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**BIRD SURVEYS OF LEE AND HILL MARSHES ON THE
PAMUNKEY RIVER: POSSIBLE AFFECTS OF SEA-
LEVEL RISE ON MARSH BIRD COMMUNITIES**



**THE CENTER FOR CONSERVATION BIOLOGY
COLLEGE OF WILLIAM AND MARY**

March, 2003

Bird Surveys of Lee and Hill Marshes on the Pamunkey River: Possible Affects of Sea-Level Rise on Marsh Bird Communities

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EXECUTIVE SUMMARY

Tidal wetlands are important to coastal ecosystems. They provide flood protection, erosion control and improve water quality. Tidal wetlands also provide essential habitats for numerous species of wildlife, many of which rely on these marsh habitats as sites for breeding and development. Historical wetland surveys indicate that as much as half of the marshes present along the Atlantic and gulf coasts in 1900 have disappeared. While direct human impact has long been a cause of wetland loss, sea level rise is quickly becoming a leading source of current and anticipated wetland losses. Brackish marshes, situated on the transition zone between tidal freshwater and oligohaline marshes, may be most at risk from the effects of sea level rise.

Lee and Hill marshes, located near the mouth of the Pamunkey River, are two of the largest brackish marshes remaining in Virginia. Due to the isolated and inaccessible nature of many brackish marshes within the Chesapeake Bay, little information exists on their associated bird communities. The objectives of this study were to provide information on the species presence, distribution, and abundance of birds within Lee and Hill marshes during the breeding and winter season. An additional objective was to quantify the relationship between birds and the dominant vegetation types within these marshes

Thirty-two survey points were established within Lee and Hill Marshes and associated with one of three habitat types (*Peltandra mix*, *Spartina cynosuroides*, and *Phragmites sp.*). Birds were surveyed 3 times at each point during the breeding season of 2001, and 3 times during the late winter of 2002. Results from surveys were used to calculate species richness and density estimates for habitat types.

A total of 3,510 detections of 38 species were made during both survey seasons within all habitat types. During the summer surveys 1,711 observations were made of 19 species. Winter surveys resulted in 1,799 detections of 26 species. Some differences were noted in species richness values and densities between habitat types. This information will be useful in monitoring and projecting changes in the bird populations of these marshes in the event of changes to the vegetation community due to sea level rise or other factors.

BACKGROUND

Context

Tidal wetlands are vital components of coastal ecosystems for a variety of reasons. They provide flood protection by storing and slowing runoff from upstream sources, this storing and slowing of runoff also contributes to erosion control and improves water quality by trapping sediments and pollutants. Tidal wetlands also provide essential habitats for numerous species of wildlife, many of which require these marsh environments as a site for breeding and development. Many of the wildlife species that rely upon these habitats, such as fish, shellfish and waterfowl, are not only critical components of the ecosystem, but are both economically and recreationally important.

Historical wetland surveys indicate that as much as half of the marshes present along the Atlantic and gulf coasts in 1900 have disappeared. Prior to the 1970's, when measures to curb wetland loss were enacted, most marsh losses were attributable to human activities. Dredging, filling, ditching and draining were rapidly destroying marsh habitats (Dahl, 1990). While direct human activities are still a leading cause of wetland loss, sea level rise due to global climatic change is an increasing concern regarding the loss of coastal marshes. Sea level rise is not a new phenomenon, the absence of historic marsh peats across large stretches of the continental shelf suggest that the rate of sea level rise after the last ice age did not allow marshes to maintain themselves or even to develop. During recent centuries sea level rise occurred at rates at which marshes could sustain themselves through accretion (Erwin, 2000). Recently, over the last several decades, an increased rate of sea level rise has been documented. While this rate of increase is only 1-2 mm, it essentially doubles the rate to 4 mm/year (Nicholls and Leatherman, 1996). Increases in the rates of sea level rise greater than that at which marshes accrete will result in changes to the vegetation community of the marsh as plants that are more tolerant of inundation replace those that are not. Compounding the problem is an increase in salinity levels in marshes along the upper tidal limits. As salinity levels increase salt tolerant plants are likely to replace vegetation that is salt intolerant, resulting in further changes to the marsh's vegetation community.

Lee and Hill marshes, located near the mouth of the Pamunkey River, are two of the largest brackish marshes remaining in Virginia. Brackish marshes are located in the transition zone, between oligohaline and fresh water wetlands, and are characterized by tidal influence, fluctuating salinity levels from 0.5 to 15 ppt, and vegetative components from both fresh water and salt tolerant communities (Odum, 1988 and Cowardian et. al., 1979). These marshes provide important breeding and stopover habitat for numerous species of passerines, marsh birds, waterfowl, shorebirds, and birds of prey. With these marshes situated on the transition zone between tidal freshwater and oligohaline marshes, they are one of the marsh complexes whose vegetation and wildlife community are most at risk from the effects of sea level rise.

Objectives

Due to the isolated and inaccessible nature of many brackish marshes within the Chesapeake Bay, little information exists on their associated bird communities. The primary objective of this study is to provide information on the presence, distribution and abundance of bird species within Lee and Hill marshes during the breeding and winter season. A secondary objective is to quantify the relationship between birds and the vegetation types within these marshes. This information will be useful in monitoring and projecting changes in the bird populations of these marshes in the event of changes to the vegetation community due to sea level rise or other factors.

METHODS

Study Area

This study was conducted entirely within Lee and Hill marshes of the Pamunkey River, located on the border of New Kent and King William Counties in the coastal plain of Virginia. These marshes are 2 large brackish marshes associated with the lower Pamunkey River approximately 5 to 20 km upstream from the mouth, where it and the Mattaponi River form the York River (Figure 1). Lee marsh is over 550 ha in size and consists primarily of dense patches of Big Cordgrass (*Spartina cynosuroides*) with smaller patches Arrow Arum (*Peltandra virginica*), sedges (*Cyperaceae*), and Phragmites (*Phragmites australis*). Hill marsh is nearly 500 ha in size and is dominated by large patches of *S. cynosuroides*, large patches of *P. virginica* intermixed with sparse marsh mallow (*Hibiscus moscheutos*), wild rice (*Zizania aquatica*), and smaller patches of *Phragmites*. Within both of these marshes the patches of *S. cynosuroides* typically occupy the portion of the marsh just above the mean high tide line while the patches of *P. virginica*, *H. moscheutos*, and *Z. aquatica* are found within the intertidal zone. Patches of *Phragmites* seem less inundation tolerant and are restricted to areas of the marshes with greater elevation. During the winter months the patches of *P. virginica* die off and the dead vegetation is removed by tidal action, exposing large mud flats. Both marshes also have a network of tidal creeks of varying widths and depths, allowing tidal waters to reach the marsh interior.

Survey Techniques

Thirty-two survey points were established within Lee and Hill Marshes (Figures 2 and 3). Points were chosen based upon vegetation composition and accessibility. Three vegetation composition types were used and consisted of 11 points within *Peltandra* mix, 10 points within *Phragmites*, and 11 points within *S. cynosuroides* (see table 1 for description of vegetation types and table 2 for list of points). Individual survey points were selected in the field by locating large patches of chosen vegetation types. Survey points were

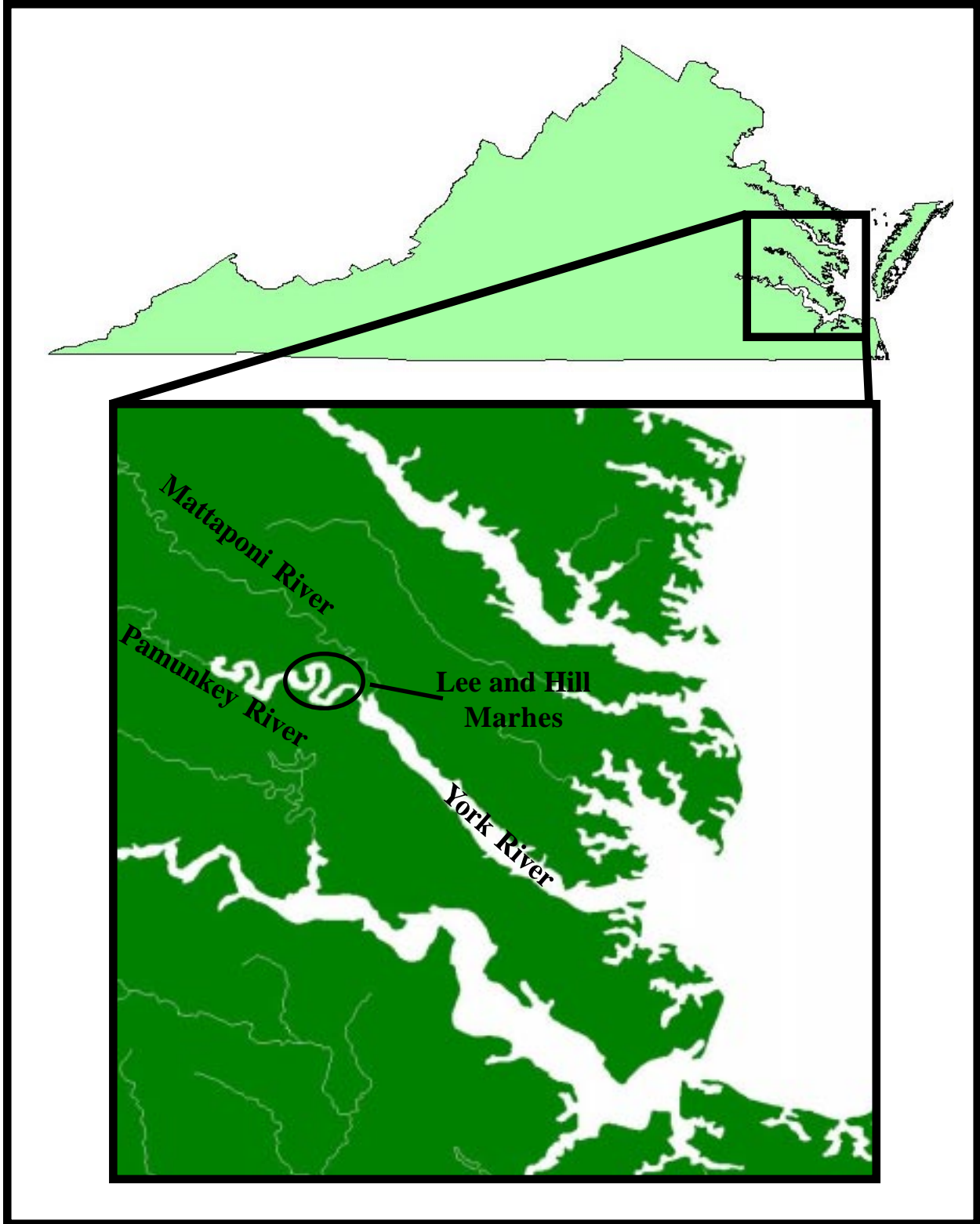


Figure 1. Map showing location of Lee and Hill Marshes of the Pamunkey River.

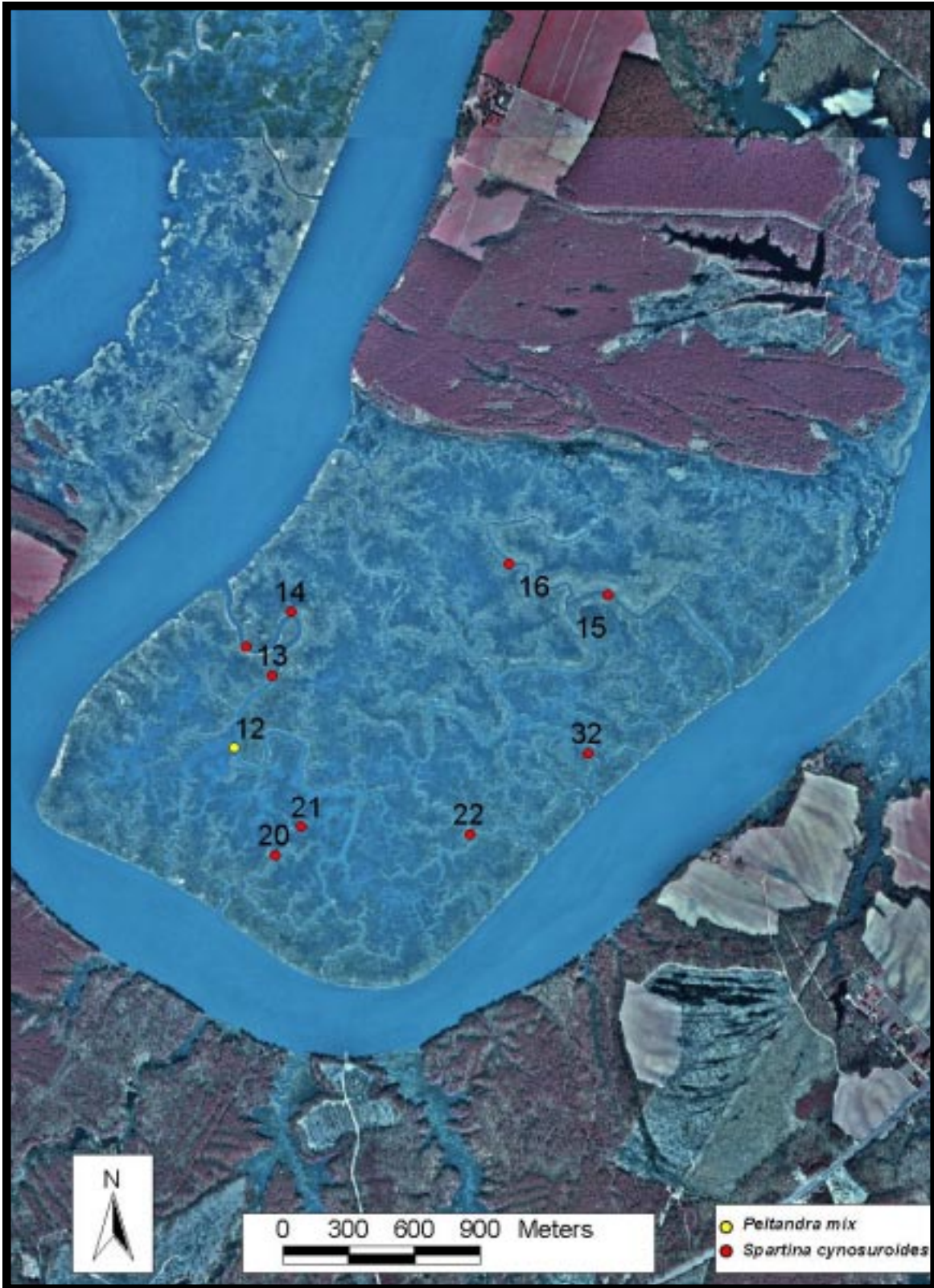


Figure 2. Map showing locations of survey point within in Lee Marsh.

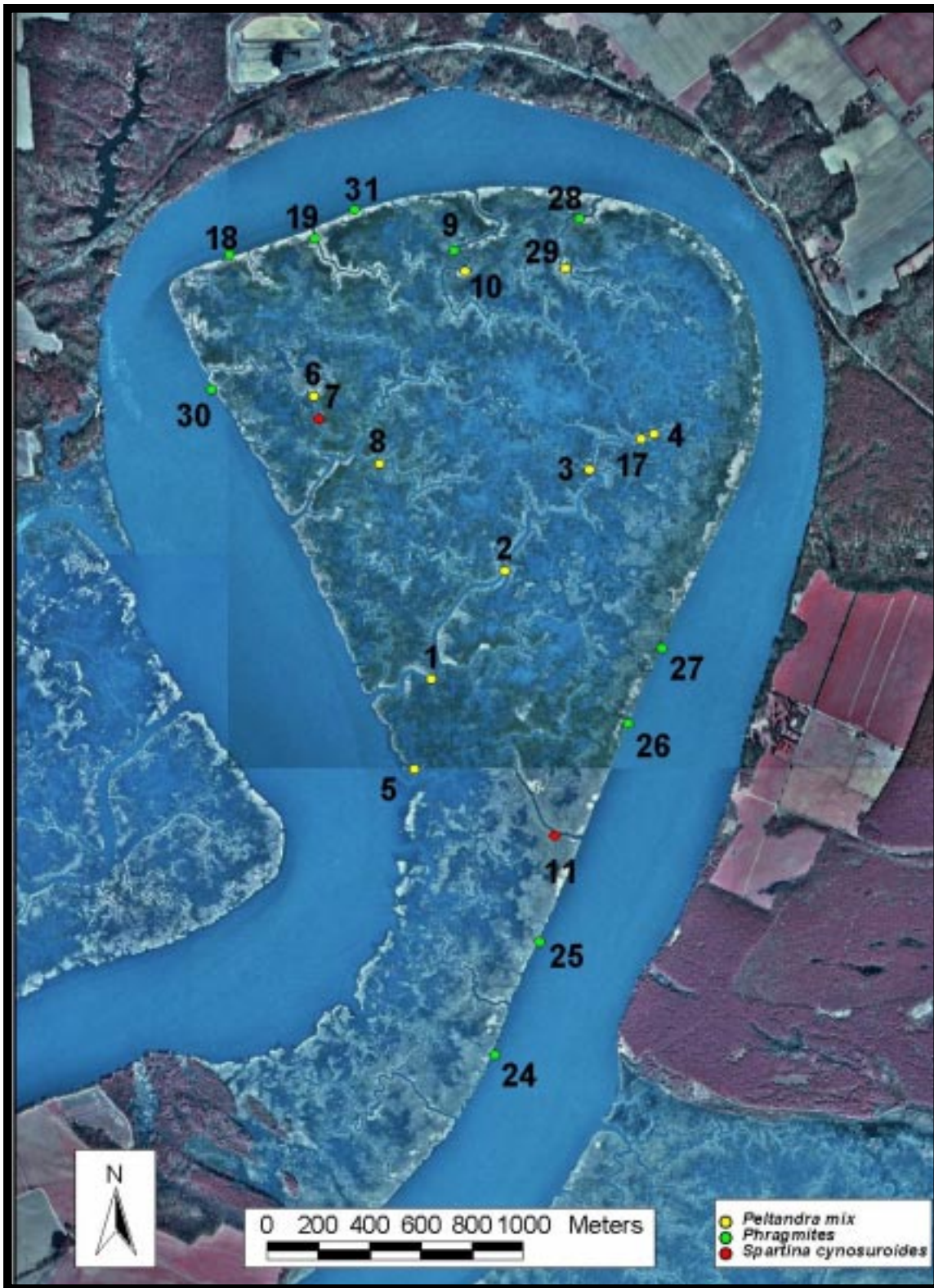


Figure 3. Map showing locations of survey points within Hill Marsh

positioned on the perimeter of selected patches, at the waters edge and were marked with flagged and numbered wooden posts sunk into the mud. The area surveyed at each point consisted of a 100-m radius circle with the wooden post marking the survey point at its center. The survey circle was bisected by the shoreline on which the point marker was located and only the semicircle with land directly adjacent to the point maker was actually surveyed. Points were situated within the marshes so that no survey area overlapped.

Birds were surveyed 3 times at each point during the breeding season of 2001 (11 June 2001 to 12 July 2001) and 3 times during the winter late winter of 2002 (13 February 2002 to 14 March 2002). All surveys were conducted by a single observer from 0.5 to 5 hours after sunrise on days with no steady precipitation and wind speeds of less than 24 km/h. Observations were made from the bow of a Boston Whaler tied to the survey post. All birds seen or heard during the survey period and within the 100 m radius semicircle were recorded, except birds in flight whose activities were not directly associated



Aerial view of Hill Marsh from the south. Note large areas of *Peltandra* (dark green), and *S. cynosuroides* (tan) (photo by Bryan Watts)

Aerial view of Lee Marsh from the west. Note extremely large patches of *S. cynosuroides* (tan) (photo by Bryan Watts).



with the habitat in the survey area. Each survey period was stratified in 4 time blocks, and consisted of 3 blocks of passive looking and listening 3, 2, and 2 min in length respectively, followed by a 4 min callback session.

Many marsh birds are difficult to detect using passive observation alone, but with the broadcast of recorded species-specific calls, detection rates of certain marsh birds can increase 93 to 1,320% (Gibbs and Melvin, 1993). Callback sessions consisted of 30 sec of territorial calls followed by 30 sec of silence for 4 species of marsh birds. The calls broadcasted included king rail (*Rallus elegans*), Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), and least bittern (*Ixobrychus exilis*). Equipment used for the broadcasting consisted of a compact disk recorded with 30 seconds of the target species territorial call and 30 seconds of silence for each of the 4 target species, a battery operated portable CD player, a mini amplifier speaker, and a stereo audio cable with 1/8 inch stereo phone plugs. During callback surveys the CD was played on the portable player at full volume and broadcasted with the mini amplifier speaker held above the head and directed towards the survey area.

All birds detected during both the passive and callback periods were identified to species and recorded on field data sheets with the date, time, point number, observer, wind speed, cloud cover and air temperature. Also recorded for each observation was the estimated distance from the survey point to the nearest 10 m, the substrate used by the bird and the time block within the survey period.

Data Analysis

All data from field sheets were entered into an Excel spread sheet. Data were associated with the recorded positions to produce GIS data layer of the survey points. Average seasonal species richness was calculated for each habitat type by averaging the species richness value for each survey round conducted within each habitat type during the respective season. To estimate seasonal bird densities in the different habitats, a correction factor was calculated for each round within each habitat type during the respective

Table 1. Description of habitat types surveyed.

Habitat	Description
<i>Peltandra</i> Mix	Dominated by <i>P. virginica</i> , intermixed with small patches <i>Hibiscus moscheutos</i> , <i>Zizania aquitica</i> , <i>Spartina</i> sp. <i>Carex</i> sp. and <i>Phramites australis</i>
<i>Spartina cynosuroides</i>	Dominated by <i>S. cynosuroides</i> , with small patches of <i>P. virginica</i> , <i>Carex</i> sp. and <i>Phramites australis</i>
<i>Phragmites</i>	Small (less than 1 ha) patches of <i>Phramites australis</i> generally surrounded by either <i>Peltandra</i> mix or <i>S. cynosuroides</i> habitats

Table 2. List of survey points with habitat classification and coordinates

Point	Classification	Marsh	x Coordinate UTM N WGS 84	y Coordinate UTM WGS 84
1	<i>Peltandra mix</i>	Hill Marsh	334892	4158866
2	<i>Peltandra mix</i>	Hill Marsh	335178	4159291
3	<i>Peltandra mix</i>	Hill Marsh	335505	4159686
4	<i>Peltandra mix</i>	Hill Marsh	335757	4159826
5	<i>Peltandra mix</i>	Hill Marsh	334824	4158515
6	<i>Peltandra mix</i>	Hill Marsh	334434	4159971
7	<i>S. cynosuroides</i>	Hill Marsh	334454	4159883
8	<i>Peltandra mix</i>	Hill Marsh	335372	4158255
9	<i>Phragmites</i>	Hill Marsh	334979	4160543
10	<i>Peltandra mix</i>	Hill Marsh	335024	4160460
11	<i>S. cynosuroides</i>	Hill Marsh	335372	4158255
12	<i>Peltandra mix</i>	Lee Marsh	335088	4155738
13	<i>S. cynosuroides</i>	Lee Marsh	335258	4156068
14	<i>S. cynosuroides</i>	Lee Marsh	335346	4156359
15	<i>S. cynosuroides</i>	Lee Marsh	336791	4156438
16	<i>S. cynosuroides</i>	Lee Marsh	336338	4156579
17	<i>Peltandra mix</i>	Hill Marsh	335707	4159804
18	<i>Phragmites</i>	Hill Marsh	334103	4160526
19	<i>Phragmites</i>	Hill Marsh	334439	4160588
20	<i>S. cynosuroides</i>	Lee Marsh	335275	4155247
21	<i>S. cynosuroides</i>	Lee Marsh	335392	4155378
22	<i>S. cynosuroides</i>	Lee Marsh	336162	4155342
23	<i>S. cynosuroides</i>	Lee Marsh	335141	4156198
24	<i>Phragmites</i>	Hill Marsh	335137	4157398
25	<i>Phragmites</i>	Hill Marsh	335314	4157840
26	<i>Phragmites</i>	Hill Marsh	335660	4158693
27	<i>Phragmites</i>	Hill Marsh	335790	4158988
28	<i>Phragmites</i>	Hill Marsh	335467	4160665
29	<i>Peltandra mix</i>	Hill Marsh	335414	4160474
30	<i>Phragmites</i>	Hill Marsh	334034	4160001
31	<i>Phragmites</i>	Hill Marsh	334592	4160700
32	<i>S. cynosuroides</i>	Lee Marsh	336699	4155712

season (Emlen, 1974). Habitat -specific correction factors were calculated for the bird community as a whole and for individual species with adequate sample sizes. Average seasonal densities were calculated for the bird community by averaging densities calculated for each survey round during the individual seasons. The densities for individual species with adequate sample sizes were determined for each point and an average density value was calculated based on the 3 survey rounds. Habitat and substrate effects were determined by using one-way ANOVA and Tukey honest significant different tests were used to evaluate the relationship of differences.

RESULTS

A total of 3,510 detections of 38 species were made during both survey seasons within all habitat types (see Appendix 1 for list of birds detected). During the summer surveys 1,711 observations were made on 19 species. Tree swallows, red-winged blackbirds, and marsh wrens were the most frequently detected species, making up 43%, 35%, and 13% of all summer observations (see Appendix 2 for summer bird list with numbers and habitats). Winter surveys resulted in 1,799 detections of 26 species. Six species of birds, herring gulls, ring-billed gulls, green-winged teal, Canada geese, dunlin, and red-winged blackbirds accounted for 89% of all observations during the winter surveys (see Appendix 3 for winter birds list with numbers and habitats).

Summer Surveys

Of the 1,711 detections made during the summer season, 732 were made at the 11 *Peltandra* mix points, 443 were made at the 11 *S. cynosuroides* points, and 536 occurred at the 10 *Phragmites* points. Species richness values were the greatest at points within the *S. cynosuroides* habitat and lowest at the *Phragmites* points (Figure 4). Overall bird densities were estimated to be the greatest within the *Peltandra* mix and *Phragmites* habitats (Figure 5). However, these densities were driven by numerous tree swallows observed foraging over survey points, especially those located within *Peltandra* mix and *Phragmites* habitats (Figure 6). Habitat type had a significant influence on the density of 2 of the 3 most frequently detected species, excluding tree swallows (Table 3). The density of red-winged blackbirds within the *Peltandra* mix habitat was calculated to be significantly higher than densities calculated for the same species in both *S. cynosuroides* and *Phragmites* habitats (Figure 7). The density calculated for common yellowthroats within *Phragmites* habitats was significantly higher than those in either *Peltandra* mix or *S. cynosuroides* habitats (Figure 8). While the calculated densities for marsh wrens were higher in both *Peltandra* mix and *S. cynosuroides* than in *Phragmites* habitats the differences were not found to be significant (Figure 9).

The birds detected at survey points within individual habitat types were not necessarily using the target substrate. This is especially true for points within *Peltandra* mix and *Phragmites* habitats. At numerous points target substrates were patchy or linear in nature

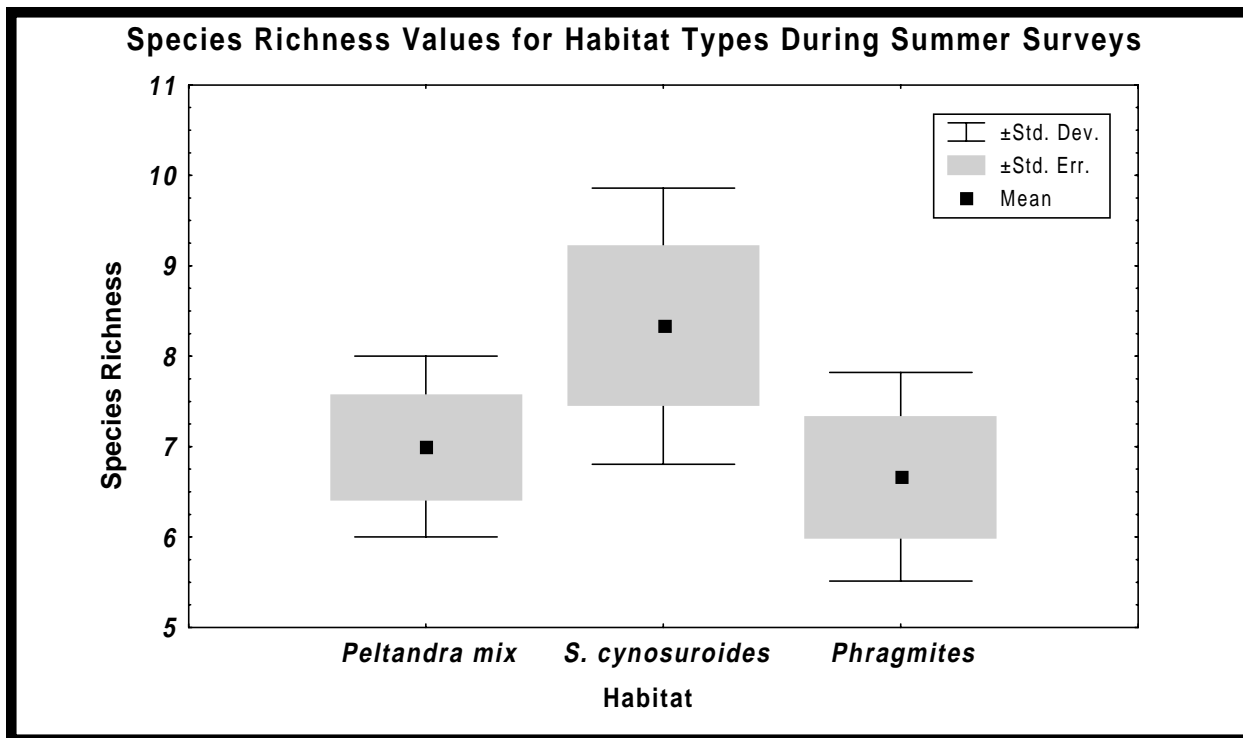


Figure 4. Species richness values calculated for the 3 habitat types during the summer breeding season.

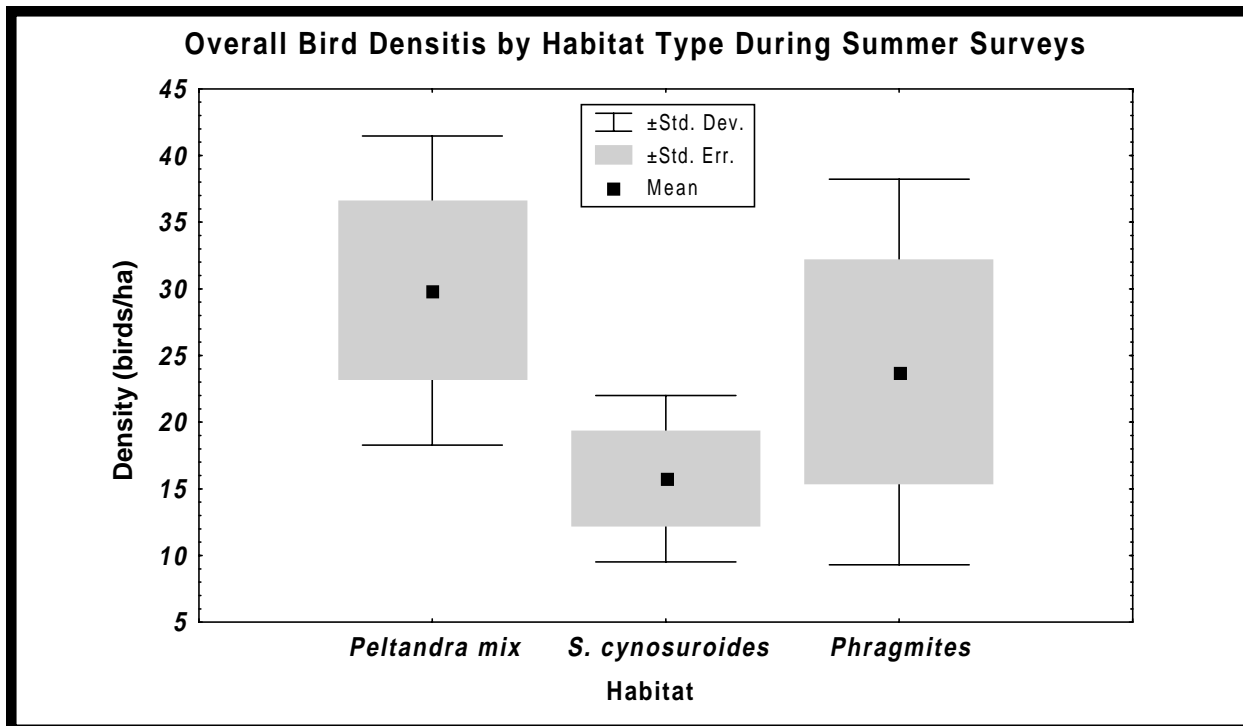


Figure 5. Overall bird densities calculated for the 3 habitat types during the summer breeding season.

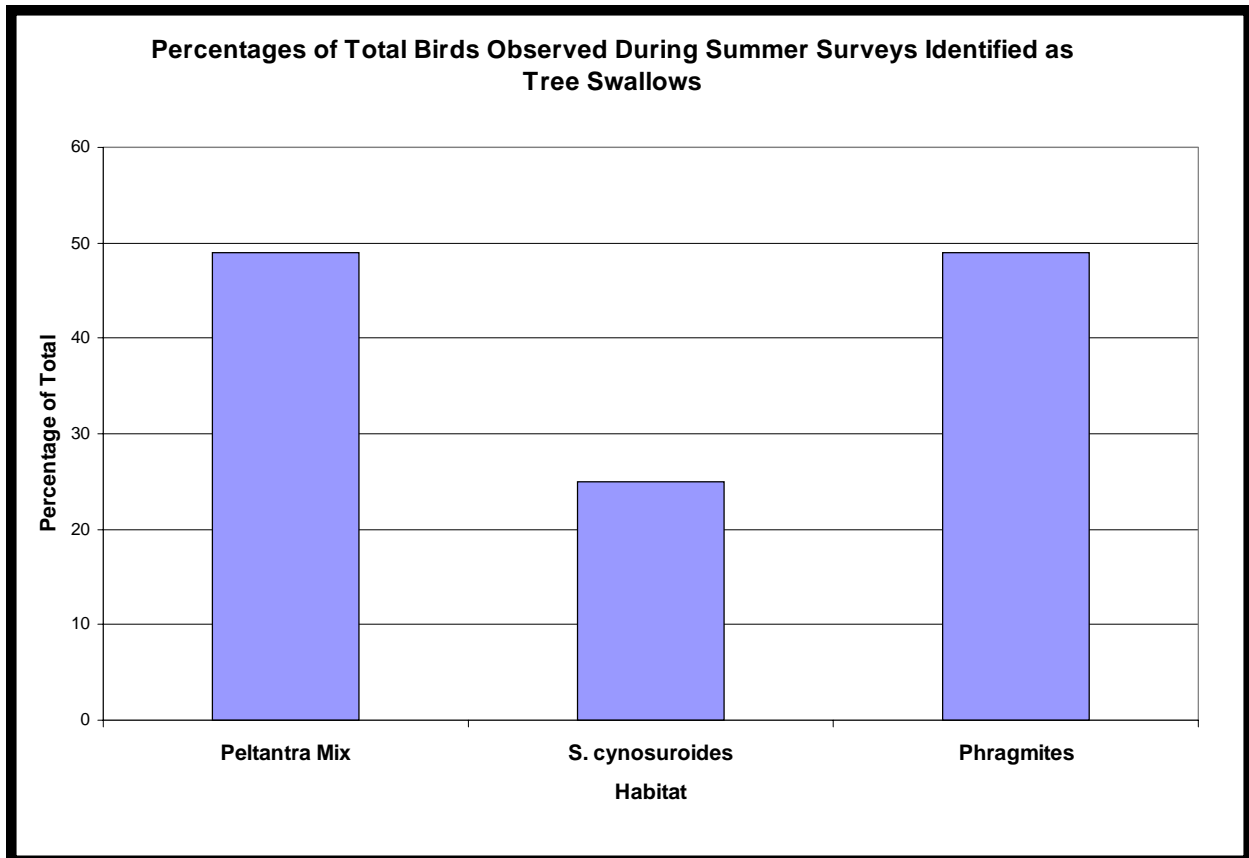


Figure 6. Percentages of the total number of birds observed during the summer breeding season, within the 3 habitat types, accounted for by tree swallows.

Table 3. Results of one-way ANOVAs comparing mean densities of selected species detected during summer surveys across habitat types within Lee and Hill Marshes.

Species	SS	MS	MSE	F	P
Red-winged Blackbird	131.3	65.6	7.2	9.14	<0.001
Marsh Wren	13.8	6.9	4.0	1.72	>0.05
Common Yellowthroat	8.5	4.2	0.3	13.73	<0.001

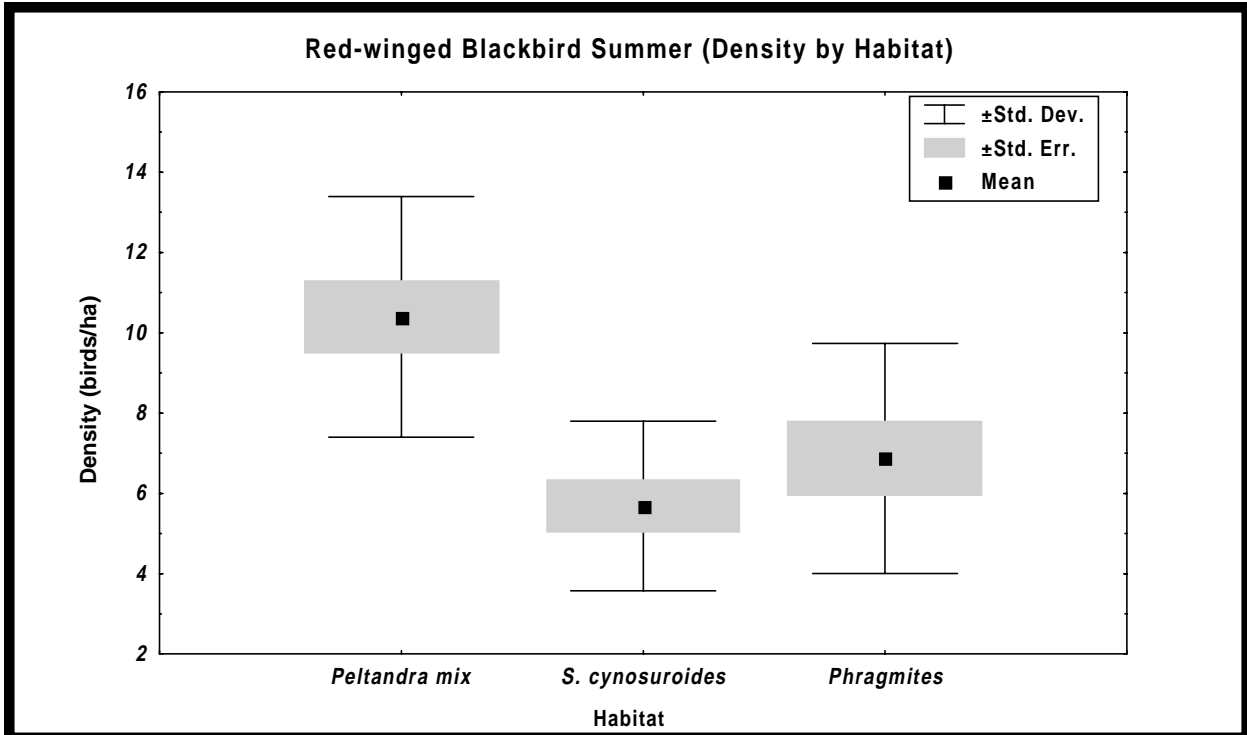


Figure 7. Red-winged blackbird densities calculated for the 3 habitat types during the summer breeding season

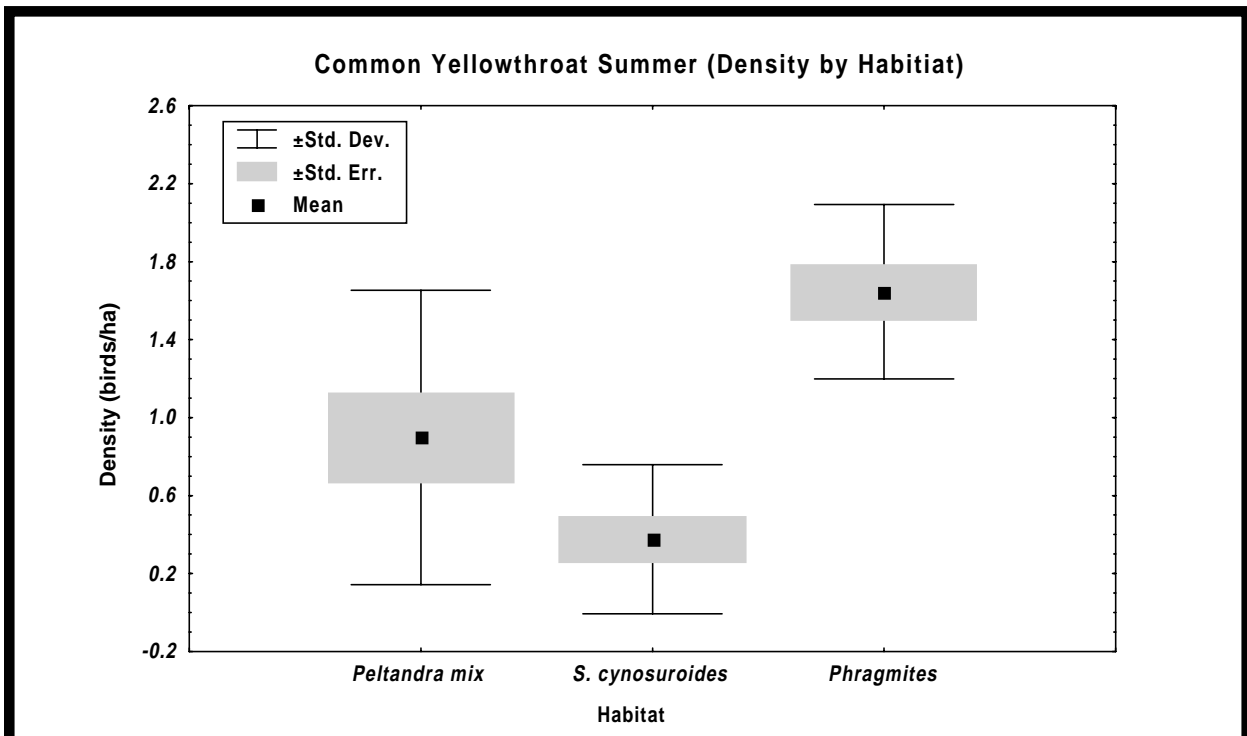


Figure 8. Common yellowthroat densities calculated for the 3 habitat types during the summer breeding season.

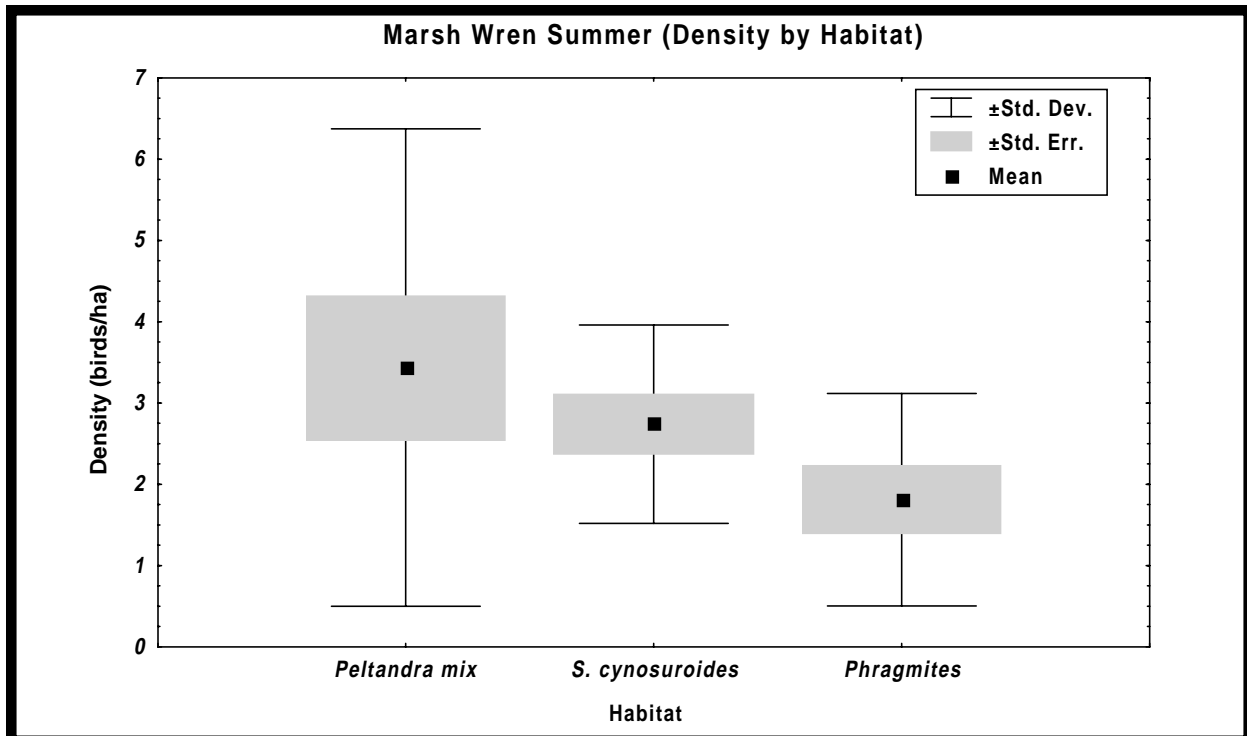


Figure 9. Marsh wren densities calculated for the 3 habitat types during the summer breeding season.

and may have only occupied a fraction of the actual survey area. For this reason species richness and density values were also calculated for detections that occurred within like substrate and habitat types. Species richness values for substrates followed the same trend observed in habitat types with the highest values occurring in *S. cynosuroides* substrates and the lowest values occurring in *Phragmites* habitats (Figure 10). Overall bird density shifted with the greatest density occurring in the *S. cynosuroides* substrate (Figure 11). Substrate type had significant influences on the densities of all 3 of the most frequently detected species (Table 4). Red-winged blackbirds and marsh wrens were observed at higher densities in *S. cynosuroides* than in either *Peltandra mix* or *Phragmites* (Figures 12 and 13) and common yellowthroats were found at higher densities in *Phragmites* than in the other 2 substrate types (Figure 14).

Additional observations of interest included large flocks of tree swallows. These flocks roosted on *Phragmites* and *H. moscheutos* and foraged over the marshes, and were particularly abundant on Hill marsh. Tree swallows were detected during each survey round during the summer season but the numbers detected increased as the season progressed, reaching a high of 572 detections during the last round of surveys (Figure 15). Thousands of individuals were observed off of survey points.

Least bitterns were observed frequently while moving to survey points. While only one was detected within a survey point, at least 11 other detections were made off of

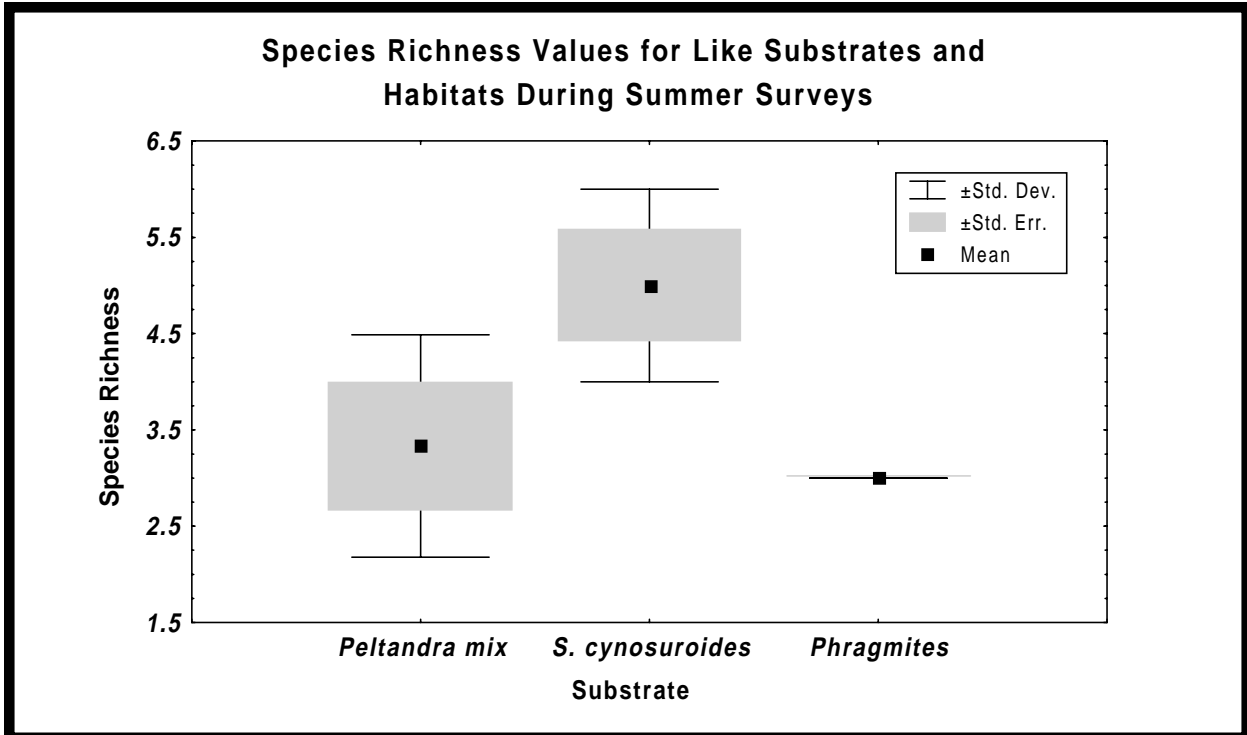


Figure 10. Species richness values calculated for like substrates and habitats during the summer breeding season.

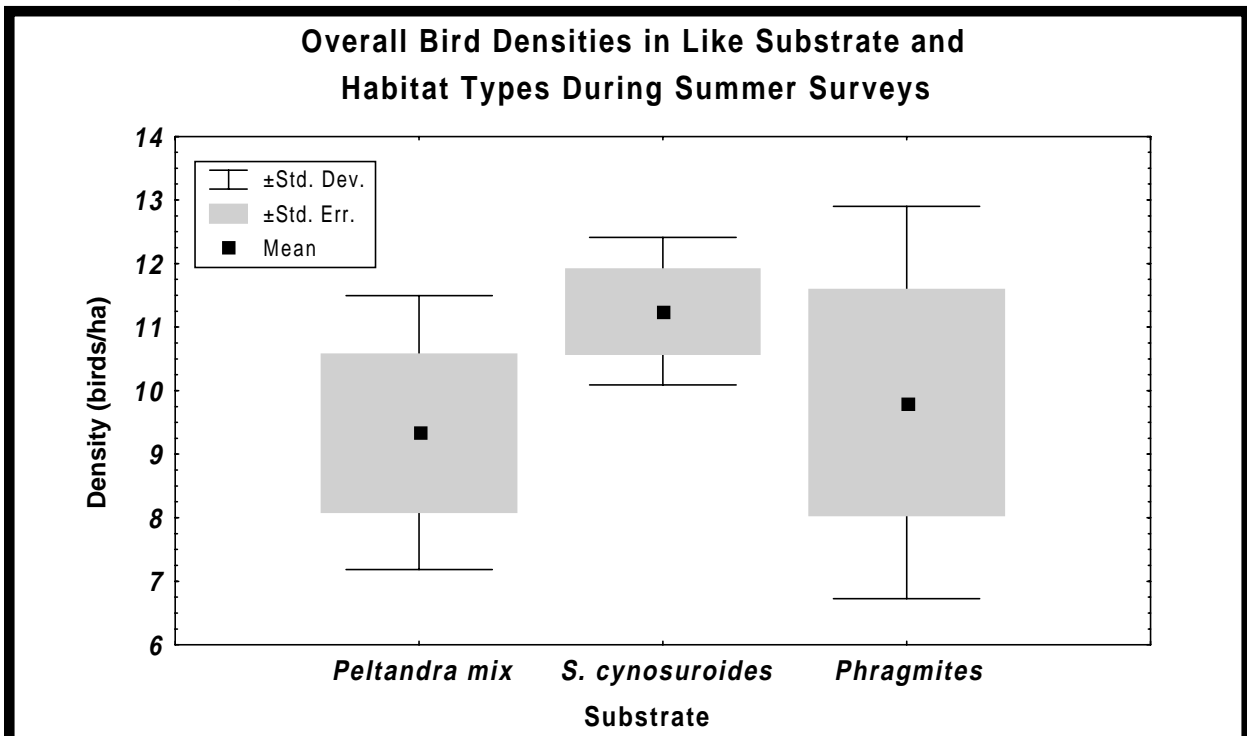


Figure 11. Overall bird densities calculated for like substrates and habitats during the summer breeding season.

Table 4. Results of one-way ANOVAs comparing mean densities of selected species detected during summer surveys across like substrate and habitat types within Lee and Hill Marshes.

Species	SS	MS	MSE	F	P
Red-winged Blackbird	190.7	95.4	19.5	4.89	<0.05
Marsh Wren	274.7	137.4	6.1	22.44	<0.001
Common Yellowthroat	13.5	6.8	0.4	19.26	<0.001

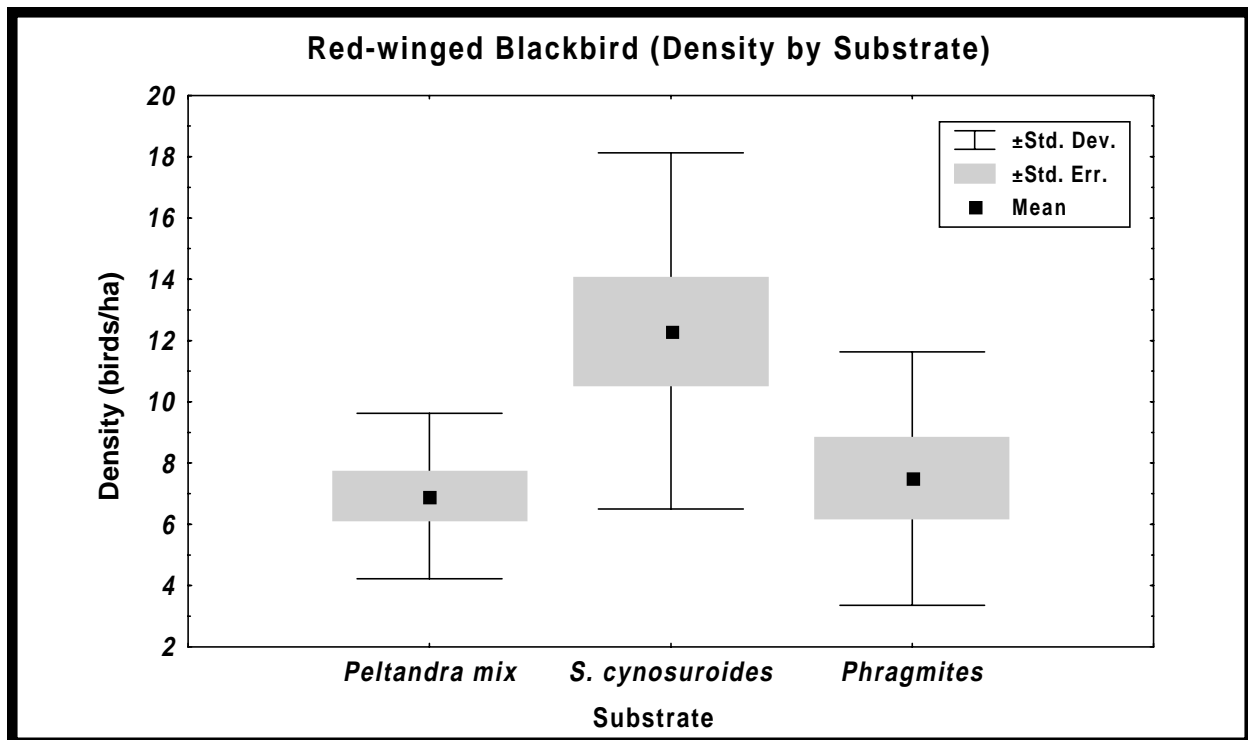


Figure 13. Red-winged blackbird densities calculated for like substrates and habitats during the summer breeding season..

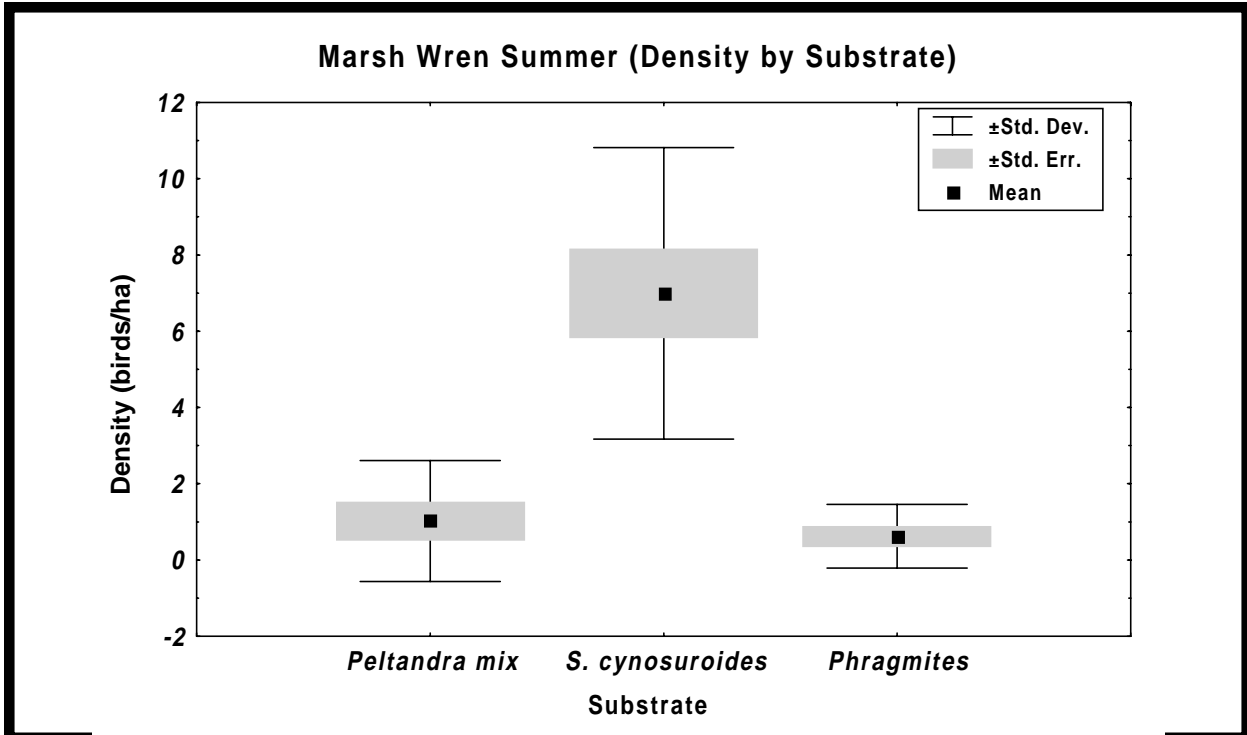


Figure 13. Marsh wren densities calculated for like substrates and habitats during the summer breeding season..

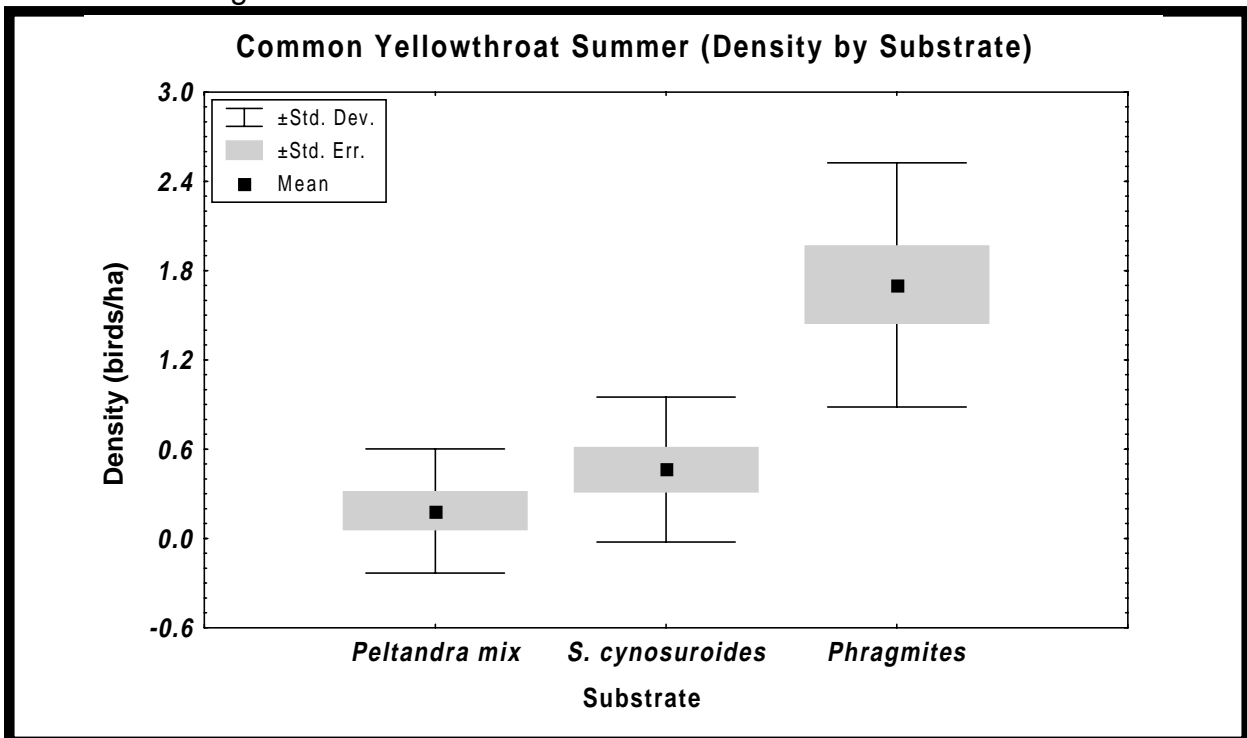


Figure 14. Common yellowthroat densities calculated for like substrates and habitats during the summer breeding season..

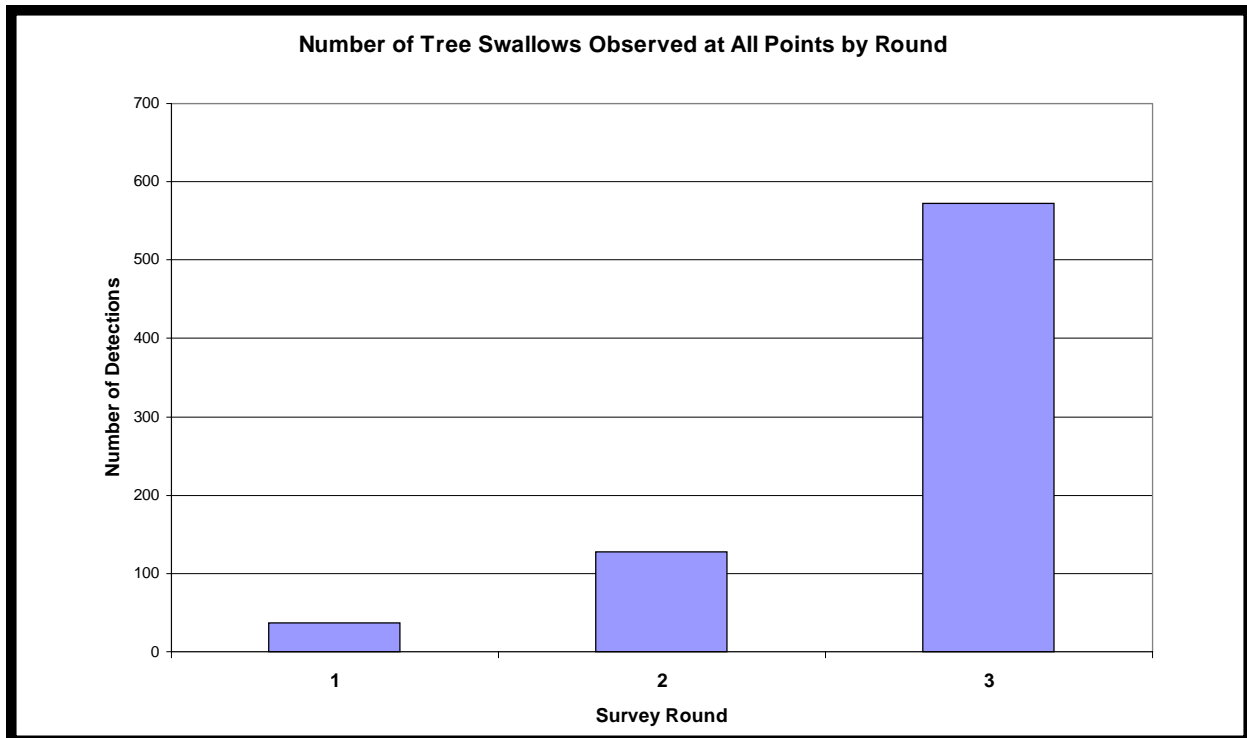


Figure 1. Temporal pattern of tree swallow observations ,in all habitat types combined, during the summer breeding season.

survey areas. Least bitterns were typically observed on or flushed from the exposed mud banks at the waters edge and were most often associated with the *Peltandra* mix habitat.

Thirteen king rails were detected on survey points. Observations were made in all habitat types, but were most frequent at points within *Peltandra* mix and *S. cynosuroides* habitats. Six detections were made at survey points within each of these habitats.

Winter Surveys

Of the 1,799 detections made during winter surveys, the vast majority (1,720 or nearly 96%) occurred within *Peltandra* mix habitats, while *S. cynosuroides* and *Phragmites* accounted for only 51 and 28 detections respectively. *Peltandra* habitats also exhibited the greatest species richness (Figure 16) and overall bird density (Figure 17). The high bird numbers and species diversity within the *Peltandra* mix habitats was driven by birds utilizing the exposed mud flats created after most of the dense *Peltandra* vegetation died and was removed through tidal action. Large numbers of waterfowl, gulls, and shorebirds foraged amongst the remaining old and newly emerging vegetation. Habitat type significantly influenced the densities of one of the two most frequently observed species, excluding waterfowl, gulls and shorebirds (Table 5). Red-winged blackbirds were detected at greater densities within *Peltandra* mix and *S. cynosuroides* habitats than in



Large patch of *Peltandra* mix habitat located within Hill Marsh (photo by Bryan Watts).

King rail, this species was detected within all habitat types but was most frequently associated with *Peltandra* mix, and *Spartina cynosuroides* habitats (photo by Bryan Watts).



Table 5. Results of one-way ANOVAs comparing mean densities of selected species detected during winter surveys across habitat types within Lee and Hill Marshes.

Species	SS	MS	MSE	F	P
Red-winged Blackbird	16.6	8.3	2.3	3.57	<0.05
Swamp Sparrow	130.0	64.9	133.5	0.49	>.05

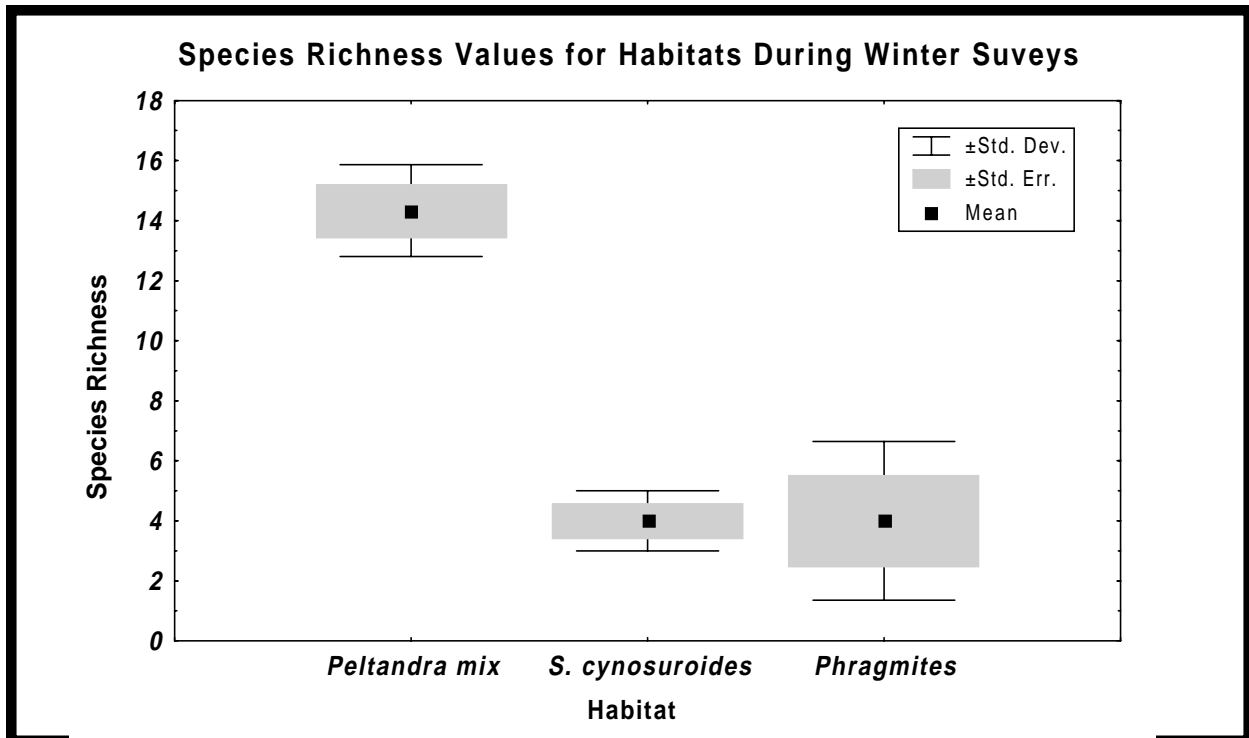


Figure 16. Species richness values calculated for the 3 habitat types during the winter season.

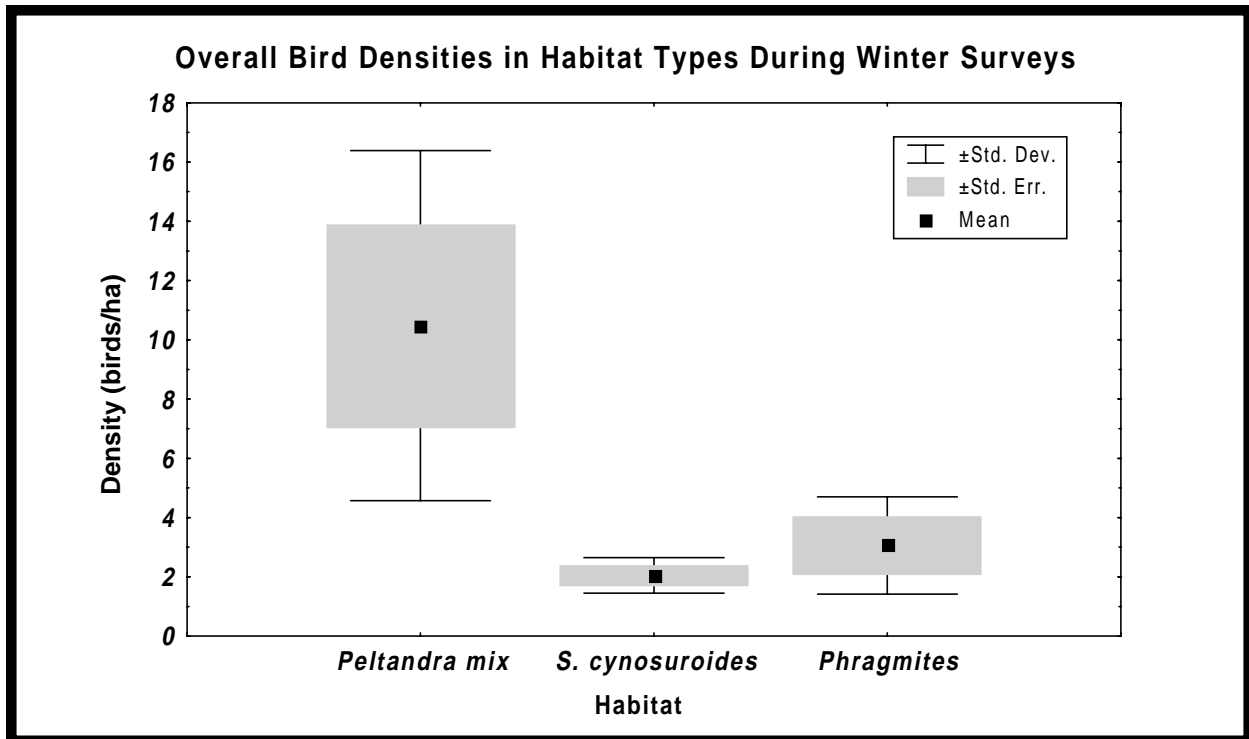


Figure 17. Overall bird densities calculated for the 3 habitat types during the winter season.

Phragmites (Figure 18). While swamp sparrow densities appeared greater within *S. cynosuroides* habitats no significant difference was found when compared to the other habitat types (Figure 19).

When only detections made in like substrate and habitat type were included in analyses, species richness and overall bird density was still found to be greatest in *Peltandra* mix substrates (Figure 20 and 21). Densities of red-winged blackbirds were significantly influenced by substrate type (Table 6), with greater the densities observed in *S. cynosuroides* than in *Phragmites* (Figure 22). Swamp sparrow densities were again higher, but not significant, in *S. cynosuroides* (Figure 23).

Shorebirds and waterfowl were recorded at points within the *Peltandra* mix habitat only. Mixed species flocks of ducks and shore bird were often observed foraging in the mud amongst dead and newly emerging *Peltandra* vegetation. Data from waterfowl surveys of Hill and Lee marshes were acquired from the Virginia Department of Game and Inland Fisheries. These data were collected from aerial surveys of the marshes conducted in November and January of 1998, 1999, 2000, 2001, and January of 2002 resulting in 9 surveys for each marsh. During these 9 surveys significantly greater species richness values and waterfowl numbers were observed in Hill marsh than in Lee marsh (see Appendix 4 for species and numbers of waterfowl detected in each marsh during VDGIF surveys). Mean species richness values for Hill marsh were 4.22 ± 1.79 , while the value for Lee

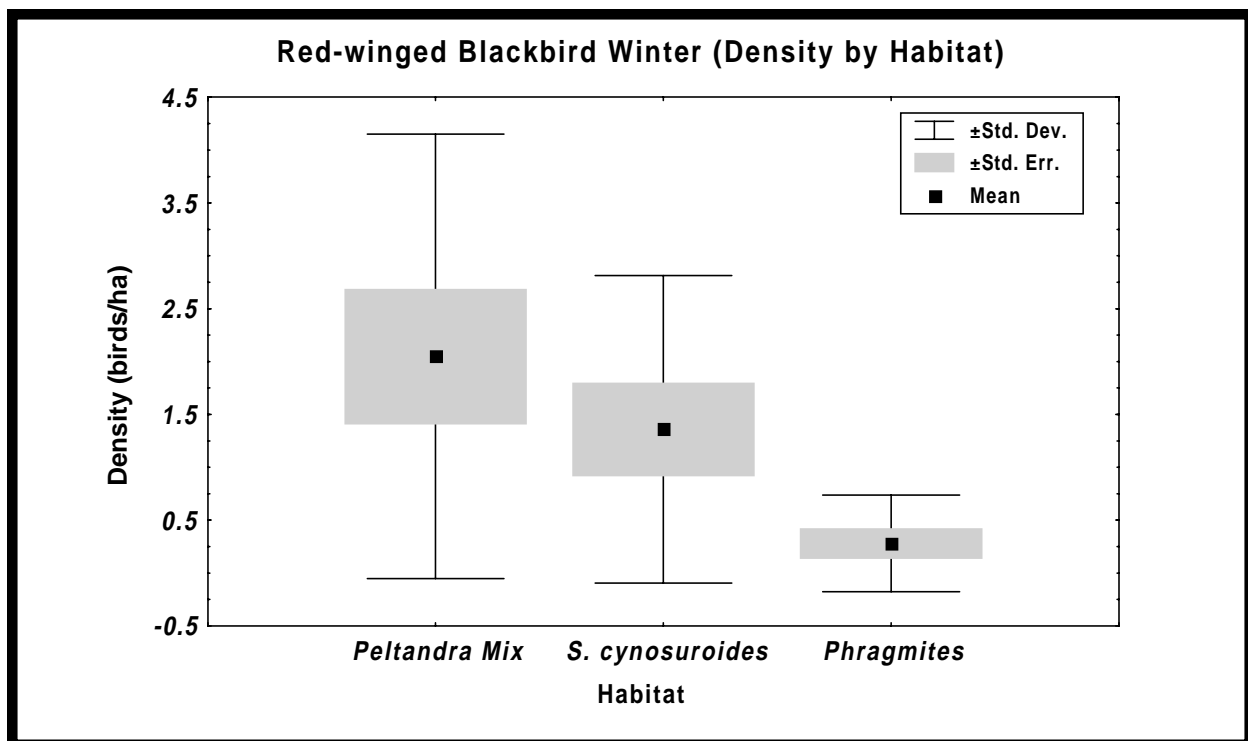


Figure 18. Red-winged blackbird densities calculated for the 3 habitat types during the winter season.

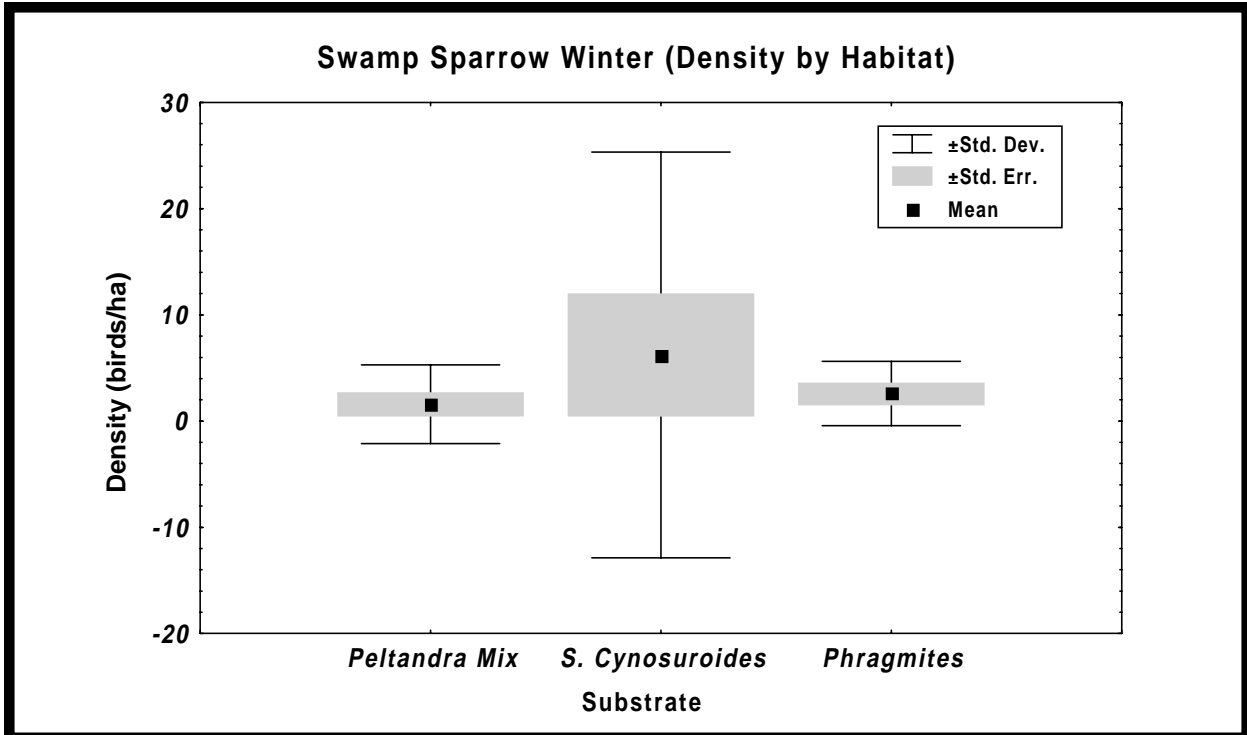


Figure 19. Swamp sparrow densities calculated for the 3 habitat types during the winter season.

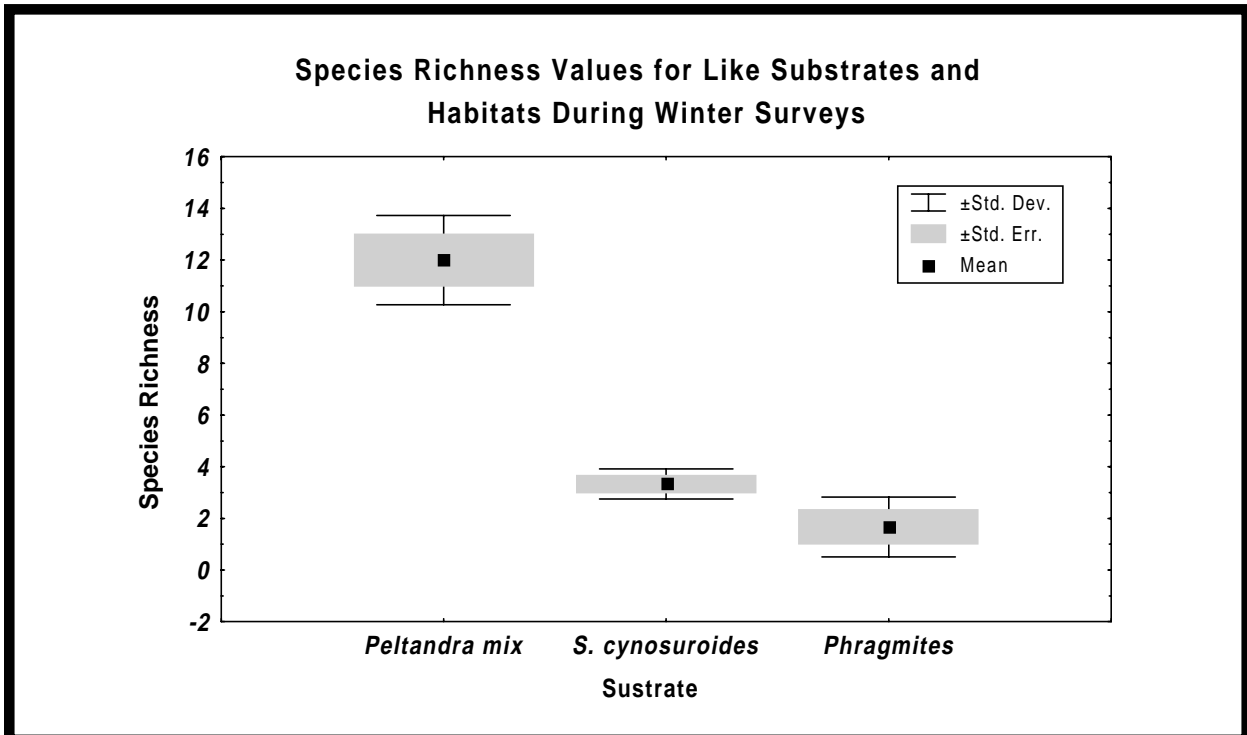


Figure 20. Species richness values calculated for like substrates and habitats during the winter season..

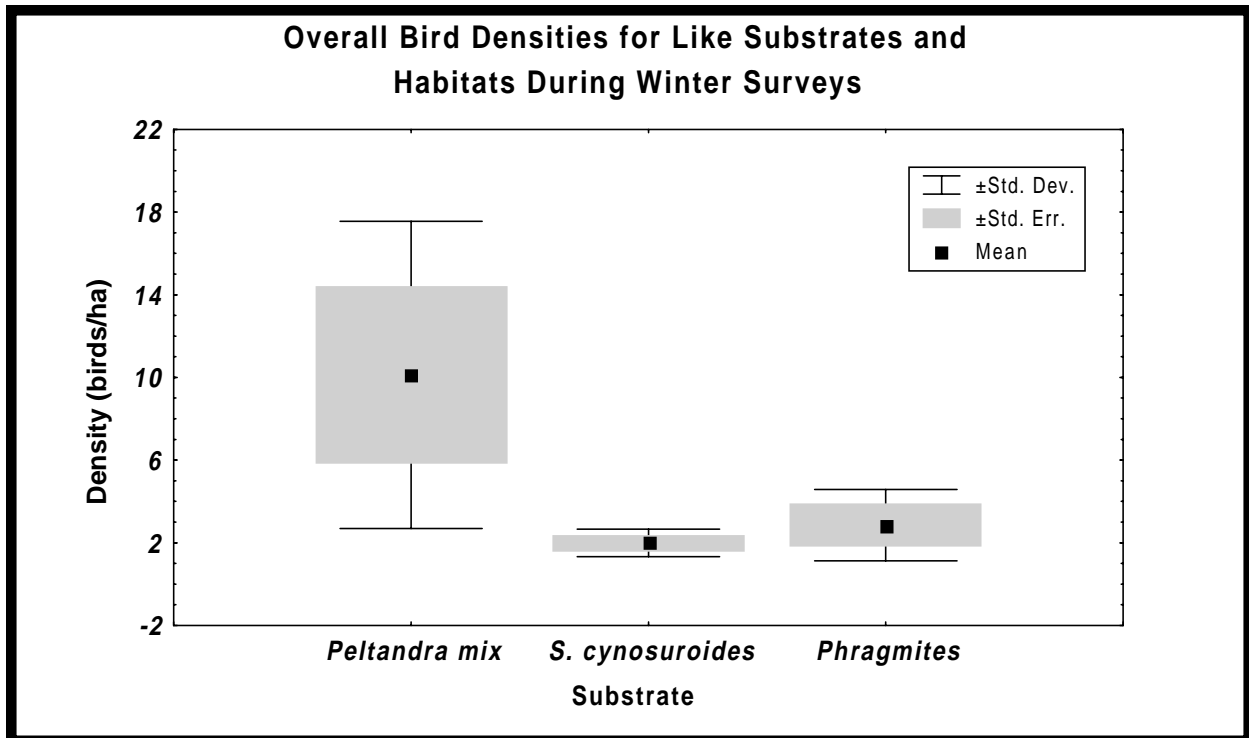


Figure 21. Overall bird densities calculated for like substrates and habitats during the winter season.

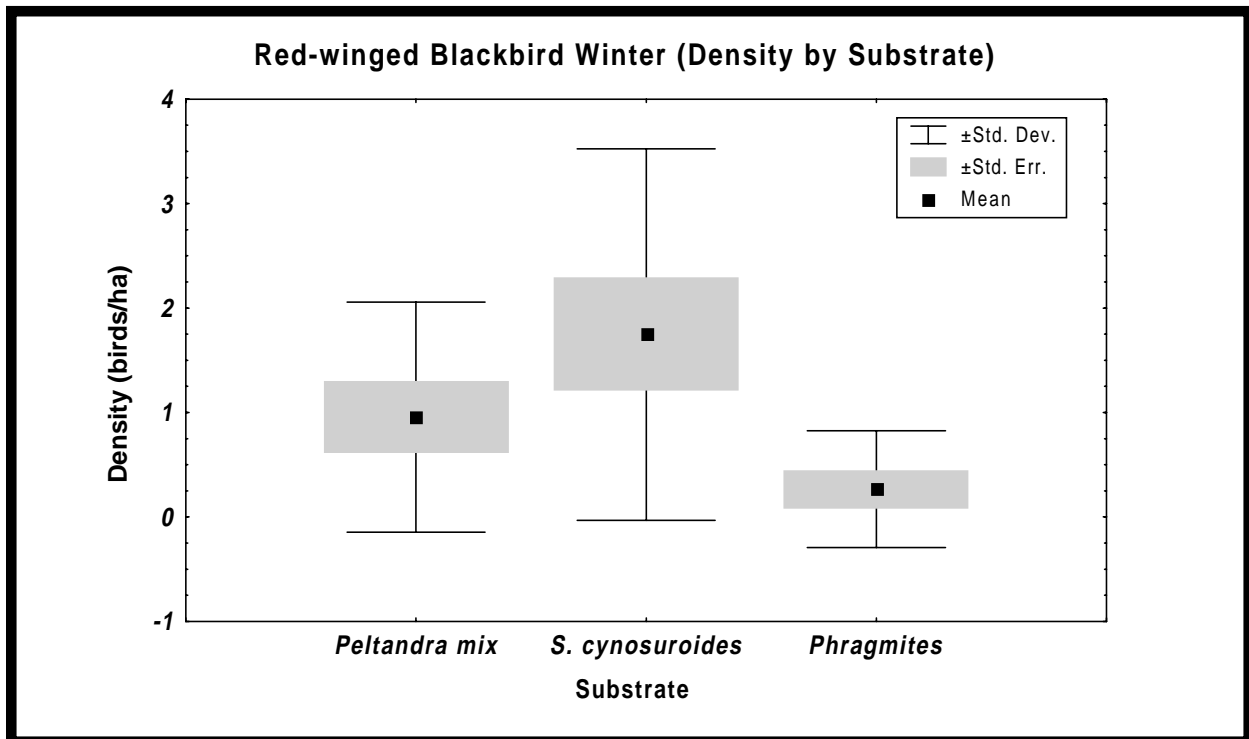


Figure 22. Red-winged blackbird densities calculated for like substrates and habitats during the winter season.

Table 6. Results of one-way ANOVAs comparing mean densities of selected species detected during winter surveys across like substrate and habitat types within Lee and Hill Marshes.

Species	SS	MS	MSE	F	P
Red-winged Blackbird	11.5	5.8	1.6	3.60	<0.05
Swamp Sparrow	244.7	122.4	134.0	0.91	>.05

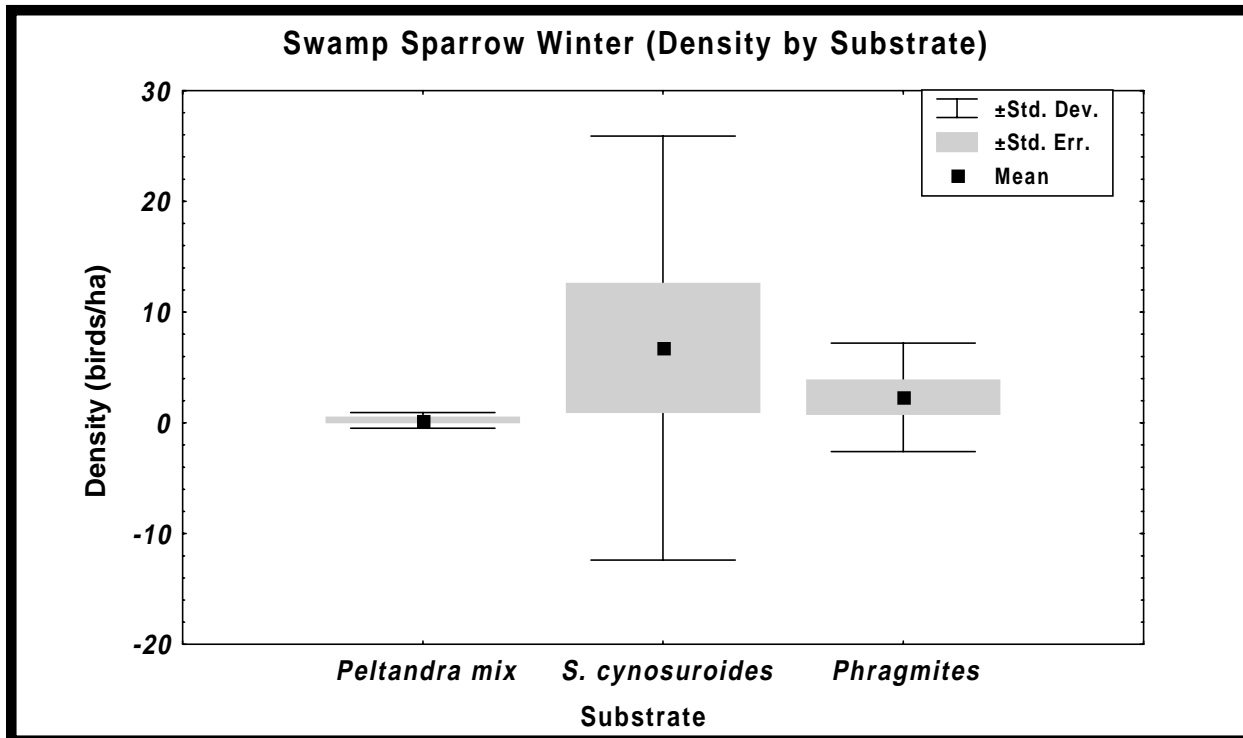


Figure 23. Swamp sparrow densities calculated for like substrates and habitats during the winter season.

marsh was 2.44 ± 0.73 (t-test: $t=2.76$, $p<0.05$, $n=9$, 9). Mean numbers of waterfowl detected in Hill and Lee marshes were 1128.11 ± 976.28 and 171.78 ± 140.06 respectively (t-test: $t=2.91$, $p<0.05$, $n=9$, 9).

DISCUSSION

Hill and Lee Marshes appear to provide important breeding, stopover, and winter habitat for a variety of bird species. In addition to providing the habitat types required by the different bird species, these marshes also are very large in size. There is a strong correlation in the patch size of marshes and the species richness and abundance of the birds that occupy it (Watts, 1992). The 3 vegetation communities used in this study were unique when bird abundance and the species of birds using them were compared.



Peltandra mix habitat in Hill Marsh during the winter season, after the dead vegetation has been removed by tidal actions.

***Peltandra* mix** – During the summer breeding this habitat type supported similar densities of birds overall as *S. cynosuroides* and Phragmites. Only marsh wrens and common yellowthroats were detected at significantly lower densities within *Peltandra* mix substrates than either of the other 2 habitat types. Marsh birds seemed to prefer the *Peltandra* mix, with nearly half of all king rail observations and the only least bittern detection occurring at points associated with this habitat. The large flocks of tree swallows that foraged over the marshes seemed particularly numerous over *Peltandra* patches. These flocks may be taking advantage of large hatches midges (*Chironomidae*) observed covering *Peltandra* vegetation during the same period.

In the winter, after the *Peltandra* vegetation dies and is removed by tidal actions, large mud flats are exposed. These mud flats were utilized by large numbers of waterfowl, gulls, and shorebirds. Surveys were conducted prior to the peak spring migration for both shorebirds and waterfowl, so it is not known whether these mudflats would be available for these migrant species. If the mud flat were accessible to migrant waterfowl and shorebird, the actual number of birds utilizing this habitat could be many times higher than what was observed.

S. cynosuroides – Surveys of this habitat during the breeding season revealed the highest densities of red-winged blackbirds, marsh wrens, and birds overall. The marsh wren density was calculated at nearly 7 times higher than either of the other habitats. As

many king rails were detected at points within *S. cynosuroides* habitats as were detected at *Peltandra* points.

During the winter the density of birds within this habitat declined dramatically but it still provided habitat for fewer numbers of red-winged blackbirds, marsh wrens and two species of sparrows that were not detected during the summer surveys (swamp sparrows

Phragmites – Only one species of bird, the common yellowthroat, was detected at higher densities within this habitat during summer surveys. Overall bird densities were comparable to the other habitats, but species richness values were the lowest in *Phragmites*. The patches of *Phragmites* found within these two marshes typically only occupy the highest elevation and are therefore small patches restricted to tall hummocks or banks. The edges of these small patches seem to provide cover and nesting substrate that certain species of birds are utilizing along with other marsh vegetation. The small size of these *Phragmites* patches increases the area of edge making them more attractive to some species. Large, monocultures of *Phragmites* are typically considered poor habitat for birds and support few individuals and low diversity (Meyerson et. al., 2000). Many tree swallows were observed using *Phragmites* as a roosting site. During winter surveys, bird densities declined dramatically as in *S. cynosuroides* habitats and the species richness values remained low for this habitat.

If sea levels continues to rise as predicted, changes will be observed in the vegetation communities of marshes. As water levels rise and salinity levels increase, plant species that are intolerant to frequent inundation and higher salinity levels are likely to be replaced by species more tolerant of these conditions. Based on the surveys of habitat types and the bird densities estimated for the specific habitat types, general projections could be made for changes in bird densities for speculated changes in the vegetation community (see Table 7 for seasonal list of estimated densities). A possible scenario

Table 7. Seasonal density estimates, for selected bird species and groups, within like substrate and habitat types.

Species	<i>Peltandra</i> Mix		<i>S. cynosuroides</i>		<i>Phragmites</i>	
	Summer	Winter	Summer	Winter	Summer	Winter
All Birds	9.3	10.1	11.2	2.0	9.8	2.9
Red-winged Blackbird	7.5	1.0	8.0	1.4	7.5	0.3
Marsh Wren	1.0	-	6.9	-	0.6	-
Common Yellowthroat	0.2	-	0.5	-	1.7	-
Swamp Sparrow	-	0.2	-	6.2	-	2.3
Waterfowl	-	2.3	-	-	-	-
Shorbirds	-	5.7	-	-	-	-

could be small reductions in breeding red-wing blackbird and increases in foraging winter waterfowl if *S. cynosuroides* was replaced by *Peltandra* after a rise in water level (Figure 24). However to make the best predictions of changes in the bird community one would have to know the plant communities expected to replace the current communities, as well as the bird densities associated with them, after sea level rise events.

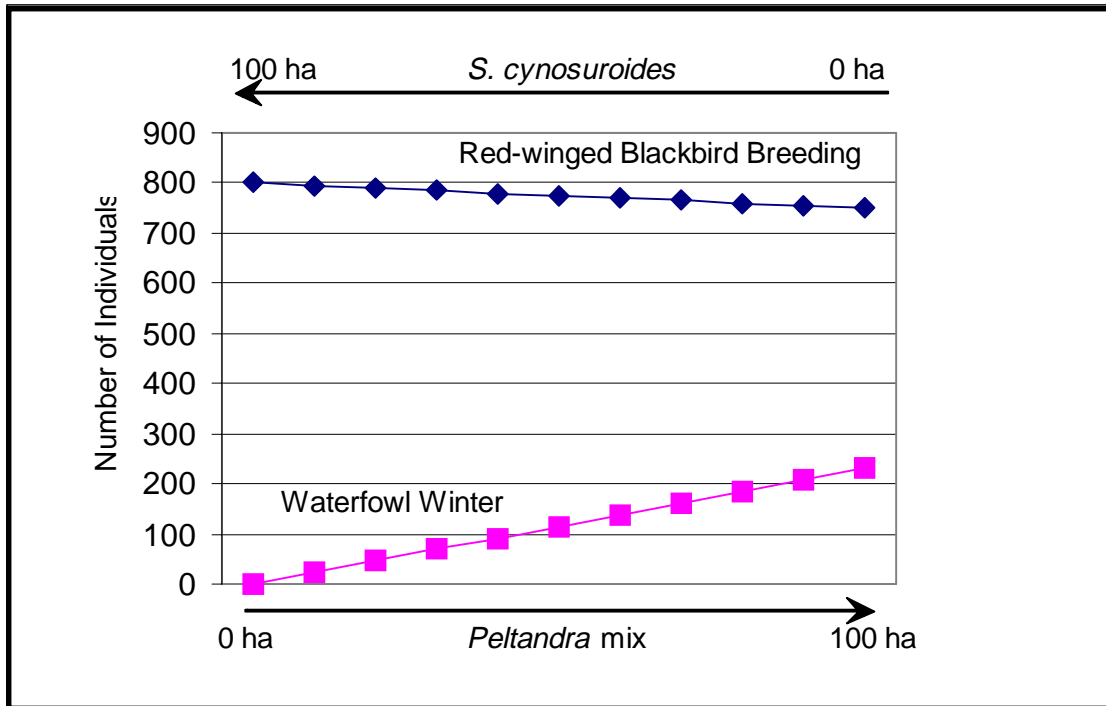


Figure 24. Projections of red-winged blackbird and waterfowl populations if 100 ha of *S. cynosuroides* habitat would be replaced by *Peltandra* mix habitat.

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Appendix I: List of Species detected during surveys.

Common Name	Scientific Name
Least Bittern	<i>Ixobrychus exilis</i>
Great Blue Heron	<i>Ardea herodias</i>
Canada Goose	<i>Branta canadensis</i>
Wood Duck	<i>Aix sponsa</i>
Mallard	<i>Anas platyrhynchos</i>
American Black Duck	<i>Anas rubripes</i>
American Green-winged Teal	<i>Anas crecca</i>
Northern Harrier	<i>Circus cyaneus</i>
Red-tailed Hawk	<i>Buteo jamaicensis</i>
Bald Eagle	<i>Haliaeetus leucocephalus</i>
Osprey	<i>Pandion haliaetus</i>
King Rail	<i>Rallus elegans</i>
Virginia Rail	<i>Rallus limicola</i>
Killdeer	<i>Charadrius vociferus</i>
Greater Yellowlegs	<i>Tringa melanoleuca</i>
Lesser Yellowlegs	<i>Tringa flavipes</i>
Spotted Sandpiper	<i>Actitis macularia</i>
Dunlin	<i>Calidris alpina</i>
Least Sandpiper	<i>Calidris minutilla</i>
Common Snipe	<i>Gallinago gallinago</i>
Ring-billed Gull	<i>Larus delawarensis</i>
Herring Gull	<i>Larus argentatus</i>
Belted Kingfisher	<i>Ceryle alcyon</i>
American Crow	<i>Corvus brachyrhynchos</i>
Purple Martin	<i>Progne subis</i>
Bank Swallow	<i>Riparia riparia</i>
Tree Swallow	<i>Tachycineta bicolor</i>
Cliff Swallow	<i>Petrochelidon pyrrhonota</i>
Barn Swallow	<i>Hirundo rustica</i>
Marsh Wren	<i>Cistothorus palustris</i>
Common Yellowthroat	<i>Geothlypis trichas</i>
Savannah Sparrow	<i>Passerculus sandwichensis</i>
Song Sparrow	<i>Melospiza melodia</i>
Swamp Sparrow	<i>Melospiza georgiana</i>
Brown-headed Cowbird	<i>Molothrus ater</i>
Red-winged Blackbird	<i>Agelaius phoeniceus</i>
Common Grackle	<i>Quiscalus quiscula</i>
House Finch	<i>Carpodacus mexicanus</i>

Appendix II: Species list and numbers of birds detected during summer surveys within the 3 habitat types.

Common Name	<i>Peltandra</i> mix	<i>S.</i> <i>cynosuroides</i>	<i>Phragmites</i>	Total
Least Bittern	1	0	0	1
Great Blue Heron	0	1	0	1
Canada Goose	5	0	0	5
Wood Duck	3	0	0	3
American Black Duck	0	1	0	1
Osprey	0	1	0	1
King Rail	6	6	1	13
Spotted Sandpiper	0	1	0	1
Purple Martin	0	4	4	8
Bank Swallow	1	0	1	2
Tree Swallow	362	112	262	736
Cliff Swallow	0	1	0	1
Barn Swallow	13	10	32	55
Marsh Wren	62	119	33	214
Common Yellowthroat	18	10	42	70
Brown-headed Cowbird	0	1	0	1
Red-winged Blackbird	261	176	159	596
Common Grackle	0	0	1	1
House Finch	0	0	1	1
Total	732	443	536	1711

Appendix III: Species list and numbers of birds detected during winter surveys within the 3 habitat types.

Common Name	<i>Peltandra</i> mix	<i>Spartina</i> <i>cynosuroides</i>	<i>Phragmites</i>	Total
Great Blue Heron	1	0	0	1
Canada Goose	135	0	0	135
Mallard	2	0	0	2
American Black Duck	51	0	0	51
American Green-winged Teal	364	0	0	364
Northern Harrier	1	0	0	1
Red-tailed Hawk	0	0	1	1
Bald Eagle	1	0	0	1
King Rail	0	2	1	3
Virginia Rail	0	0	1	1
Killdeer	18	0	0	18
Greater Yellowlegs	21	0	0	21
Lesser Yellowlegs	7	0	0	7
Dunlin	140	0	0	140
Least Sandpiper	2	0	0	2
Common Snipe	24	0	0	24
Ring-billed Gull	721	0	0	721
Herring Gull	104	0	0	104
Belted Kingfisher	1	0	0	1
American Crow	13	0	0	13
Tree Swallow	0	0	3	3
Marsh Wren	3	3	5	11
Savannah Sparrow	1	0	0	1
Song Sparrow	1	5	2	8
Swamp Sparrow	7	5	11	23
Red-winged Blackbird	102	36	4	142
Total	1720	51	28	1799

Appendix IV: List of Species detected during surveys.

Date	Hill Marsh									Lee Marsh			
	MALL	ABDU	COGO	AGWT	GADW	AMWI	NOPI	MERG	RNDU	MALL	ABDU	CAGO	AGWT
January 1998	55	5	705	-	-	-	-	-	-	139	133	-	20
November 1998	200	25	375	-	-	-	-	-	-	130	23	-	-
January 1999	1012	1065	400	170	120	60	40	8	-	5	84	7	5
November 1999	30	42	8	-	-	-	-	-	-	80	3	-	-
January 2000	249	31	175	10	-	-	-	-	150	40	15	-	-
November 2000	7	38	100	-	100	-	-	-	-	128	362	-	-
January 2001	358	261	900	-	-	-	-	5	885	51	131	-	-
November 2001		7	867	-	-	-	-	-	-	38	22	-	-
January 2002	467	80	964	-	4	-	-	-	175	48	62	-	20