow		
Barn Swallow[c]		
Blue Jay		
Sedge Wren[c]		
Cedar Waxwing		
European Starling		
Yellow Warbler[c]		
Common Yellowthroat[c]		
Song Sparrow[c]		
Swamp Sparrow[c]		
Red-winged Blackbird[c]		
Common Grackle[c]		
Northern Oriole		
American Goldfinch[c]		

[a] Species considered breeding at purple loosestrife sites according to the criteria of Brown and Dinsmore (1986).

[b] Species considered breeding at reference sites.

[c] Species found breeding at both purple loosestrife and reference sites.

Avian densities for the nine most abundant bird species observed were compared between purple loosestrife and reference sites (Table 8). Densities averaged across study sites for both purple loosestrife and reference habitat types did not significantly differ for all nine species. The Sedge Wren (F=2.15, P=0.1436), Marsh Wren (F=3.05, P=0.0814), and Virginia Rail (F=1.09, P=0.2967) had lower mean densities across purple loosestrife sites compared with reference sites (Table 8). Sedge Wrens were only observed at study sites densely vegetated by a variety of *Carex* spp. Densities were similar between Maisou Island (4.4 birds per hectare) and Portage (4.5 birds per hectare) reference sites (orthogonal contrast, F=0.03, P=0.8620). However, densities were much lower (0.9 birds per hectare) at Quanicassee, the only site with purple loosestrife as a dominant, where Sedge Wrens were observed.

Marsh Wrens were not observed at any time during the entire study at sites dominated by purple loosestrife. Reference sites containing dense stands of *Typha* spp. were the only sites where breeding Marsh Wrens were observed. Marsh Wren densities found on survey plots positioned in narrow-leaved cattail zones were similar between Rose Lake and Somerset (orthogonal contrast, F=1.14, P=0.2865) reference sites. Densities found at Maple River were the highest of all study sites with a mean of 16 birds per hectare (Table 8).

Virginia Rails responded to broadcast calls at all purple loosestrife sites and were observed most frequently at Quanicassee and Boot Lake (6.9 and 6.8 birds per hectare, respectively) (orthogonal contrast, F=4.06, P=0.0446). Densities were significantly greater during wetter years (vegetation x year interaction, F=29.22, P=0.0001) at study sites having the deepest water depths recorded. Virginia Rails were also common at

Table 8. Mean avian density ± SE of the most abundant species found on study sites surveyed during the 1997-1999 breeding seasons.

		Density (no.birds/ha)[b]								
Habitat	**n[a]**	**Sedge Wren**	**Marsh Wren**	**Virginia Rail**	**Common Yellowthroat**	**Yellow Warbler**	**American Goldfinch**	**Red-winged Blackbird**	**Swamp Sparrow**	**Song Sparrow**
Purple loosestrife										
Quanicassee	68	0.9 ± 0.4 B	ns	6.9 ± 0.8 A	1.8 ± 1.2 C	3.4 ± 1.3 CD	0.4 ± 0.7 C	10.4 ± 2.9 D	115.2 ± 3.3 A	ns
Lake Lansing	54	ns	ns	2.2 ± 0.9 BD	11.5 ± 1.3 AB	4.8 ± 1.5 BC	8.9 ± 0.8 A	60.6 ± 3.2 B	76.9 ± 3.7 B	1.1 ±1.1 D
Boot Lake	36	ns	ns	6.8 ± 1.2 AB	11.7 ± 1.6 AB	2.0 ± 1.8 CD	0.8 ± 0.9 C	40.1 ± 4.1 C	60.2 ± 4.7 C	ns
Shiawassee	66	ns	ns	2.0 ± 0.8 BD	8.2 ± 1.2 B	33.0 ± 1.4 A	6.4 ± 0.7 B	13.9 ± 2.9 D	21.5 ± 3.4 E	28.6 ± 1.0 A
Morrow Lake	35	ns	ns	3.2 ± 1.2 CD	3.4 ± 1.6 C	ns	0.9 ± 0.9 C	78.0 ± 4.1 A	8.6 ± 4.8 F	17.7 ± 1.4 B
Reference										
Maisou Island	48	4.4 ± 0.5 A	ns	3.8 ± 1.0 BC	2.5 ± 1.4 C	0.6 ± 1.6 D	ns	4.3 ± 3.6 E	43.1 ± 4.2 D	ns
Rose Lake	35	ns	4.0 ± 1.2 B	5.2 ± 1.2 BC	3.4 ± 1.6 C	n.s.	ns	55.2 ± 4.2 B	18.5 ± 4.8 EF	0.9 ± 1.4 D
Somerset	36	ns	5.8 ± 1.2 B	9.3 ± 1.2 A	4.2 ± 1.6 C	8.3 ± 1.8 B	ns	41.8 ± 4.1 C	85.2 ± 4.7 B	5.8 ± 1.4 C
Maple River	46	ns	16.3 ± 1.1 A	8.2 ± 1.0 A	0.7 ± 1.4 C	ns	ns	32.7 ± 3.7 C	29.8 ± 4.3 E	ns
Portage	40	4.5 ± 0.5 A	ns	3.2 ± 1.1 CD	15.0 ± 1.5 A	ns	0.8 ± 0.9 C	1.1 ± 3.9 DE	22.2 ± 4.5 E	2.8 ± 1.3 CD
Purple loosestrife:	**259**	**0.2 ± 0.8**	**ns**	**4.2 ± 1.2**	**7.3 ± 2.3**	**8.8 ± 4.5**	**3.5 ± 1.3**	**40.5 ± 11.4**	**56.6 ± 16.1**	**9.5 ± 4.2**
Reference:	**205**	**1.8 ± 0.8**	**5.2 ± 2.1**	**5.9 ± 1.2**	**5.1 ± 2.3**	**1.8 ± 4.5**	**0.2 ± 1.3**	**29.0 ± 11.5**	**39.8 ± 16.1**	**1.9 ± 4.2**

[a] Number of 0.1ha avian survey plots sampled during the 1997-1999 breeding seasons.

[b] Means within columns followed by the same letter do not significantly differ (P>0.05) as determined by ANOVA (orthogonal contrast).

ns = Species not sighted at study site.

reference sites with peak densities found at Somerset (9.3 birds per hectare) and Maple River (8.2 birds per hectare).

Six of the nine most abundant species observed had greater mean densities across purple loosestrife sites when compared to reference sites. These species include the Common Yellowthroat (F=0.44, P=0.5075), Yellow Warbler (F=1.21, P=0.2721), American Goldfinch (F=3.61, P=0.0580), Red-winged Blackbird (F=0.52, P=0.4725), Swamp Sparrow (F=0.54, P=0.4616), and the Song Sparrow (F=1.62, P=0.2031) (Table 8). Common Yellowthroats were observed at varying densities at each study site. Lake Lansing, Boot Lake, and Shiawassee had the greatest Common Yellowthroat densities found at purple loosestrife sites and were not significantly different from one another (Table 8). A peak response of 15.0 birds per hectare occurred at the Portage reference site.

Yellow Warblers had highest densities at sites containing woody shrub species (Shiawassee, Lake Lansing, and Somerset) relative to other study sites. Yellow Warbler densities were greatest (33 birds per hectare) at Shiawassee where a mixture of buttonbush (*Cephalanthus occidentalis*) and purple loosestrife occurred. Yellow Warblers had moderate densities at Quanicassee, Boot Lake, and Maisou Island and were not observed at Morrow Lake, Rose Lake, Maple River, and Portage (Table 8). Study sites where Yellow Warblers were not observed were the only sites not containing intermixed or adjacent woody shrub species.

American Goldfinches were found at all five purple loosestrife dominated study sites and were not common at reference sites. American Goldfinches were most abundant at Lake Lansing and Shiawassee, having densities of 8.9 and 6.4 birds per hectare, respectively. Portage was the only reference site where American Goldfinches were observed and densities were similar to those found at Boot Lake, Morrow Lake, and Quanicassee (Table 8).

Red-winged Blackbirds were observed at varying densities across each study site (Table 8). Red-winged Blackbirds were second in abundance to the Swamp Sparrow at both purple loosestrife and reference sites. Mean density was greater across purple loosestrife sites (40.6 birds per hectare) when compared to reference sites (29 birds per hectare). Red-winged Blackbirds reached a peak density of 78 birds per hectare at Morrow Lake with no apparent trends occurring across purple loosestrife dominated sites. Study sites with an interspersion of *Typha* spp., such as Lake Lansing and Rose Lake, had relatively high densities of breeding Red-winged Blackbirds. Densities were lowest in wet meadow zones sampled at Quanicassee, Maisou Island, and Portage where *Carex* spp. and blue-joint grass dominated.

Swamp Sparrow densities significantly decreased in relation to an increasing dominance of purple loosestrife (Table 8). Quanicassee had the greatest Swamp Sparrow density (115.2 birds per hectare) relative to other purple loosestrife sites, whereas Morrow Lake had the lowest density (8.6 birds per hectare). Orthogonal contrasts indicate that sites with moderate to dense stands of purple loosestrife (Boot Lake, Shiawassee, and Morrow Lake) had similar or significantly lower Swamp Sparrow densities when compared to paired reference sites (Table 8). Swamp Sparrows were common at all study sites and were the most abundant bird species found using purple loosestrife, making up approximately 44% of the total bird observations at purple loosestrife study sites.

The Song Sparrow was most abundant where purple loosestrife had highest density and percent cover values relative to other purple loosestrife sites, a trend opposite of that observed for the Swamp Sparrow. Song Sparrows were not observed at Quanicassee and Boot Lake, and were found in low relative abundance at Lake Lansing (1.1 birds per hectare). Dense stands of purple loosestrife sampled at Shiawassee and Morrow Lake had the highest Song Sparrow densities (28.6 and 17.7 birds per hectare, respectively) (orthogonal contrast, F=41.74, P=0.0001). Rose Lake, Somerset, and Portage were the only reference sites where Song Sparrows were observed, which had significantly lower densities based on orthogonal contrasts, when compared to Shiawassee and Morrow Lake (Table 8).

Avian Diversity and Richness

Avian diversity did not significantly differ (Mixed Procedure, F=2.61, P=0.1072), (when averaged on an avian survey plot basis) between purple loosestrife dominated sites (0.55 ± 0.09) and reference sites (0.34 ± 0.09) (Table 9). Likewise, when averaged on a study site basis, diversity did not significantly differ between purple loosestrife (1.19 ± 0.19) and reference sites (1.21 ± 0.19) (Mixed Procedure, F=0.01, P=0.9401). Although not significantly different (Mixed Procedure, F=2.44, P=0.1195), mean species richness was greater by approximately one species per avian survey plot at purple loosestrife sites (3.3 ± 0.42) when compared to reference sites (2.3 ± 0.42) (Table 9). Shiawassee had the highest diversity (0.84 ± 0.05), species richness per plot (4.9 ± 0.2), and total avian richness (16 species including "flythrough species") relative to all other study sites. The lowest diversity value, mean species richness, and total richness were found at the

Maisou Island reference site. Quanicassee and Morrow Lake (sites with the lowest and highest importance values for purple loosestrife, respectively) did not significantly differ from one another based on mean diversity (orthogonal contrast: F=0.03, P=0.8713). Diversity was also similar between Lake Lansing and Boot Lake (orthogonal contrast: F=1.45, P=0.2287) (Table 9).

Table 9. Mean avian diversity (Shannon and Weaver 1949) ± SE, mean species richness ± SE, and total species richness for the 1997-99 breeding seasons combined.

Habitat	**Study Site**	**n[a]**	**Diversity[b]**	**Richness[c]**	**Total[d] Richness**
Purple loosestrife	Quanicassee	68	0.33 ± 0.05 C	3.0 ± 0.2 B	15
	Lake Lansing	54	0.68 ± 0.06 B	3.6 ± 0.3 B	7
	Boot Lake	36	0.57 ± 0.07 B	2.9 ± 0.3 BC	8
	Shiawassee	66	0.84 ± 0.05 A	4.9 ± 0.2 A	16
	Morrow Lake	35	0.31 ± 0.07 C	1.9 ± 0.3 DE	6
Reference	Maisou Island	48	0.12 ± 0.06 D	1.5 ± 0.2 E	5
	Rose Lake	35	0.28 ± 0.07 CD	2.1 ± 0.3 CDE	9
	Somerset	36	0.61 ± 0.07 B	3.6 ± 0.3 B	10
	Maple River	46	0.35 ± 0.06 C	2.2 ± 0.2 CD	8
	Portage	40	0.33 ± 0.06 C	2.2 ± 0.2 CD	8
Purple loosestrife[e]:		**259**	**0.55 ± 0.09**	**3.3 ± 0.42**	**22**
Reference[e]:		**205**	**0.34 ± 0.09**	**2.3 ± 0.42**	**17**

[a] Number of 0.1ha avian survey plots sampled throughout the 1997, 1998, and 1999 breeding seasons.

[b] Diversity Index (per 0.1 ha avian survey plot) values followed by the same letter do not significantly differ (P>0.05) as determined by ANOVA (orthogonal contrast).

[c] Mean species richness (per 0.1 ha avian survey plot) excluding "flythrough" species. Means followed by the same letter do not significantly differ (P>0.05) as determined by ANOVA (orthogonal contrast).

[d] Total avian richness found at each study site including "flythrough" species.

[e] Mean diversity and richness over all reference sites and those dominated by purple loosestrife.

Nest Site Characteristics

Nests of 182 individuals of 15 species were located on 0.05 ha nest search plots in 1997, 1998, and 1999 (Table 10). A total of 69 active and 113 inactive nests were found. Swamp Sparrow and Red-winged Blackbird nests were most common at purple loosestrife sites, making up 39% and 49% of the total number of nests, respectively. Marsh Wren and Red-winged Blackbird nests were most abundant on reference sites, accounting for approximately 73% of the nests found. Six breeding species, the Sora, American Coot, Mourning Dove, Common Yellowthroat, Song Sparrow, and American Goldfinch were found using purple loosestrife as a nesting substrate (Tables 11 and 12). Five breeding species found unique to reference sites include the American Bittern, Canada Goose, Virginia Rail, Sedge Wren, and Marsh Wren. Nesting species common to both purple loosestrife and reference wetlands include the Mallard, Yellow Warbler, Swamp Sparrow, and Red-winged Blackbird (Tables 11 and 12).

Refer to Appendix C for detailed records of nest site measurements for the Swamp Sparrow and the Red-winged Blackbird. See Appendix D for the number of Muskrat houses located on 0.05 ha search plots as well as the type of vegetation used for building material.

Table 10. Total number of nests found on 0.05 ha nest search plots positioned within 0.1ha avian survey plots during the 1997-1999 sampling seasons.

Year	Habitat	Nest Type		Total
		Active	Inactive	
1997	**Purple loosestrife**[a]	11	10	21
	Reference	—	—	—
1998	**Purple loosestrife**	18	6	24
	Reference	10	19	29
1999	**Purple loosestrife**	13	41	54
	Reference	17	37	54
Total		69	113	182

[a] Only sampled Quanicassee, Lake Lansing, and Shiawassee study sites in 1997.
Dashes (—) indicate that reference sites were not sampled in 1997.

Table 11. Number of active nests and associated nesting substrate found on 0.05 ha plots during the 1997-1999 sampling periods. Multiple substrates indicate more than one plant species used to support a nest.

Habitat	Nesting Substrate	Species	n
Purple loosestrife	*L. salicaria*	Mourning Dove	1
		Swamp Sparrow	4
		Red-winged Blackbird	9
	L. salicaria/C. canadensis	Sora	1
		Swamp Sparrow	5
	L. salicaria/C. canadensis/Carex spp.	Swamp Sparrow	3
	L. salicaria/Carex spp.	Swamp Sparrow	6
		Red-winged Blackbird	2
	L. salicaria/P. arundinacea	Swamp Sparrow	1
		Red-winged Blackbird	3
	L. salicaria/Typha spp.	Swamp Sparrow	1
	Carex spp./C. canadensis	Mallard	1
	Carex spp./L. salicaria/Typha spp.	Red-winged Blackbird	1
	Cornus amomum	Red-winged Blackbird	1
	C. amomum/L. salicaria	Swamp Sparrow	1
	Cornus stolonifera	Red-winged Blackbird	1
	C. stolonifera/L.salicaria	Swamp Sparrow	1
		Total	**42**
Reference	*C. canadensis*	Mallard	1
	Carex spp.	American Bittern	1
		Sedge Wren	2
		Swamp Sparrow	1
	P. arundinacea	Swamp Sparrow	1
		Red-winged Blackbird	1
	P. arundinacea/Aster puniceus	Mallard	1
	Rosa palustris	Yellow Warbler	2
	Scirpus acutus/P. arundinacea	Red-winged Blackbird	1
	Typha spp.	Marsh Wren	4
		Red-winged Blackbird	10
	Typha spp./Sparganium eurycarpum	Red-winged Blackbird	2
		Total	**27**

Table 12. Number of inactive nests and associated nesting substrate found on 0.05 ha plots during the 1997-1999 sampling periods. Multiple substrates indicate more than one plant species used to support a nest.

Habitat	Nesting Substrate	Species	n
Purple loosestrife	Dead *L. salicaria*	American Coot	1
	Dead *Acer spp.*	Yellow Warbler	1
	L. salicaria	Common Yellowthroat	1
		Song Sparrow	3
		Red-winged Blackbird	32
	L. salicaria/Carex spp.	Swamp Sparrow	17
	C. stolonifera	Red-winged Blackbird	1
	N.A.	American Goldfinch	1
		Total	**57**
Reference	*Carex spp.*	Mallard	2
		Sedge Wren	3
		Swamp Sparrow	3
	Carex spp./Decodon verticillatus	Virginia Rail	1
	Carex spp/C. stolonifera	Red-winged Blackbird	1
	Carex spp/C. canadensis	Red-winged Blackbird	1
	Dead *Typha spp.*	Canada Goose	3
	Typha spp.	Virginia Rail	1
		Marsh Wren	22
		Red-winged Blackbird	19
		Total	**56**

DISCUSSION

In Michigan, purple loosestrife is established in moist soil zones in wetlands throughout various watersheds. The invasion does not appear complete at this time and some watersheds remain void of purple loosestrife. The recent establishment of purple loosestrife has limited research efforts and there are few studies documenting competitive interactions and structural changes occurring within native wetland plant communities (Anderson 1995, Hager and McCoy 1998). A review of the interactions between purple loosestrife and native plant species by Anderson (1995), indicates that under laboratory settings, purple loosestrife has the ability to outcompete native wetland plants (Gaudet and Keddy 1988). Field studies (Rawinski 1982, Shamsi and Whitehead 1974, Anderson 1995) indicate that many native plant species may have an advantage when competing with purple loosestrife for resources in natural field conditions, however. Over time, Thompson et al. (1987) conclude that an increase in the biomass of purple loosestrife reduces native food and cover plants, thus reducing plant species richness, leading to the possible extinction of rare and endangered endemics. Plant composition (both richness and diversity) sampled at purple loosestrife dominated sites during this study do not reveal such patterns.

Study sites dominated by purple loosestrife did not significantly differ in overall mean plant diversity when compared to reference study sites. The level at which mean diversity was computed (at individual survey plots or over an entire study site) provided like results, indicating similar richness and distribution at both scales on purple loosestrife sites when compared to reference sites. Diversity was similar between coastal wet meadow (Quanicassee) and riverine sites (Shiawassee and Morrow Lake) dominated by purple loosestrife. Isolated inland marshes such as Lake Lansing, and Boot Lake were the most diverse wetlands containing purple loosestrife. Morrow Lake and Maple River, the deepest sites dominated by dense stands of aggressive disturbance related species (purple loosestrife and *Typha* spp., respectively) had the lowest mean diversity values, possibly a result of hydrologic influences and human disturbance.

Mean plant taxon richness did not significantly differ when averaged across survey plots at purple loosestrife dominated sites compared to reference sites. These results coincide with that of Treberg and Husband (1998) which addressed the hypothesis of reduced plant diversity associated with the presence of purple loosestrife. Treberg and Husband (1998) reported that plant richness on plots containing purple loosestrife adjacent to the Bar River, Canada did not significantly differ from plots lacking purple loosestrife. There was also a lack of correlation found between percent cover of purple loosestrife and total plant species richness. Similarly, Anderson (1991) failed to report a significant relationship between plant richness (native and exotic) and purple loosestrife abundance within three community types at the Ipswich River Wildlife Sanctuary in Massachusetts.

Importance values calculated for each plant taxon at purple loosestrife and reference sites reveal a number of native plant taxa that are co-dominant with purple loosestrife. A total of nine native taxa were considered co-dominants with purple loosestrife according to the criteria used in this study. All purple loosestrife study sites had at least two co-dominant taxa associated with purple loosestrife. Native co-dominants had lower importance values relative to purple loosestrife at all sites except Quanicassee, where sedge (species grouped into the genera *Carex*) and blue-joint grass were found to be the most abundant dominants. Sedge was a common dominant taxon at sites containing low to moderate relative abundance of purple loosestrife whereas reed-canary grass and arrow arum appeared to co-dominate at sites with high purple loosestrife abundance. Thompson et al. (1987) list *Typha* spp., reed-canary grass, sedges and rushes as the most common plants (occurring within 1m of loosestrife plants) associated with purple loosestrife. Dominant plant associates observed at purple loosestrife dominated wetland sites during this study were similar, although a greater variety of dominants were found to be competing with purple loosestrife.

The species composition of avian communities found at wetlands is dependent upon the suitability of nesting substrate, territory acquisition, the presence of food, and an overall complex of proximal habitat cues (Weller and Spatcher 1965, Weller and Fredrickson 1974, Cody 1981). The establishment of purple loosestrife within emergent habitat zones of wetlands has been known to alter vegetation structure and overall wetland appearance (Thompson et al. 1987, Anderson 1995). Purple loosestrife adds a strong woody shrub-like structure to the emergent zone of wetland habitats. Thus, providing additional structural diversity, which may allow for greater niche diversification among marsh nesting species (Burger 1985). Since marsh birds have been found to select breeding habitats based on plant structure rather than taxonomic composition, wetlands altered by purple loosestrife should experience a shift in breeding bird species to those limited by plant life-form rather than taxonomic categories (Beecher 1942, Weller and Spatcher 1965, Burger 1985). A change in the distribution, diversity, and size of breeding bird communities should result. During this study, avian community composition observed at a broad range of purple loosestrife dominated study sites illustrate such structural aspects of purple loosestrife that appear to be attracting a complex breeding bird community.

Forty-one avian species (including species flying through survey plots) were observed at wetlands with varying degrees of purple loosestrife dominance. Individual species response to the abundance of purple loosestrife varied among study sites. The most abundant species using purple loosestrife include the Sedge Wren, Virginia Rail, Common Yellowthroat, Yellow Warbler, American Goldfinch, Red-winged Blackbird, Swamp Sparrow, and the Song Sparrow. Mean density per hectare did not significantly differ between purple loosestrife and references sites. However, differences in avian density and composition among purple loosestrife study sites reveal structural and hydrologic patterns essential in determining avian use.

Sedge Wrens had the lowest density per hectare at purple loosestrife study sites. Quanicassee was the only purple loosestrife study site where Sedge Wrens appeared to tolerate a low relative abundance of purple loosestrife, which was intermixed with dominant *Carex* spp. and blue-joint grass. Nests were only located in shallow emergent zones dominated by dense stands of *Carex* spp. Breeding Sedge Wrens were also observed nesting in coastal and inland sedge meadows at Maisou Island and Portage reference sites, respectively. Whitt et al. (1999) also observed Sedge Wrens use of wet meadow zones at the Quanicassee study site (study area replicated during this study). Concurrent with the study by Whitt et al. (1999), Sedge Wrens appear to breed in shallow wet meadows dominated by purple loosestrife, yet Sedge Wren abundance appears to decline as purple loosestrife abundance increases. Although, the dominance of *Carex* spp. at purple loosestrife dominated sites may be the determining factor in Sedge Wren occurrence. Maisou Island and Portage, reference sites with similar importance values for *Carex* spp. as Quanicassee had significantly higher Sedge Wren densities. Wet meadow zones at sites such as Lake Lansing and Boot Lake that had low importance values for *Carex* spp. and a high relative abundance of purple loosestrife, support the declining Sedge Wren trend reported by Whitt et al. (1999).

Consistent with the observations of Rawinski and Malicki (1984) and Whitt et al. (1999), Marsh Wrens appeared to avoid stands of purple loosestrife altogether. In Michigan, Marsh Wrens prefer narrow-leaved cattail and cord-grass marshes where nests are woven to cattails, reeds, rushes, and bushes (Brewer et al. 1991). Marsh Wrens were observed at reference sites such as Rose Lake, Somerset, and Maple River where densely vegetated stands of narrow-leaved cattail occurred. Common cattail (*Typha latifolia*) was generally found intermixed at purple loosestrife and reference sites yet densities were not high enough to support a community of breeding Marsh Wrens. The multi-stemmed woody structure that purple loosestrife creates does not appear to be an acceptable replacement for dense stands of narrow-leaved cattail, which were commonly selected by Marsh Wrens for breeding territories and nest construction.

The Virginia Rail and the Sora were the only secretive rail species found using sites dominated by purple loosestrife. Soras were observed at Quanicassee and Shiawassee having significantly lower densities than those found at reference sites. Soras preferred wetter reference sites whereas Virginia Rails appeared to tolerate varying water depths found at both purple loosestrife and reference sites. Virginia Rails were observed at all study sites having similar densities between purple loosestrife and reference sites. Virginia Rails had moderate densities at Shiawassee and Morrow Lake, the most densely vegetated purple loosestrife sites. Brewer et al. (1991) note that Virginia Rails feed primarily on insects and snails, indicating that sites dominated by purple loosestrife may provide an important invertebrate food source for breeding Virginia Rails.

Whitt et al. (1999) observed Virginia Rails utilizing coastal wetlands dominated by purple loosestrife in the Saginaw Bay, Michigan. Purple loosestrife density and dominance found at study sites containing a variety of hydrologic patterns did not reveal significant trends in Virginia Rail densities. However, seasonal and yearly variation in water depth may provide a better indication of breeding Virginia Rail use of purple loosestrife dominated wetlands.

Six breeding passerine species, including the Common Yellowthroat, Yellow Warbler, American Goldfinch, Red-winged Blackbird, Swamp Sparrow, and the Song Sparrow, were found to occur in higher densities on purple loosestrife dominated habitats when compared to reference sites. Common Yellowthroats were observed at each study site, having relatively high breeding densities across a range of purple loosestrife study sites. Densities were comparable to, although higher than those reported in by Whitt et al. (1999). In Michigan, the Common Yellowthroat primarily breeds in shrub wetlands, although use of a variety of nesting habitat types has been reported (Brewer et al. 1991). Study sites containing diverse native plant communities as well as the presence of woody shrub species attracted a high number of breeding individuals. Common Yellowthroats appeared to be a generalist species that utilized a number of habitat zones at a variety of purple loosestrife and reference sites.

Unlike the Common Yellowthroat, Yellow Warblers had a much higher response at sites dominated by purple loosestrife when compared to reference sites. Yellow Warblers reached a peak density at Shiawassee where buttonbush was interspersed with tall clumps of competing purple loosestrife. Study sites containing native shrub species appear to attract a high number of breeding individuals. Yellow Warblers were not observed at Morrow Lake, the only purple loosestrife site where adjacent shrub species were not present. Breeding densities found at Quanicassee, Lake Lansing, and Boot Lake were much lower although similar to Yellow Warbler densities reported by Whitt et al. (1999).

American Goldfinches were observed using each purple loosestrife site at variable densities. Although American Goldfinches flying through survey plots were common, use of reference sites was relatively low when compared to purple loosestrife sites. High densities of American Goldfinches at Lake Lansing may be attributed to a forested/scrub-shrub border surrounding purple loosestrife dominated emergent zones of this wetland. However, high densities of American Goldfinches were also observed at Shiawassee, where survey plots were positioned up to 900m from a noted change in habitat or classification type. The presence of buttonbush at Shiawassee may be the cause of relatively high densities observed at this site. American Goldfinches may be attracted to the presence of dense woody habitats situated adjacent to purple loosestrife survey plots or to the dense shrub-like structure that purple loosestrife provides.

American Goldfinch nests were located at Lake Lansing which support the observations of Kiviat (1996), where nests of 15 American Goldfinches were located in dense stands of purple loosestrife over a 23 year study in the Hudson Valley. Whitt et al. (1999) also provide documented breeding use of purple loosestrife dominated coastal wetlands by the American Goldfinch in the Saginaw Bay, Michigan.

Red-winged Blackbirds were the second most abundant breeding species found on purple loosestrife study sites. Breeding densities were highest at sites containing dense stands of purple loosestrife (Morrow Lake) and at sites where *Typha* spp. were present. Nests were commonly located on the outermost edge of dense clumps of purple loosestrife and were made of dead cattail, sedges, and grasses. Live robust stems as well as the previous years dead purple loosestrife stalks were used to anchor nests. Purple loosestrife also provided suitable Red-winged Blackbird song posts, used for attracting mates and defending territories. Rawinski and Malecki (1984) found similar breeding evidence of Red-winged Blackbirds in dense stands of purple loosestrife at the Montezuma National Wildlife Refuge in central New York. Red-winged Blackbirds were found nesting in purple loosestrife at much greater densities than in adjacent cattail stands (Rawinski and Malecki 1984). Similarly, Whitt et al. (1999) observed low densities (1.7 birds per hectare) of Red-winged Blackbirds utilizing purple loosestrife dominated wet meadow and scrub-shrub habitats. The Red-winged Blackbird, a species common to N. American wetlands which utilizes a wide breadth of suitable breeding habitats, appears to benefit from the occurrence of purple loosestrife. However, further research is needed to determine if Red-winged Blackbird nest success in dense stands of purple loosestrife is comparable to wetlands containing native nesting cover.

The Swamp Sparrow was the most abundant breeding species observed at purple loosestrife study sites and appeared to select sites with low purple loosestrife abundance. As the stem density and percent cover values for purple loosestrife increased across purple loosestrife study sites, Swamp Sparrow density significant decreased. Swamp Sparrows appear to be attracted to wetland sites that lack dense stands of purple loosestrife and have a mixture of sedges and grasses. Breeding Swamp Sparrows may benefit from the structural aspects of purple loosestrife for both nest building and song posts. Male Swamp sparrows were commonly heard calling while perched on dead stalks of purple loosestrife. Swamp Sparrow densities at Quanicassee (115.2 birds per hectare) were higher than those reported by Whitt et al. (1999), who reported 27.8 and 44.2 birds per hectare in wet meadow/scrub-shrub/loosestrife and wet meadow/loosestrife habitat types, respectively. However, yearly changes in water level at coastal wet meadow sites may determine Swamp Sparrow densities. Swamp Sparrow nests made up 39% of the total nests found at purple loosestrife sites in this study and appears to be a species responding to the structural component that purple loosestrife provides, when in low relative abundance.

Song Sparrows were also commonly observed in dense stands of purple loosestrife. The woody structure of purple loosestrife found at Shiawassee and Morrow Lake study sites appears to be attracting Song Sparrows, which generally prefer dense brushy habitats consisting of native vegetation (Brewer et al. 1991). Evidence of Song Sparrows using purple loosestrife as a nesting substrate was confirmed at Morrow Lake in 1998. An inactive nest made of fine grasses was located near the ground within a dense clump of purple loosestrife. Previous literature documenting the use of purple loosestrife dominated wetlands by breeding Song Sparrows does not exist and it appears that purple loosestrife may provide an extension of the breeding habitat available to the Song Sparrow.

Further observations of such avian/purple loosestrife associations may provide greater evidence of specific avian communities that are selecting and adapting to purple loosestrife dominated wetlands. It appears that the addition of purple loosestrife to Michigan wetlands is causing a shift in breeding avian communities (both in composition and density), to those that tolerate and/or prefer the presence of purple loosestrife. Plant composition, diversity, and richness at purple loosestrife dominated wetlands remain similar to comparable reference wetlands and do not suggest monocultures of purple loosestrife that are not utilized by breeding avifauna. Further quantitative research is needed at a variety of wetlands types dominated by purple loosestrife in order to assess the number of confounding spatial (structure and composition) and temporal (age of loosestrife stands and hydrologic succession) variables influencing avian community use.

APPENDICES

Appendix A. List of 78 plant species and 5 genera found on 1612 quadrats (0.25 m^2) sampled at all study sites during 1998 and 1999. Species common to both purple loosestrife and reference sites as well as species unique to both are indicated (based on Voss 1972, Voss 1985, Voss 1996, and Reed 1998).

Common (Purple loosestrife and Reference)	Purple loosestrife	Reference
Species	Species	Species
Apocynum sibiricum Jacq.[b]	*Acer negundo* L.[c]	*Asclepias syriaca* L.[a]
Asclepias incarnata L.[d]	*Acer saccharinum* Marsh.[c]	*Bidens spp.**
Aster borealis (T. & G.) Prov.[d]	*Cephalanthus occidentalis* L.[d]	*Brassenia schreberi* J. F. Gmelin[d]
Aster puniceus L.[d]	*Cornus amomum* Miller[c]	*Chelone glabra* L.[d]
Boehmeria cylindrica (L.) Sw.[d]	*Echinocystis lobata* (Michaux) T. & G.[c]	*Cirsium muticum* Michaux.[d]
Calamagrostis canadensis (Michaux) Beauv.[d]	*Nymphaea odorata* Aiton[d]	*Convolvulus sepium* L.[d]
Campanula aparinoides Pursh[d]	*Osmunda regalis* L.[d]	*Juncus spp.**
Cardamine pensylvanica Willd.[c]	*Ribes americanum* Miller[c]	*Nasturtium officinale* R. Br.[d]
*Carex spp.**	*Sambucus canadensis* L.[c]	*Nuphar advena* (Aiton) Aiton f.[d]
Cicuta bulbifera L.[d]	*Saururus cernuus* L.[d]	*Pilea pumila* (L.) A. Gray[c]
Cornus racemosa Lam.[c]	*Sparganium americanum* Nutt.[d]	*Prosperinaca palustris* L.[d]
Cornus stolonifera Michaux[c]		*Ricciocarpus natans* (L.) Corda[d]
Decodon verticillatus L. Ell.[d]		*Ranunculus sceleratus* L.[d]
*Eleocharis spp.**		*Salix eriocephala* Michaux[c]
Epilobium leptophyllum Raf.[d]		*Scirpus acutus* Muhl.[d]
Equisetum fluviatile L.[d]		*Scirpus validus* Vahl.[d]
Eupatorium maculatum L.[d]		*Sium suave* Walter[d]
Eupatorium perfolatum L.[c]		*Stachys palustris* L.[d]
Galium boreale L.[b]		*Utricularia cornuta* Michaux[d]
Impatiens capensis Meerb.[c]		*Vitis riparia* Michaux[c]
Iris versicolor L.[d]		

Appendix A (cont'd).

Common (Purple loosestrife and Reference) Species	Purple loosestrife Species	Reference Species
Lathyrus palustris L.[c]		
Leersia oryzoides (L.) Swartz.[d]		
Ludwigia palustris (L.) Ell.[d]		
Lycopus americanus W. P. C. Barton[d]		
Lysimachia thrysiflora L.[d]		
Lythrum salicaria L.[d]		
Mentha arvensis L.[c]		
Mimulus ringens L.[d]		
Onoclea sensibilis L.[c]		
Peltandra virginica (L.) Kunth.[d]		
Phalaris arundinacea L.[c]		
Phragmites australis (Forsk.) Chiov.[c]		
Polygonum amphibium L.[d]		
Polygonum sagittatum L.[d]		
Pontedaria cordata L.[d]		
Potentilla palustris (L.) Scop.[d]		
Rorippa palustris (L.) Besser[d]		
Rosa palustris Marsh.[d]		
Rumex orbiculatus A. Gray[d]		
Sagittaria latifolia Willd. Wapato.[d]		
Salix exigua Nutt.[d]		
Scutellaria epilobiifolia A. Ham.[d]		
Solanum dulcamara L.		

Appendix A (cont'd).

Common (Purple loosestrife and Reference) Species	Purple loosestrife Species	Reference Species
Sparganium eurycarpum Engelm.[d]		
Sphagnum spp. *		
Thelypteris palustris Schott.[c]		
Traidenum virginicum (L.) Raf.[d]		
Typha angustifolia L.[d]		
Typha latifolia L.[d]		
Urtica dioica L.[b]		

* Similar species grouped into genera.

[a] Facultative Upland- Occasionally occurs in wetlands, but usually occur in non-wetlands (estimated 1% - 33% probability).

[b] Facultative- Equally likely to occur in wetlands or non-wetlands (estimated 34% - 66% probabilty).

[c] Facultative Wetland- Usually occurs in wetlands, but occasoionally found in non-wetlands (estimated 67% - 99% probaibility).

[d] Obligate- Occurs almost always in wetlands under natural conditions (estimated > 99% probability).

Appendix B. List of bird species found over all study sites during the 1997, 1998, and 1999 breeding seasons.

Family	Species	Common Name
Podicipedidae	*Podilymbus podiceps* (Linnaeus).	Pied-Billed Grebe
Ardeidae	*Botaurus lentiginosus* (Rackett).	American Bittern
	Ixobrychus exilis (Gmelin).	Least Bittern
	Ardea herodias Linnaeus.	Great Blue Heron
	Casmerodius albus (Linnaeus).	Great Egret
	Butorides striatus (Linnaeus).	Green Heron
Anatidae	*Branta canadensis* (Linnaeus).	Canada Goose
	Aix sponsa (Linnaeus).	Wood Duck
	Anas platyrhynchos Linnaeus.	Mallard
	Anas discors Linnaeus.	Blue-Winged Teal
	Aythya americana (Eyton).	Redhead
Rallidae	*Rallus limicola* Vieillot.	Virginia Rail
	Porzana carolina (Linnaeus).	Sora
	Fulica americana Gmelin.	American Coot
Gruidae	*Grus canadensis* (Linnaeus).	Sandhill Crane
Charadriidae	*Charadrius vociferus* Linnaeus.	Killdeer
Laridae	*Larus delawarensis* Ord.	Ring-billed Gull
	Larus argentatus Pontoppidan.	Herring Gull
	Sterna hirundo Linnaeus.	Common Tern
	Sterna forsteri Nuttall.	Forster's Tern
	Chlidonias niger (Linnaeus).	Black Tern
Columbidae	*Zenaida macroura* (Linnaeus).	Mourning Dove
Apodidae	*Chaetura pelagica* (Linnaeus).	Chimney Swift
Trochilidae	*Archilochus colubris* (Linnaeus).	Ruby-throated Hummingbird
Alcedinidae	*Ceryle alcyon* (Linnaeus).	Belted Kingfisher
Picidae	*Picoides pubescens* (Linnaeus).	Downy Woodpecker
	Colaptes auratus (Linnaeus).	Northern Flicker
Tyrannidae	*Empidonax alnorum* Brewster.	Alder Flycatcher
	Empidonax traillii (Audubon).	Willow Flycatcher
	Tyrannus tyrannus (Linnaeus).	Eastern Kingbird
Hirundinidae	*Tachycineta bicolor* (Vieillot).	Tree Swallow
	Hirundo pyrrhonota Vieillot.	Cliff Swallow

Appendix B (cont'd).

Family	Species	Common Name
Hirundinidae	*Hirundo rustica* Linnaeus.	Barn Swallow
Corvidae	*Cyanocitta cristata* (Linnaeus).	Blue Jay
Troglodytidae	*Cistothorus platensis* (Latham).	Sedge Wren
	Cistothorus palustris (Wilson).	Marsh Wren
Muscicapidae	*Turdus migratorius* Linnaeus.	American Robin
Bombycillidae	*Bombycilla cedrorum* Vieillot.	Cedar Waxwing
Sturnidae	*Sturnus vulgaris* Linnaeus.	European Starling
Emberizidae	*Dendroica petechia* (Linnaeus).	Yellow Warbler
	Geothlypis trichas (Linnaeus).	Common Yellowthroat
	Cardinalis cardinalis (Linnaeus).	Northern Cardinal
	Melospiza melodia (Wilson).	Song Sparrow
	Melospiza georgiana (Latham).	Swamp Sparrow
	Zonotrichia leucophrys (Forster).	White-crowned Sparrow
	Agelaius phoeniceus (Linnaeus).	Red-winged Blackbird
	Xanthocephalus xanthocephalus (Bonaparte).	Yellow-Headed Blackbird
	Quiscalus quiscula (Linnaeus).	Common Grackle
	Icterus galbula (Linnaeus).	Northern Oriole
Fringillidae	*Carduelis tristis* (Linnaeus).	American Goldfinch

Appendix C. Active nest site characteristics ± SE of the most abundant species nesting in purple loosestrife for the 1997-1999 breeding seasons.

Species	Study Site	n	VOM (cm)	Plant Height (cm)	Nest Height (cm)	Water Depth (cm)	Canopy Cover[b] (%)
Red-winged Blackbird	Lake Lansing[a]	7	134 ± 9.9	155 ± 8.5	97 ± 7.3	4 ± 2.2	60 ± 10.7
	Boot Lake[a]	4	125 ± 12.6	125 ± 8.2	78 ± 2.6	13 ± 2.7	70 ± 11.2
	Shiawassee[a]	1	150 ± 0.0	141 ± 0.0	130 ± 0.0	0 ± 0.0	49 ± 0.0
	Morrow Lake[a]	5	146 ± 4.0	179 ± 23.2	134 ± 20.0	14 ± 3.7	64 ± 18.8
	Rose Lake	10	118 ± 11.7	134 ± 8.7	61 ± 5.2	13 ± 0.7	70 ± 4.9
	Maple River	2	75 ± 75.0	184 ± 12.5	96 ± 12.0	52 ± 1.5	84 ± 0.5
	Portage	2	115 ± 35.0	143 ± 16.5	64 ± 9.5	6 ± 5.5	26 ± 26.0
	Purple loosestrife:	**17**	**139 ± 2.8**	**150 ± 5.6**	**110 ± 6.5**	**8 ± 1.7**	**61 ± 2.2**
	Reference:	**14**	**103 ± 6.4**	**154 ± 7.1**	**74 ± 5.2**	**24 ± 6.6**	**60 ± 8.1**
Swamp Sparrow	Quanicassee[a]	16	106 ± 5.8	132 ± 5.7	44 ± 4.0	9 ± 2.9	91 ± 3.1
	Lake Lansing[a]	3	N.A.	N.A.	47 ± 8.8	0 ± 0.0	N.A.
	Boot Lake[a]	1	120 ± 0.0	137 ± 0.0	49 ± 0.0	12 ± 0.0	99 ± 0.0
	Shiawassee[a]	2	150 ± 0.0	141 ± 4.2	55 ± 15.8	0 ± 0.0	98 ± 1.6
	Somerset	1	40 ± 0.0	73 ± 0.0	16 ± 0.0	50 ± 0.0	79 ± 0.0
	Maple River	1	40 ± 0.0	61 ± 0.0	26 ± 0.0	6 ± 0.0	59 ± 0.0
	Purple loosestrife:	**22**	**125 ± 4.8**	**137 ± 1.0**	**49 ± 1.0**	**5 ± 1.3**	**96 ± 0.9**
	Reference:	**2**	**40 ± 0.0**	**67 ± 6.0**	**21 ± 5.0**	**28 ± 22.0**	**69 ± 10.0**

[a] Sites dominated by purple loosestrife.

[b] Canopy cover measured with a spherical densiometer (Lemmon 1959).

Appendix D. Number and type of vegetation used for construction of muskrat houses located on 0.05 ha search plots during the 1997-1999 sampling periods.

Habitat	**Material Used**	**n**
Purple loosestife	*L. salicaria*	8
	L. salicaria/Carex spp.	7
	L. salicaria/Phragmites australis	1
	L. salicaria/Typha spp.	2
	Carex spp.	1
	Typha spp.	2
	Total	**19**
Reference	*Typha spp.*	12
	Total	**12**

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