Interim Wormsloe Fellow Report

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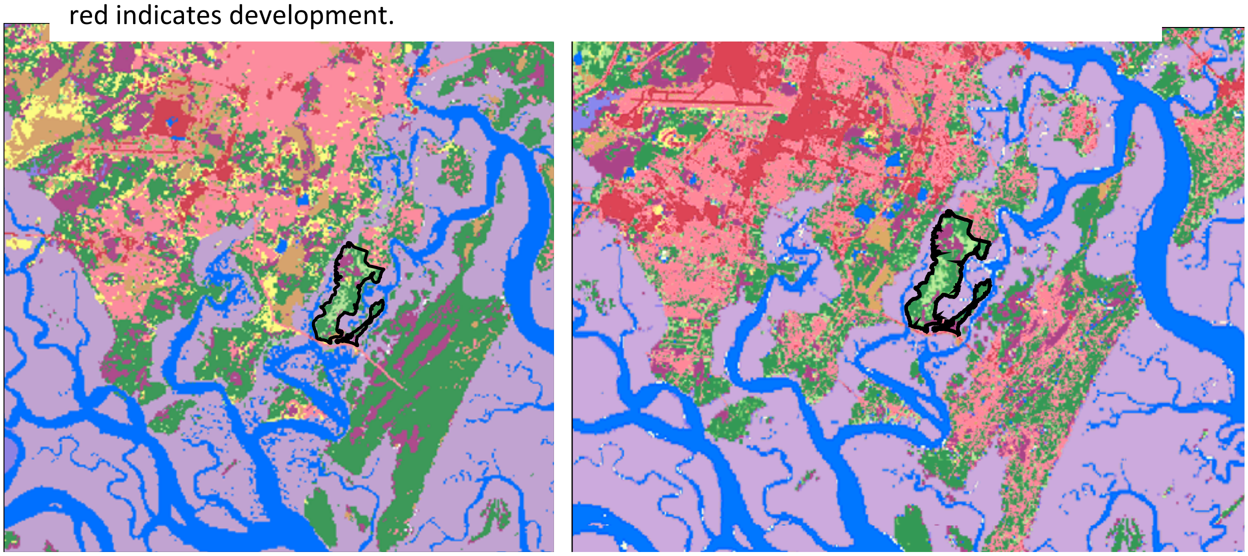
Regional land use – land cover around Wormsloe in 1978 (left) and 2008 (right). Pink and red indicates development.



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1 Introduction

I have been a Wormsloe Fellow since August 2010. My initial project, and scope of work as a Wormsloe Fellow, was a vertebrate inventory of Wormsloe. I collected field data from March 2011 thru July 2012. However, the focus of my work shifted as I discovered what species occurred at Wormsloe, the seasonality of freshwater ponds, and continuing land-use legacy of drainage ditches. Additionally, when possible, I incorporated other aspects of Wormsloe into class projects. Consequently, given the broad extent of my work as a Wormsloe Fellow, this report summarizes a diverse number of projects.

2 Vertebrate Inventory

2.1 Amphibians and Reptiles

The historical as well as current distribution of amphibians and reptiles (herpetofauna or herps) on the coastal islands of Georgia is poorly understood. The literature reports mostly incidental observations, museum holdings, time-constrained surveys, or anuran (frog) call surveys. The larger, seaward islands have received the most attention, with relatively little information on the numerous smaller islands lying between the mainland and the outermost islands, e.g. transitional islands like Wormsloe on the Isle of Hope.

2.1.1 Methods for Amphibians and Reptiles

I first reviewed the literature to determine which species were likely to occur (Gibbons and Harrison 1981, Laerm et al. 2000, Shoop and Ruckdeshcel 2003, Tuberville et al. 2005, Dodd and Barichivich 2007, Dorcas and Gibbons 2008, Gibbons, Greene and Mills 2009, Mitchell and Gibbons 2010, Gibbons and Coker 1978). I did not find any drift fence studies in the region. Some species are unlikely to occur at Wormsloe since it does not have permanent freshwater (e.g. some frogs with long larval periods, some turtles or snakes). Field surveys techniques were then designed to capture the species likely to occur.

Seasonal water was likely to be a concentrating factor for herps. Therefore, field sampling focused around seasonal water. LiDAR derived digital terrain model used to identify depressions followed by site visits to verify that the depressions had field indicators of seasonal water (e.g. vegetation, water marks on trees). All sites were established >100 m from main interpretive trail and were not visible from the trail (Figure 1).

Four quantitative methods were used to effectively sample all herpetofauna: 1) drift fence trapping arrays and 2) cover boards targeted terrestrial herps (snakes, lizards, turtles, salamanders), 3) PVC pipes targeted arboreal tree frogs, and 4) Dip netting and minnow trapping to capture tadpoles and aquatic salamanders. Sampling intensity of the four methods varied, in part due to equipment and labor costs. Sampling protocols for each method is described below

Drift fence trap arrays are commonly used to sample herpetofauna (Gibbons and Semlitsch 1981, Dalrymple et al. 1991, Enge 2001, Ryan et al. 2002, Enge 2005, Davis, Castleberry and Kilgo 2010), but there is no standard array design. The Enge (2001) design has three “arms” or “spokes” of fencing material radiating from a center point. Each arm rose ~ 2 ½ to 3 ft vertical from the ground and was ~10 m (30 ft) long so that the diameter of area covered was 20 m (~60 ft; ~0.03 ha). The fencing material was insect screening material (i.e. used for screening porches). There were nine wire traps and one pit-fall trap associated with each array. Wire traps were constructed out of 1/8” gauge hardware cloth; trap diameter was ~12” and 36” long (Dalrymple et al. 1991). A pair of traps with funnels at either end was placed along each arm of the array (one trap on either side of fencing; 6 traps total) and a single trap with funnels that straddled each side of the fencing material was placed at the end of each arm (3 traps total). There was a single pitfall trap place in the center where the three arms of the array met. The pitfall trap was simply a 5 gallon bucket placed in a hole so that the top was flush with the ground. Holes were drilled in the bottom to allow water to drain. A portion of all traps was shaded with sun-block material, and a wet sponge in a small plastic dish provided moisture. The wire funnel traps captured larger snakes and lizards and the pitfall traps captured toads. Five drift fence traps arrays were established around natural seasonal ponds in spring 2011. Sites were operated continuously for ~two months each late spring/early summer in 2011 and 2012. Additionally, traps were operated opportunistically other months of the year.

Cover objects ((Willson and Gibbons 2010) ~1 m x 0.5 m) cut from plastic tarp material (recommended by Dr. John Maerz, Warnell School of Forestry and Natural Resources, University of Georgia) were deployed. Ten cover objects were placed near the five drift fence sites and checked monthly from April 2011 to August 2011.

PVC pipe stations were used to sample arboreal tree frogs (Boughton, Staiger and Franz 2000). PVC pipes were simply 24" long pieces of 1" or 1 ½" inner diameter pvc, capped at the bottom end. The pipes provided refugia for treefrogs; since animals can readily leave the pvc, there was no tree frog mortality. Each sampling station consisted of 25 pipes mounted on a tree, with the bottom of the pipe ~2 m above ground. Initially, three habitats were sampled, each with five replicates (15 sites total). The three habitat types were: near seasonal fresh water (same as used for drift fence sites), far from seasonal freshwater and near brackish water. Sites were checked monthly. Due to lack of animals in brackish water (expected), these pipe refugia were moved to near seasonal freshwater sites, so that number of pipes near seasonal ponds increased from 25 to 50 in January 2012, while number of pipes at sites far from seasonal ponds remained at 25.

Dip netting and minnow trapping were used in seasonal ponds to capture tadpoles and other aquatic fauna. Given the lack of standing water in ponds, trapping occurred only 3 times in 18 months.

2.1.2 Results for Amphibians and Reptiles

Based upon literature review of the sea islands region, 76 herptiles (26 amphibians and 50 reptiles) have been reported from the Georgia coastal islands. Based upon available habitat at Wormsloe, I believe that 52 species (17 amphibians and 35 reptiles) could potentially occur at Wormsloe, with two other reptiles using the surrounding brackish marshes.

A total of 17 species (8 amphibians and 9 reptiles) were trapped. Amphibians were more abundant (992 individuals) than reptiles (78 individuals; Table 1). However, two species of amphibians (Southern toad and Eastern spadefoot) accounted for 87% of all individuals. Even so, capture rate of these two species was episodic, especially Eastern spadefoot. In a single 12 hour period in March 2012, 29% of all Southern toads and 85% of all Eastern spadefoots were captured. Only one salamander was captured. While captured at three of the five sites, abundance was skewed toward one site (5 of 7 salamanders). Lizards were the most common reptiles (3 species); only 15 snakes of 4 different species were captured. One turtle (Eastern mud turtle) was captured, but ~six shells of this species were found. See below for ancillary information on Eastern box turtle.

Overall, mortality from drift fence trapping was low (<0.5%); most mortalities occurred during the hot, dry periods. In July 2012, it became obvious that mammals were disturbing the wire traps; traps were removed from the fencing material, sat upon, and the wire doors opened. On some days, all 9 traps had been disturbed, and therefore ineffective at trapping herps. I presume that raccoons or opossums were trying to get at the water dishes in the traps, since the sponges were frequently ripped apart and carried away. Trapping was suspended ~10 days early in July 2012 due to regular trap disturbance.

The only species observed in four monthly checks under cover objects was Little brown skink (*Scincella laterale*). This species was commonly observed scurrying thru the leaf litter, and occasionally trapped. The tarp material was supposed to be an expensive, easily transported and stored cover object (compared to plywood). While the ends of tarps were weighted, it was evident that either animals or wind frequently were moving the tarps. Sometimes the ends were simply folded over, but other times the tarps had been moved several meters. Raccoon prints were common on the top of tarps, since rain and dew collected in the folds of the tarp; this concentration of freshwater probably attributed to disturbance. Overall, tarp material as cover objects added little information. Therefore, they were discontinued in August 2011, rather than have the tarp material spread as litter.

PVC pipe refugia were checked monthly from April 2011 to August 2012. Three species of treefrogs occurred, two of which were not detected by drift fence trapping (Table 2). No treefrogs occurred near brackish water or in forested areas “far” from depressions. Therefore, treefrogs were preferentially using areas close to the seasonally wet depressions. Regardless, no egg masses or tadpoles were found in two wet seasons. Moreover, there were differences in species occurrences even among the sites near seasonally depressions. Only one site supported all three species; this site also had the highest number of individuals of two of three species. The Pinewoods treefrog was most abundant at a site did not support either of the other two species. It was not unusual to find two treefrogs using the same pipe refugia, sometimes of different species. Since one of the most common, IACUC-approved method to mark amphibians (toe clipping) is inappropriate for treefrogs, it was not possible to mark individuals to determine if they re-used same PVC pipe or stayed in the area.

Dip netting/minnow trapping was only feasible three times. One individual was captured: Southern leopard frog. This species was not detected by other methods. While common on other sea islands, this species requires ~60 to 90 for reproduction. Based upon recently observed hydroperiod of seasonal ponds at Wormsloe (<30 days), I was surprised to capture even one individual of this species at Wormsloe. In comparison, it was common (>50 adults on one day) at a pond on Skidaway Island State Park. Crabs were the most frequently trapped species in minnow traps. Fishes and freshwater macro-invertebrates (Belostomatids, Dytiscids) typical of seasonal depressions were uncommon. Only one fish was captured (*Fundulus* spp, probably *F. confluentus*).

2.2 Birds

Birds are frequently the most diverse vertebrate group, and also tend to draw in the public. Moreover, the coastal region is within the Atlantic migratory flyway for neo-tropical migrant warblers. For migrants, stopover sites may be critical habitat even though the sites are used for a small part of the year (see (Norris, Wunder and Boulet 2006)). However, the geographical context of Wormsloe within the Georgia Bight of the Atlantic coast needs further study to determine the relative importance of the region to migrants.

2.2.1 Methods for Birds

To determine species were likely to occur at Wormsloe, I compiled species list from several of the protected sea islands (USFWS 2001, Bambach, Roth and Wigh 2006). The nearest area was Skidaway Island State Park (~1 km miles to the east). I considered that all species present on Skidaway SP should also be present at Wormsloe so long as suitable habitat occurred within Wormsloe.

Point counts were the most suitable method for forested habitat. To cover the entire site, a 200 m grid was overlaid on the Wormsloe boundary, using the evened number multiples of the UTM co-ordinates (e.g. Easting 493400 Northing 3538200 as the northernmost point). Sixty-nine (69) intersection points occurred (Figure 2). A ten-minute point count occurred at each of these points in June 2011 (Summer/Breeding), September 2011 (Migration), January 2012 (Winter) and May 2012 (Migration/Breeding). Opportunistic sightings were also recorded, to generate as complete of species list for the island as possible.

2.2.2 Results for Birds

Based upon review of regional species lists, 284 species have been recorded in the Georgia sea islands. Many of these species are shore birds (plovers, sandpipers, gulls) or birds relying upon permanent water (ducks, herons, egrets). One hundred sixty five (165) species have been noted at Skidaway Island State Park, the area closest to Wormsloe. Excluding species associated with shore or permanent water, I consider that 93 species may be expected to occur on WSHS, with an additional 48 species (e.g. wading birds, rails, shorebirds) possible in the adjacent marsh

A cumulative total of 42 bird species during the four point count surveys (Table 3). Twenty-two species were residents, 9 occurred in summer, 5 only during migration (i.e. transient) and 6 were wintering species (Table 4). Resident species accounted for ~79% of all individuals (1,097). The most common species were Tufted titmouse (235 birds; see Table 3), Bluejay (175), Northern cardinal (149), Carolina wren (145), and Red-bellied woodpecker (120). Ten species occurred only once.

Most species occurred at 9 or fewer of the point counts (29 of 42 species). No species occurred at each of the survey points. As expected, the most abundant species occurred at the greatest number of points.

There was no obvious geographical pattern in either species diversity or abundance (Figures 3 and 4). Future analyses will use LiDAR data to derive forest canopy closure and forest vertical structural diversity around each point to relate to bird occurrences.

2.3 Verified Vertebrate Species List

Based upon a review of available information, 145 vertebrates may possibly occur at Wormsloe. An additional 79 species, mainly birds, may use the adjacent marsh. By comparison, 394 species occur on the adjacent mainland. Not all species that occur in the sea islands region are expected to occur at Wormsloe. Species requiring long-hydroperiod to permanent freshwater wetlands are expected to be absent. In reviewing species lists, it was clear that some surveys included the adjacent brackish marsh while others did not. Moreover, many times surveys were for a vertebrate class (e.g. amphibians or birds) rather than all vertebrates. Therefore, the summary numbers are guides, and may under-represent species diversity for actual places.

As of August 2012, 85 vertebrate species have been verified at Wormsloe (Tables 5 and 6). As expected, amphibians requiring longer hydroperiods for development were absent (many salamanders and true frogs). While all vertebrate classes were depauperate, snakes were especially so (35 or 29% of expected). Some habitat specialists, such as Eastern hognose snake (*Heterodon platirhinos*), were surprisingly absent give the presence of their main habitat requirements (e.g. abundance of toads and sandy soil). More importantly, common, backyard generalist species such as Ring-necked snake (*Diadophis punctatus*) were also absent. Overall, relative to expected ~145 species, verifies species diversity (85) at Wormsloe is relatively depauperate (58% of expected).

While this vertebrate inventory indicates lack of present-day species diversity, resources management can improve this. Moreover, this baseline study will provide a gage by which to measure the success of any future resources management or other natural changes.

3 Ancillary Work

3.1 Eastern Box Turtles

Surveys for eastern box turtles (*Terrapene carolina carolina*) were opportunistic rather than systematic, and relied upon working with Merlot, an English springer spaniel with natural ability to find turtles. Merlot and I avoided the southern end of the island (more visitors) during park hours (i.e. most daylight, working hours). Moreover, searching for turtles with Merlot was only after I had finished other, systematic surveys, and Merlot was available. A total of 27 Eastern box turtles have been captured (Figure 5; Table 7). Of the 27 turtles, 20 were marked with a unique number. Nine were females, and 18 were males. Straight line carapace length ranged from 8.5 cm to 14.7 cm, with an average length of 12.7 cm. Weight ranged from 134 g to 630 g, with an average weight of 445 g. Merlot found 21 turtles, compared to 5 found by NKO (1 turtle was tie; NKO was unlikely to find to any turtles if Merlot hadn't been working the area).Turtles were frequently underneath leaf little or in dense shrubs, making them impossible to visually find. Turtles were frequently captured within 50 to 75 m of one another, even on the same day. There has been one recapture, occurring within ~50 m of original capture.

The geographical plot of turtle captures (see Figure 5) should be interpreted with caution since sampling was not systematic. Captures were clustered on the north portion of Wormsloe. While the Merlot and I searched for turtles on the southern end of the island on 2 separates days, we did not find any turtles. And, there were other days in which we searched the northern and middle portion of the island without finding any turtles. Clustering of turtles at the northern end of Wormsloe is unexpected, since this is adjacent to the most developed part of the Isle of Hope.

Morphometrics of turtles were summarized and compared to literature reports of Eastern box turtle size. There was no sexual dimorphism in carapace length (t-test, d f= 8, 18, t = 0.573; p = 0.571) or weight (df = 24, t = 0.719, p = 0.479). The straight line carapace length of Wormsloe turtles(12.7 cm) fell within the range reported for the populations in Florida and West Virginia (12 cm to 15 cm). Weight (445 g) was similar to some Florida populations (Dodd 1997, Pilgrim, Farrell and May 1997) and to West Virginia populations (Weiss 2009), but less than other Florida populations (~600 grams; (Verdon and Donnelly 2005). The 2:1 sex ratio of males to females was higher than other studies, but may be biased by relatively low sample size (n=27).

3.2 Amphibians and the Influence of Drainage Ditches on Seasonal Freshwater Ponds

Amphibians have experienced the highest decline among vertebrate species (Pechmann et al. 1991, Wake and Vredenburg 2008). In many regions, the loss of the seasonal freshwater ponds required for amphibian breeding is the most obvious single factor (McMenamin, Elizabeth and Wright 2008, Blaustein et al. 2001).

At Wormsloe, all of the historic freshwater ponds are connected to tidal marsh by drainage ditches, a land-use legacy. During the spring/summer 2012, I directly observed tidal influence and I measured salinity of water in depressions or of the soil (when depressions were dry; Table 8). In April and November high tides, tidal water pushed along ditches into depressions was not wholly pulled back out with receding tide. Therefore, tidal water soaked into the ground, depositing salts. The salts remained in the soil and leached out (see Table 8). Therefore, occasional tidal inundation negatively affected pond hydrology for months.

While the seasonal ponds have at least a bi-annual tidal influence, somehow seven species of adult frogs persist (see Table 5). Regardless, no breeding occurred in natural seasonal ponds in spring 2011 or 2012. One species, the Southern toad, breeds in the water garden behind the Big House. Rainfall has been below average during this time, which likely exacerbates residual salinity from tidal intrusion. However, frogs tend to have explosive breeding events, and may only need to breed successfully every three to ten years to persist. On a rainy evening in March 3, 2012, I captured an explosive breeding attempt by two species of toads. More than 450 toads were captured in ~12 hours. Despite this explosive occurrence of adults, breeding did not occur; it was in April 2012 that I discovered the salinity issue.

Like Wormsloe, many of the conservation lands throughout coastal Georgia have a similar land-use legacy of drainage ditches associated with seasonal freshwater ponds (personal observation from both field and remote sensing data; to be quantified in Spring 2013). Therefore, this study has regional implications for amphibian conservation in coastal Georgia.

3.3 Verification of canopy tree extraction from LiDAR

The spatial scale of most remotely sensed data is of little use in determining structure and function at finer scales, such as vegetation plots, or at a scale relevant to all but the largest wildlife species (Vierling et al. 2008). Moreover, verification of remotely sensed metrics using field-measured metrics can provide a bridge between finer scale and broader scale studies.

Recent improvements and availability of two remote sensing technologies may allow determination of actual canopy tree number and location at the plot level. Imagery with resolution as fine as 1 m is collected by the National Agricultural Inventory Program (NAIP) and freely distributed. Light detection and ranging (LiDAR) has the ability to simultaneously measure both vegetation structure and topography at the fine scale required for studies of small to medium size animals. LiDAR has been effectively used in forestry applications to estimate canopy closure, canopy height, and in some cases, the metrics of carefully selected trees (Akira et al. 2009, Bater et al. 2009, Cédric and Sylvie 2011, Desclée et al. 2008, Edson and Wing 2011, Jonathan et al. 2008).

To investigate, I first measured tree location on the ground in 10 plots; 6 plots were in mixed hardwood/pine and 4 in pine. Each circular plot was 50 meter diameter or ~ 0.2 ha. I measured GPS location of the plot center using a Garmin eTrex Vista (~3 m accuracy). The distance and azimuth of each tree was measured from center point using a laser rangefinder (1 cm) and digital compass (0.1^o). From this data, I geometrically calculated the X, Y location of each tree. The number of canopy trees measured on the ground was considered the "truth", but there was error in X, Y locations stemming from error in GPS location of the center point of the plot. I then compared number of canopy trees and X, Y location calculated by two remote sensing methods: 1) heads-up digitizing from 1m true-color NAIP and 2) canopy tree extraction from airborne LiDAR (horizontal accuracy of ~1.2 m) using LiDAR Analyst for ArcGIS.

Digitizing from NAIP detected an average of 69% of canopy trees while LiDAR Analyst detected 16% of canopy trees (Table 9; excluding one plot with overestimation). There was no difference in accuracy for pine versus mixed forest plots. Rectification issues between methods may contribute to error, but were not considered the main issue.

For both NAIP and LiDAR, I consider the issue to be overlapping, spreading tree crowns. Unlike many pines, the loblolly and slash pines of the southeastern USA tend to have spreading crowns, more similar to hardwood trees. The inverse watershed segmentation algorithm used by LiDAR Analyst and other programs to extract individual trees is not effective if tree crowns are not distinct.

The inverse watershed segmentation relies upon clear maxima and minima. However, both of the forest types in this study lack clear maxima (tree crown) and minima (space between tree crowns). Crown geometry, which is related to both the species and the tree spacing within the forest, determine whether clear maxima and minima exist. The pine forests tend to have more clear minima than the hardwood (Figures 6). Regardless, the pine species in this area have a broad, spreading canopy rather than conical form characteristic of many coniferous trees. Even in the "best" pine forest scenario, the difference between maxima and minima was <3 feet (measured using QT Reader).

Software other than LiDAR Analyst may be more effective at extracting tree crowns. USFS Fusion software was used on a few pine plots, but did not appear to perform any better. Moreover, Fusion explicitly relies on inverse watershed segmentation which is the implicit algorithm used by LiDAR Analyst. Unlike LiDAR Analyst, Fusion required that each plot was processed separately (computer crashed when attempted to run for entire study site). Consequently, programs that use object based analyses and can include multiple types of data, such as eCognition, may be able to detect tree crowns using both height and spectral data. This would avoid reliance on inverse watershed algorithm to detect tree crowns.

Much of the work on tree extraction has focused on managed pine forests (Bater et al. 2009, Cédric and Sylvie 2011, Edson and Wing 2011, Itoh, Matsue and Naito 2009, Kaiguang, Sorin and Ross 2009). These forests tend to have even age trees, so that canopy sizes tend to be similar. Moreover, the geographical location of the study forests meant that the dominant species had conical canopies, with little overlap between trees. One of the few studies in southeastern forests (Joseph et al. 2009) compared canopy metrics. Their results also found the need for cross calibration among methods, and they concluded that LiDAR derived metrics would be applicable only at broad scales.

At this point, it is still not possible to accurately determine number of canopy trees in mixed forests of the southeastern USA at the plot level from either high resolution imagery or LiDAR using LiDAR Analyst software.

A more comprehensive report was submitted to Dr. Thomas R. Jordan for Geography 8350, and is available upon request.

3.4 Landscape Context of Wormsloe

Land use – land cover (LULC) maps of the region are freely provided as the Georgia Land Use Trend (GLUT) map processed by the University of Georgia Natural Resources Spatial Analysis Lab (http://narsal.uga.edu/) from LandSat imagery. The earliest available GLUT map was from 1978, and the most recent was 2008. I summarized LULC in a 10 km buffer around Wormsloe from 1978 and 2008 GLUT maps (Table 10; Figure 7). Urban areas have increased from 37% to 54% in the past 30 years. Urban areas tend to have pavement and buildings. These surfaces tend to cause rainfall to run-off rather than soak into the ground, thereby altering groundwater recharge. Analysis of a larger buffer indicates conversion of freshwater wetlands (forested and unforested) to non-wetland LULC (e.g. agriculture, urban). Overall, LULC maps suggest that groundwater recharge that affects hydrology of seasonal ponds may be related to the regional context of Wormsloe.

4 Management Recommendations

Species diversity of amphibians, reptiles, and birds on Wormsloe appears to be relatively depauperate compared to surrounding conservation units. Lower species diversity at Wormsloe is partly related to differences in habitat diversity (ß diversity; e.g. higher bird diversity at Skidaway Island State Park, see below). Wormsloe tends to mostly support common, generalist species. However, I would expect a site as large as Wormsloe to support additional species beyond those common in backyards and small, neighborhood parks. Several factors are likely to contribute to present-day depauperate species diversity at Wormsloe. The most obvious factor was past land-uses, including land-clearing for agriculture and logging during the antebellum and post-bellum eras, ditches to manipulate water, and clear-cutting of pine forests during the 1970s. Less obvious factors are habitat fragmentation of surrounding landscape (see below), and declining local populations, which are open to extirpation (e.g. collapsing meta-population dynamics). All regional conservation units are likely subject to similar land-use legacies and landscape factors.

Relative abundance is another measure of habitat health, but is more difficult to compare among Wormsloe and other local sites given the lack of quantitative surveys on other sites. However, I did several random bird surveys at both Skidaway Island State Park and Skidaway Institute of Oceanography (both similar land size to Wormsloe). I had the general impression that both species diversity and abundances, especially of migrant warblers, were higher at Skidaway Island State Park than at Wormsloe. This may be an artifact of sampling or related to the apparent greater ß (habitat) diversity at Skidaway Island State Park. Regardless, bird surveys at Wormsloe indicate that it provides minimal support of species requiring more understory (e.g. Hooded warbler, Eastern towhee, Gray catbird, Wood thrush).

Species diversity and abundances have been the traditional measures of habitat quality and function. However, it is important to note that closed-canopied forests, such as occurs at Wormsloe, would generally be expected to support lower diversity and abundances but such forests should support forest interior specialists (not simply habitat generalists). The question that is harder to answer is how does Wormsloe compare to its pre-colonial species diversity and, more importantly, how does Wormsloe contribute to present-day regional diversity and resilience. Neither of the questions can be easily answered. The historical record is lacking on pre-colonial species diversity for most areas. However, future work could explore wildlife at Wormsloe in a regional context.

The regional landscape context of Wormsloe affects all wildlife species. Urban area in a 10 km buffer around Wormsloe has increased from 34% in 1978 to 57% in 2008. Urban areas have increased in all directions around Wormsloe. Wormsloe has become a relative isolated natural area simply because of external development. Moreover, amphibians, reptiles, and birds are likely responding to different local and regional cues.

For amphibians, lack of reliable seasonal freshwater is limiting annual reproduction even of common species. First, it is unclear if Wormsloe ever had seasonal freshwater ponds for >6-9 months per year in the past 10 to 20 years, which would naturally exclude some amphibians that occur in the region. However, the presence of adult cypress trees in one pond suggests >6-9 month hydroperiod within the past 50 to 75 years. Secondly, increase in urban areas and impervious surfaces (e.g. pavement and buildings) likely changes groundwater recharge so that hydrology of seasonal ponds may be shorter simply because of the landscape context of Wormsloe. Thirdly, there has been a regional drought during both 2011 and 2012. During these two years, seasonal freshwater ponds on Wormsloe had surface water less than 30 days each year, which was not sufficient to support amphibian breeding. Moreover, there has been tidal influence along drainage ditches into the inland seasonal freshwater ponds (up to 400 m length of drainage ditch). This tidal influence may have been exacerbated by the regional drought. Regardless, tidal influence along drainage ditches temporarily increased salinity and negatively affected water quality for breeding amphibians. Since the tidal water saturated the ground, salt was deposited in the soil and leached out during subsequent rainy periods. Therefore, amelioration requires prevention of tidal influx. A simple solution would be earthen plugs somewhere along the drainage ditch to prevent tidal intrusion. A more active management activity would be creating or maintaining seasonal ponds during drought periods. Once reliable seasonal freshwater ponds have been re-established, re-introduction of common species presently absent could be attempted.

Lack of reptiles is likely due to past land-clearing as well as the human tendency to simply kill snakes. Unlike amphibians, it is difficult to pinpoint a single habitat deficiency to explain present-day lack of abundance and diversity. Regional urbanization is the most likely factor. Since most reptiles are carnivorous, and therefore mid to high level in the food chain, focus should be first on re-establishing the lower level, prey base (amphibians, small lizards, small mammals) . Therefore, it is difficult to recommend specific management strategies.

Birds, like reptiles, are less likely to have a single cause for their relatively low species diversity and abundance. However, unlike amphibians or reptiles, birds can readily disperse. Wormsloe supports more resident/summer breeding species (42) than migrants (18). Both resident and migrant species are responding to habitat structure. A general observation is the lack of understory and midstory (e.g. vertical structural diversity) in the forests at Wormsloe. The forests are secondary successional forests, appear relatively even aged, and therefore lacking in vertical structural diversity. Natural successional processes may ameliorate this in 25 to 50 years. However, work by Foster and colleagues at the Harvard Experimental Forest (see (Anthony, Orwig and Foster 2008)) suggests that many understory plant species fail to recolonize and that conservation of land does not usually influence supporting land uses (McDonald et al. 2007). I think that that resources management at Wormsloe should focus on improving habitat for resident/summer breeding bird species (42 verified) rather than migrants (18 verified). The main recommendation is to increase in vertical structural diversity; secondary recommendation is increase the types of understory plant (e.g. increase fruit bearing understory plants). These management recommendations are also likely to increase habitat suitability for migrants, but geographical factors may be more influential than habitat selection by migrants. One positive characteristic of Wormsloe is that the snags (i.e. standing dead trees) are of sufficient size to support even larger woodpeckers (Pileated woodpecker), the Red-headed woodpecker occurs in the pine forests, and that secondary cavity nesters (Great crested flycatcher, Eastern bluebird) occur.

In summary, the following resources management actions are recommended: 1) earthen plugs to prevent tidal intrusion along drainage ditches to improve water quality of existing seasonal freshwater depressions (improve amphibian breeding habitat); 2) experimental creation of seasonal freshwater ponds with ~6 month hydroperiod as a safe-guard for existing amphibian populations during drought periods; 3) improve vertical structural diversity of forests to support greater diversity of summer breeding birds as well as migrant and wintering birds; 4) seed bank surveys to determine if altering forest structure will facilitate natural re-establishment of understory species; 5) simultaneous, quantitative field studies of Wormsloe and other regional conservation areas to compare wildlife diversity and relative abundance among sites. Additional input from other experts prior to implementation is recommended.

5 Future Work

Amphibian trapping will continue in Spring 2013, as will investigation of tidal influence on the salinity of seasonal ponds. Additionally, the sensitivity of the Southern toad to slightly saline water will be investigated thru laboratory experiments. Analyses of bird point count data will be integrated with forest metrics (e.g. canopy cover, vertical structure) derived from LiDAR data. Digital terrain models will be derived from existing LiDAR data to map depressions, ditches and determine their area and connectivity to tidal marsh for the coastal region.

My perspective is that to truly understand the importance of Wormsloe for wildlife, it is necessary to take a regional/landscape approach. This requires comparison to other conservation lands in the region. Therefore, in October 2012, I applied for a National Science Foundation (NSF) Doctoral Dissertation Research Improvement grant (DDRI) using Wormlsoe as a cornerstone for regional work. NSF will release evaluations and funding of DDRI proposal around February 2013.

Regardless of funding success, I will sample amphibians in spring 2013 at Wormsloe and continue integration of LiDAR derived forest metrics and bird abundance.

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Figure 1. Location of sites for herp sampling sites. All methods (drift fences, cover objects, pvc pipe refugia, and dip netting/minnow trapping) were used at the Freshwater Sites.

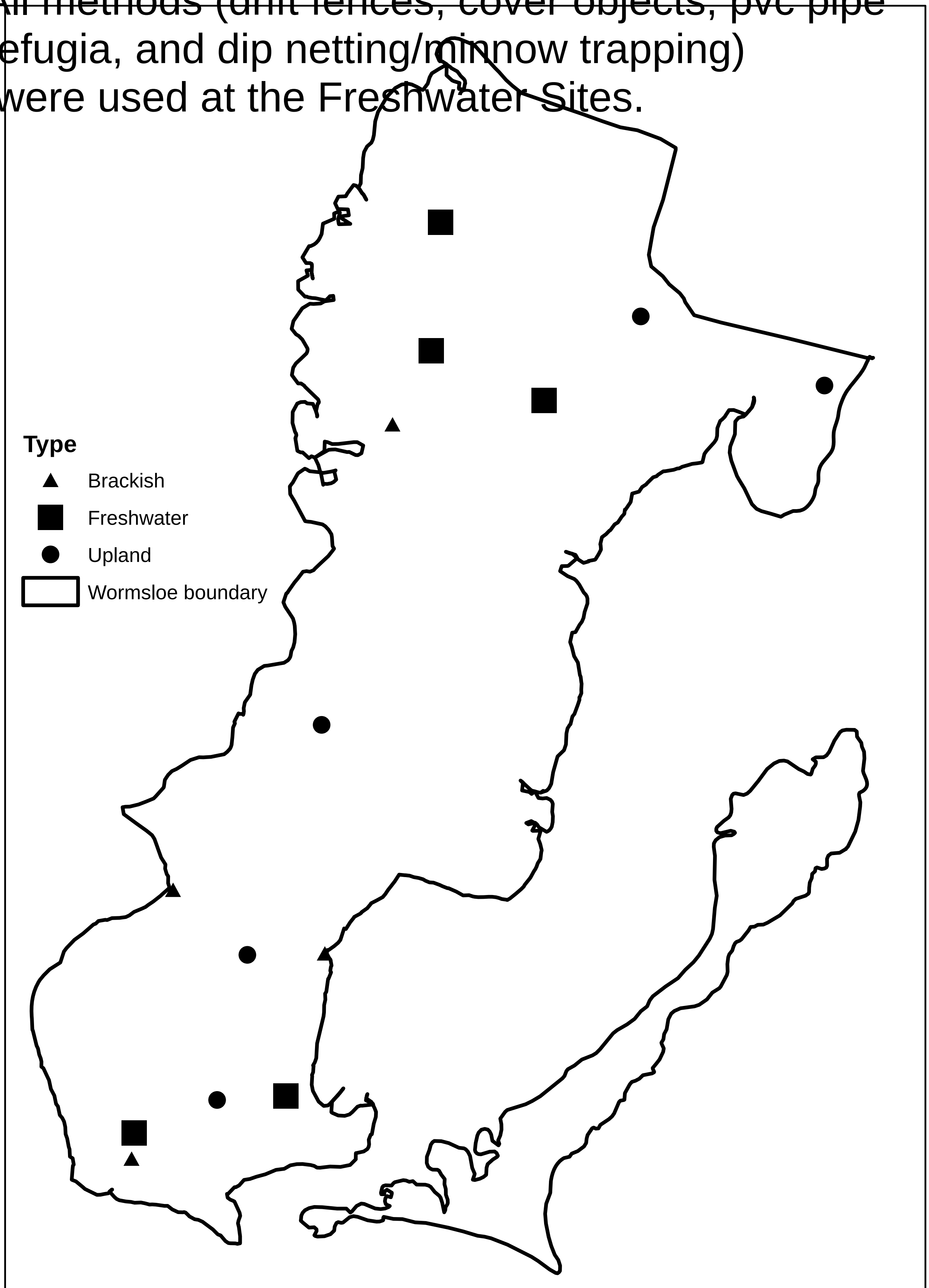


Figure 2. Location of points for 10 minute point counts for birds.

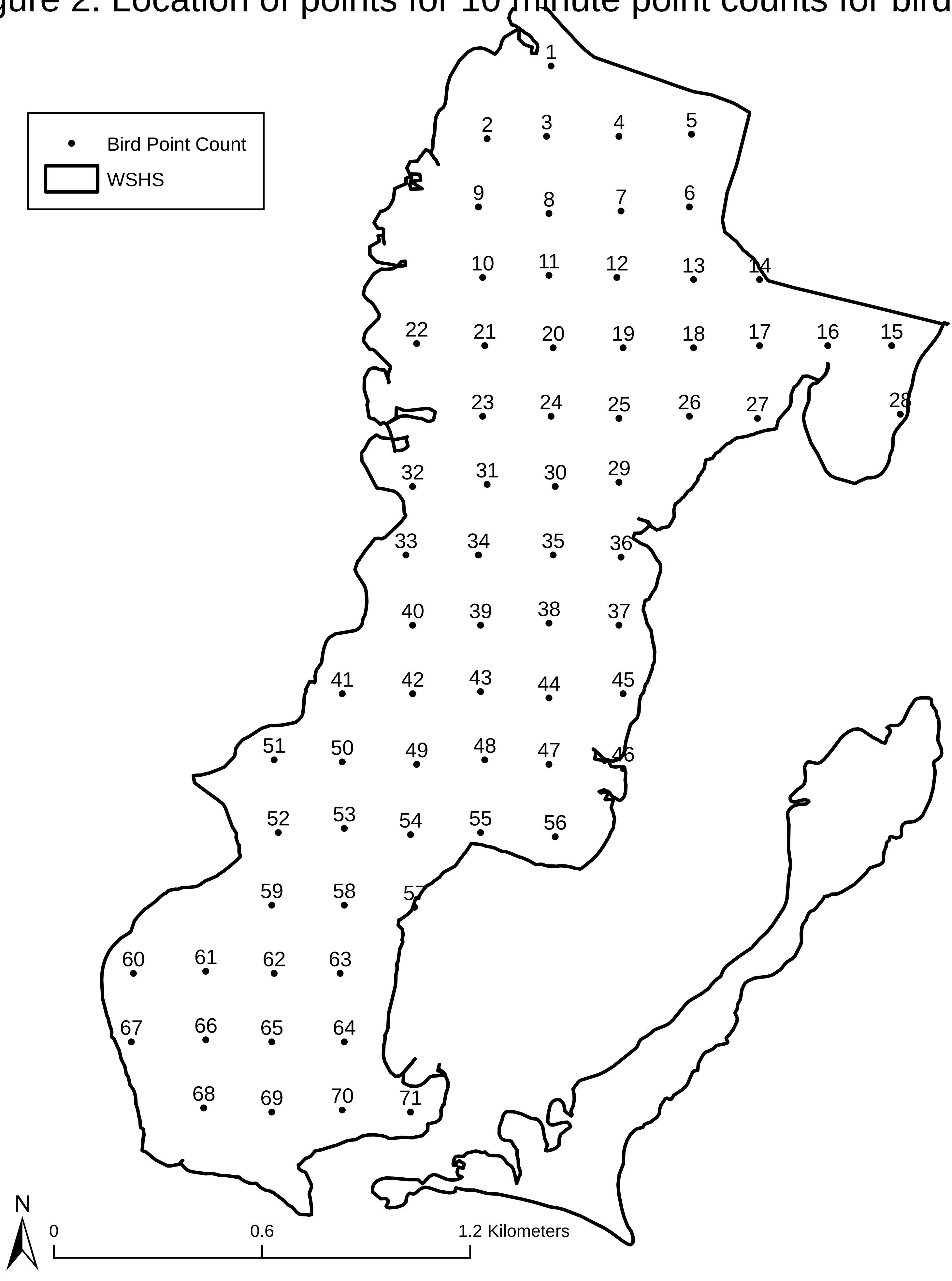


Figure 3. Cumulative number of species occuring at each point during four seasonal counts.

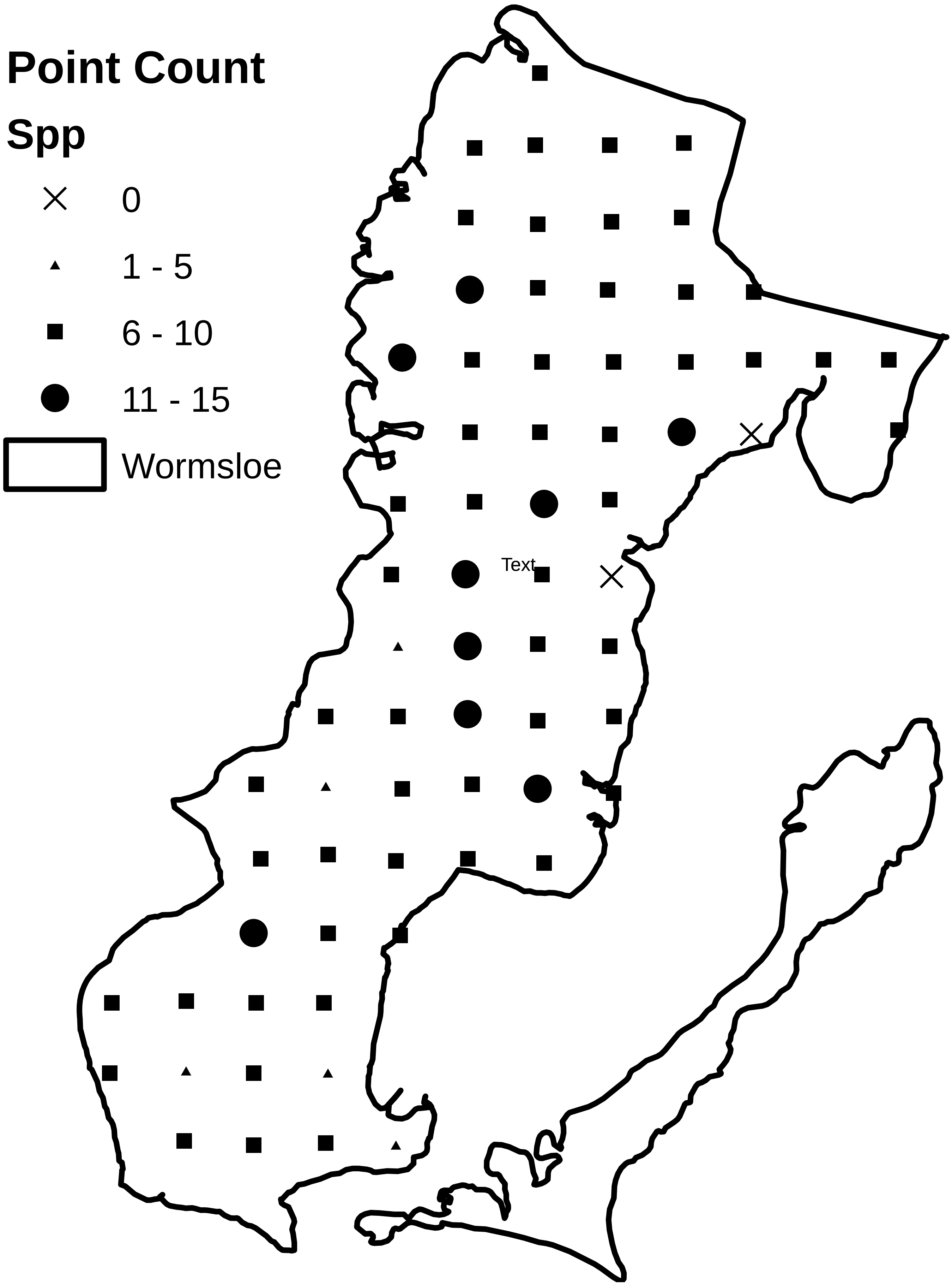


Figure 4. Number of individual birds at each of 69 points.

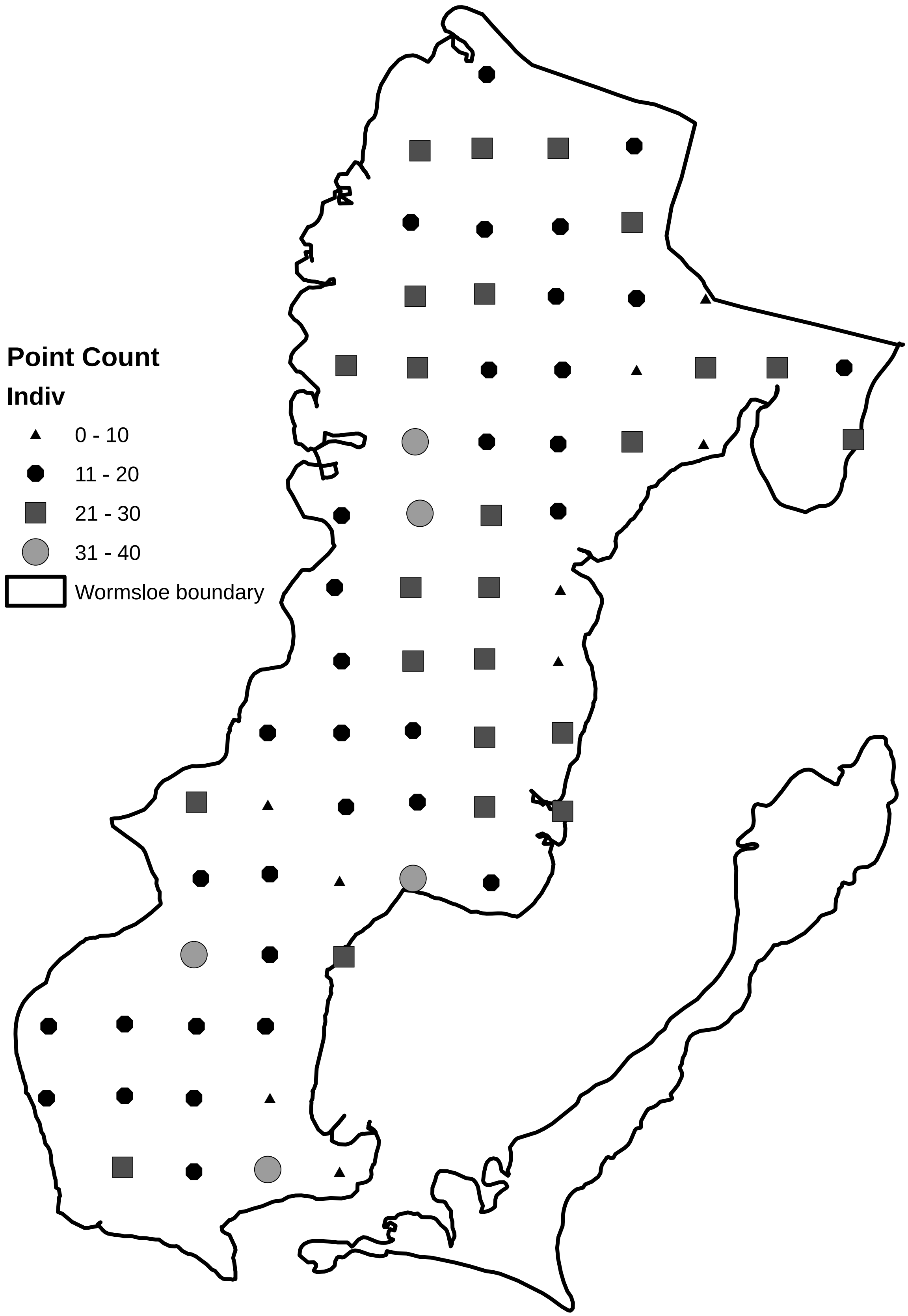


Figure 5. Locations of Eastern box turtles captures by gender. Surveys where random.

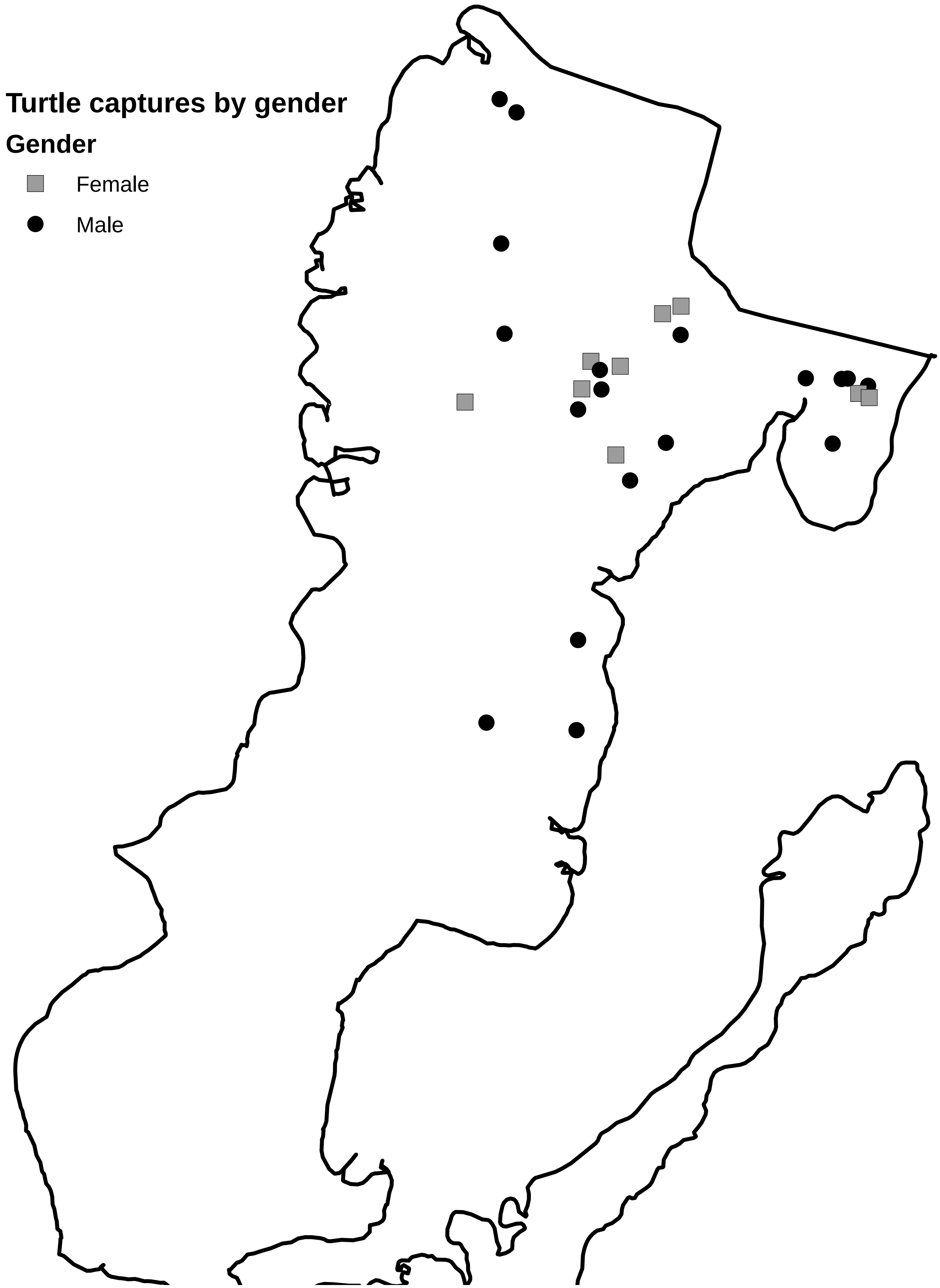
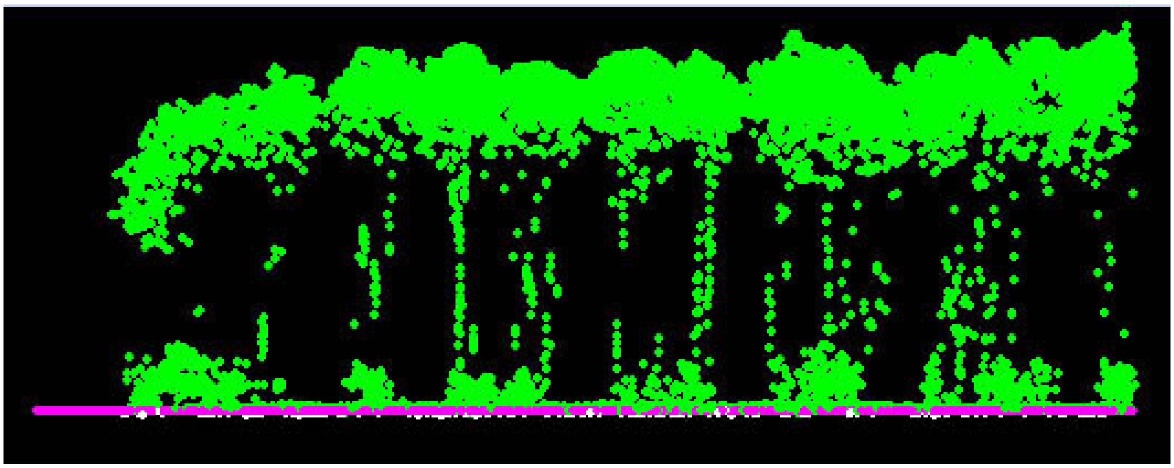


Figure 6. Examples of forest profiles from LiDAR data. Top picture is best-case scenario of pine forest, showing ~1 to 3 ft difference between canopy maxima (top of tree crown) and canopy minima (space between tree crowns). Bottom picture is worst-case scenario of hardwood forest, with no clear tree crowns.



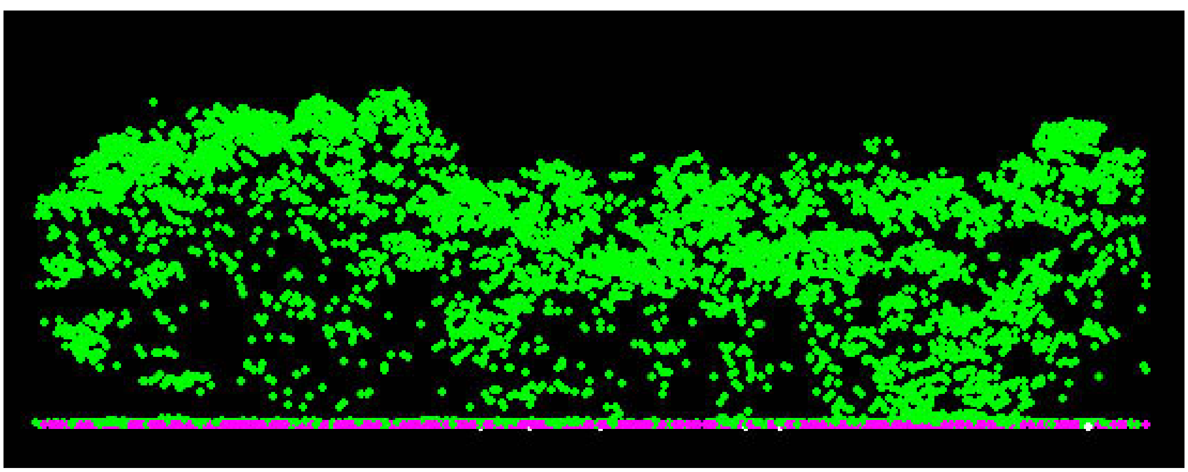


Figure 7. Landscape context of Wormsloe in 1978 and 2008.
Red line is edge of circle of 10 km around Wormsloe.

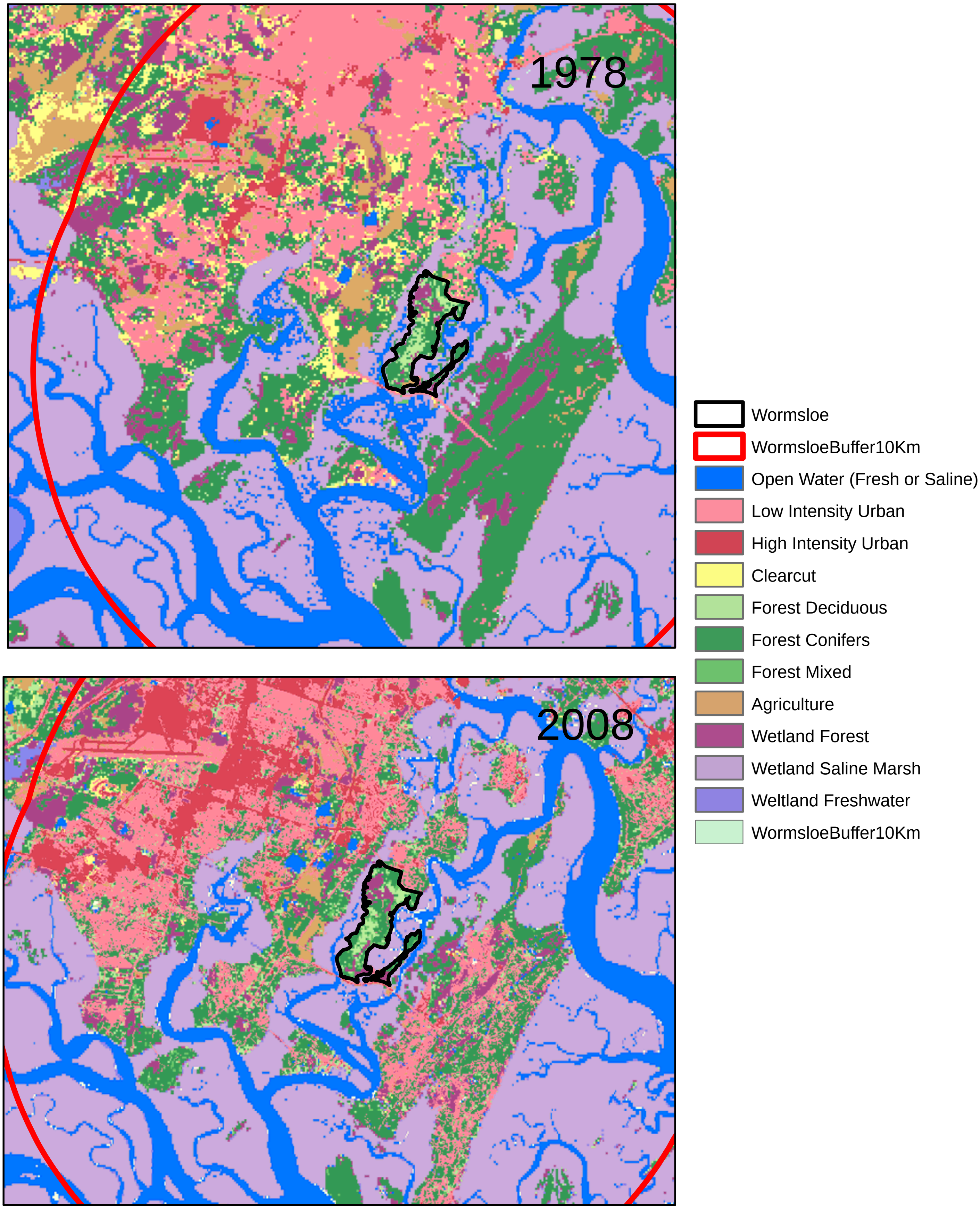


Table 1. Summary of drift fence trap arrays.

Number of Dates Each Species Trapped

Common Name	Scientific Name	Site: BentTree	Birdy	PalmGlade	VP3	Yanxi	Total Dates
Southern cricket frog	*Acris gryllus*	---	1	---	1	2	2
Southern toad	*Bufo terrestris*	17	23	15	21	14	34
Eastern narrowmouth toad	*Gastrophryne carolinensis*	7	5	3	---	6	11
Green treefrog	*Hyla cinerea*	1	1	1	---	1	3
Squirrel treefrog	*Hyla squirella*	---	---	1	---	2	3
Southern leopard frog	*Rana sphenocephala*	---	---	1	---	---	1
Eastern spadefoot	*Scaphiopus holbrookii*	8	8	4	7	5	13
Southeastern slimy salamander	*Plethodon grobmani*	2	---	1	---	1	4
Eastern mud turtle	*Kinosternon subrubrum subrubrum*	---	1	---	---	---	1
Green anole	*Anolis carolinensis*	3	---	---	4	---	7
Common fivelined skink	*Eumeces fasciatus*	1	---	---	---	---	1
Broadheaded skink	*Eumeces laticeps*	1	6	3	4	8	16
Little brown skink	*Scincella lateralis*	8	1	7	1	6	13
Copperhead	*Agkistrodon contortrix*	---	2	---	2	---	4
Scarlet snake	*Cemophora coccinea*	---	---	1	---	---	1
Black racer	*Coluber constrictor*	1	3	2	5	---	9
Eastern garter snake	*Thamnophis sirtalis*	2	---	---	---	---	2
Northern cardinal	*Cardinalis cardinalis*	---	1	---	---	---	1
Southern short-tailed shrew	*Blarina carolinensis*	1	---	---	---	---	1
Total Number of Dates*		30	27	24	23	22	39*

*Does not include dates when no animals were trapped at any site

Number of Individuals Trapped

Common Name	Scientific Name	Site: BentTree	Birdy	PalmGlade	VP3	Yanxi	Total
Southern cricket frog	*Acris gryllus*	---	1	---	1	2	4
Southern toad	*Bufo terrestris*	60	321	38	110	49	578
Eastern narrowmouth toad	*Gastrophryne carolinensis*	19	8	3	---	10	40
Green treefrog	*Hyla cinerea*	1	1	1	---	1	4
Squirrel treefrog	*Hyla squirella*	---	---	1	---	3	4
Southern leopard frog	*Rana sphenocephala*	---	---	1	---	---	1
Eastern spadefoot	*Scaphiopus holbrookii*	223	89	5	31	6	354
Southeastern slimy salamander	*Plethodon grobmani*	5	---	1	---	1	7
Eastern mud turtle	*Kinosternon subrubrum subrubrum*	---	1	---	---	---	1
Green anole	*Anolis carolinensis*	3	---	---	4	---	7
Common fivelined skink	*Eumeces fasciatus*	1	---	---	---	---	1
Broadheaded skink	*Eumeces laticeps*	1	7	4	4	11	27
Little brown skink	*Scincella lateralis*	11	1	7	1	7	27
Copperhead	*Agkistrodon contortrix*	---	2	---	2	---	4
Scarlet snake	*Cemophora coccinea*	---	---	1	---	---	1
Black racer	*Coluber constrictor*	1	3	1	3	---	8
Eastern garter snake	*Thamnophis sirtalis*	2	---	---	---	---	2
Northern cardinal	*Cardinalis cardinalis*	---	1	---	---	---	1
Southern short-tailed shrew	*Blarina carolinensis*	1	---	---	---	---	1
Cumulative Total		328	435	63	156	90	1072

Table 2. Summary of monthly checks for PVC pipe refugia for treefrogs.

Number of Dates Species Occured

Common Name	Scientific Name	Site: BentTree	Birdy	PalmGlade	VP3	Yanxi	Total Dates
Green treefrog	*Hyla cinerea*	3	---	3	---	1	7
Pine woods treefrog	*Hyla femoralis*	1	2	---	7	---	8
Squirrel treefrog	*Hyla squirella*	9	---	2	---	8	10
Green anole	*Anolis carolinensis*	1	---	---	1	---	1
Number of Dates*		9	2	5	7	8	13

*Does not include dates that no animals occurred

Number of Individuals

Common Name	Scientific Name	Site: BentTree	Birdy	PalmGlade	VP3	Yanxi	Total Numbe
Green treefrog	*Hyla cinerea*	6	---	3	---	1	10
Pine woods treefrog	*Hyla femoralis*	4	4	---	19	---	27
Squirrel treefrog	*Hyla squirella*	46	---	6	---	21	73
							0
Green anole	*Anolis carolinensis*	1	---	---	2	---	3
Total Individuals		57	4	9	21	22	113
Number of species		4	1	2	2	2	4

Table 3. Summary of point counts for birds. Maximum number of surveys was 4 and maximum number of points was 69.

Common name	Scientific name	Seasonal	Total #	# of Surveys	# Points
Mourning dove	*Zenaida macroura*	Resident	11	4	9
Turkey vulture	*Cathartes aura*	Resident	9	1	7
Black vulture	*Coragyps atratus*	Resident	2	1	1
Red-tailed hawk	*Buteo jamaicensis*	Resident	1	1	1
Red-shouldered hawk	*Buteo lineatus*	Summer	2	2	2
Bald eagle	*Haliaeetus leucocephalus*	Resident	2	1	1
Yellow-billed cuckoo	*Coccyzus americanus*	Summer	1	1	1
Downy woodpecker	*Picoides pubescens*	Resident	11	4	8
Yellow-bellied sapsucker	*Sphyrapicus varius*	Winter	2	2	2
Pileated woodpecker	*Dryocopus pileatus*	Resident	15	4	13
Red-bellied woodpecker	*Melanerpes carolinus*	Resident	120	4	55
Yellowshafted flicker	*Colaptes auratus*	Resident	2	1	2
Great crested flycatcher	*Myiarchus crinitus*	Summer	63	3	36
Eastern phoebe	*Sayonris phoebe*	Winter	5	2	4
Bluejay	*Cyanocitta cristata*	Resident	175	4	56
American crow	*Corvus brachyrhynchos*	Resident	22	4	12
Eastern towhee	*Pipilo erythrophthalmus*	Resident	1	1	1
Northern cardinal	*Cardinalis cardinalis*	Resident	149	4	61
Summer tanager	*Piranga rubra*	Summer	10	3	9
Red-eyed vireo	*Vireo olivaceus*	Summer	3	1	3
Solitary vireo	*Vireo solitarius*	Winter	1	1	1
White eye vireo	*Vireo griseus*	Summer	36	3	24
Black-and-white warbler	*Mniotilta varia*	Resident	4	2	4
Swainson's warbler	*Limnothylpis swainsonii*	Summer	5	1	4
Northern parula	*Parula americana*	Summer	16	3	15
Yellow rumped warbler	*Dendroica coronata*	Winter	85	1	21
Yellow-throated warbler	*Dendroica dominica*	Transient	6	1	5
Pine warbler	*Dendroica pinus*	Transient	21	2	19
Prairie warbler	*Dendroica discolor*	Summer	1	1	1
Ovenbird	*Seiurus aurocapillus*	Transient	2	2	2
Common yellowthroat	*Geothlypis trichas*	Resident	2	1	2
American redstart	*Setophaga ruticilla*	Transient	8	2	6
Northern mockingbird	*Mimus polyglottos*	Resident	3	3	3
Gray catbird	*Dumetella carolinensis*	Resident	1	1	1
Brown thrasher	*Toxostoma rufum*	Resident	8	4	6
Carolina wren	*Thryothorus ludovicianus*	Resident	145	4	60
Brown creeper	*Certhia americana*	Winter	1	1	1

Table 4. Summary of number of species and individuals of birds by survey period.

	Species	Individuals	Number of Points
June 2011	20	349	64
Sept 2011	23	348	65
Jan 2012	23	246	48
May 2012	26	353	65
Totals	42	1297	69

Table 5. List of all species verified at Wormsloe.
For birds, season of occurrence is also noted. Resident and Summer species would breed.

Common Name	Scientific Name	Season	Number*
Southern cricket frog	*Acris gryllus*		4
Southern toad	*Bufo terrestris*		578
Eastern narrowmouth toad	*Gastrophryne carolinensis*		40
Green treefrog	*Hyla cinerea*		14
Pine woods treefrog	*Hyla femoralis*		27
Squirrel treefrog	*Hyla squirella*		77
Southern leopard frog	*Rana sphenocephala*		1
Eastern spadefoot	*Scaphiopus holbrookii*		354
Southeastern slimy salamander	*Plethodon grobmani*		8
Eastern box turtle	*Terrapene carolina carolina*		4
Eastern mud turtle	*Kinosternon subrubrum subrubrum*		2
Green anole	*Anolis carolinensis*		10
Common fivelined skink	*Eumeces fasciatus*		1
Broadheaded skink	*Eumeces laticeps*		29
Little brown skink	*Scincella lateralis*		29
Copperhead	*Agkistrodon contortrix*		4
Scarlet snake	*Cemophora coccinea*		1
Black racer	*Coluber constrictor*		8
Eastern garter snake	*Thamnophis sirtalis*		2
Gull-billed tern	*Sterna nilotica*	Summer	1
Blue-winged teal	*Anas discors*	Winter	7
Wood stork	*Mycteria americana*	Summer	2
Great blue heron	*Ardea herodias herodias*	Resident	1
Great egret	*Casmerodius albus*	Resident	6
Snowy egret	*Egretta thula*	Resident	1
Little blue heron	*Egretta caerula*	Resident	1
Mourning dove	*Zenaida macroura*	Resident	18
Turkey vulture	*Cathartes aura*	Resident	9
Black vulture	*Coragyps atratus*	Resident	2
Red-tailed hawk	*Buteo jamaicensis*	Resident	2
Red-shouldered hawk	*Buteo lineatus*	Summer	2
Bald eagle	*Haliaeetus leucocephalus*	Resident	2
Barred owl	*Strix varia*	Resident	
Yellow-billed cuckoo	*Coccyzus americanus*	Summer	1
Downy woodpecker	*Picoides pubescens*	Resident	12
Yellow-bellied sapsucker	*Sphyrapicus varius*	Winter	2
Pileated woodpecker	*Dryocopus pileatus*	Resident	16
Red-headed woodpecker	*Melanerpes erythrocephalus*	Resident	1

Table 5. List of all species verified at Wormsloe.
For birds, season of occurrence is also noted. Resident and Summer species would breed.

Common Name	Scientific Name	Season	Number*
Dark-eyed junco	*Junco hyemalis*	Winter	
Eastern towhee	*Pipilo erythrophthalmus*	Resident	1
Northern cardinal	*Cardinalis cardinalis*	Resident	150
Painted bunting	*Passerina ciris*	Summer	1
Summer tanager	*Piranga rubra*	Summer	10
Cedar waxwing	*Bombycilla cedrorum*	Winter	30
Red-eyed vireo	*Vireo olivaceus*	Summer	3
Solitary vireo	*Vireo solitarius*	Winter	1
White eye vireo	*Vireo griseus*	Summer	36
Black-and-white warbler	*Mniotilta varia*	Resident	4
Swainson's warbler	*Limnothylpis swainsonii*	Summer	5
Northern parula	*Parula americana*	Summer	17
Yellow rumped warbler	*Dendroica coronata*	Winter	100
Yellow-throated warbler	*Dendroica dominica*	Transient	6
Pine warbler	*Dendroica pinus*	Transient	21
Prairie warbler	*Dendroica discolor*	Summer	1
Ovenbird	*Seiurus aurocapillus*	Transient	2
Northern waterthrush	*Seiurus noveboracensis*	Transient	2
Common yellowthroat	*Geothlypis trichas*	Resident	5
American redstart	*Setophaga ruticilla*	Transient	8
Northern mockingbird	*Mimus polyglottos*	Resident	3
Gray catbird	*Dumetella carolinensis*	Resident	2
Brown thrasher	*Toxostoma rufum*	Resident	10
Carolina wren	*Thryothorus ludovicianus*	Resident	145
Brown creeper	*Certhia americana*	Winter	1
Tufted titmouse	*Parus bicolor*	Resident	235
Carolina chickadee	*Parus carolinensis*	Resident	100
Ruby-crowned kinglet	*Regulus calendula*	Winter	7
Blue-gray gnatcatcher	*Polioptila caerulea*	Resident	1
Wood thrush	*Hylocichla mustelina*	Summer	1
Veery	*Catharus fuscescens*	Transient	2
Hermit thrush	*Catharus guttatus*	Winter	4
Eastern bluebird	*Sialia sialis*	Resident	1
American robin	*Turdus migratorius*	Winter	21
Virginia opossum	*Didelphis virginiana*		2
Southern short-tailed shrew	*Blarina carolinensis*		1
Gray squirrel	*Sciurus carolinensis*		
Red fox	*Vulpes vulpes*		1

Table 6. Comparison of species verified at Wormsloe to number of possible species, determined from literature review of species occurrences on all Georgia coastal islands.

Vertebrate Class	Verified Species	Individuals	Possible Species	Percentage
Amphibians	9	1,103	17	53%
Reptiles	10	90	35	29%
Birds			93	0%
Resident	29	1,047		
Summer	13	143		
Transient	6	41		
Winter	12	182		
Total	60	1,413		
Mammals*	6		29**	
	145		145	100%

*No targeted surveys for Mammals; only incidental observations
**Many of these are bats; bats have been observed at Wormsloe but not identified to species

Table 7. Location and metrics of Eastern box turtles found at Wormsloe.

Date	UTMEast	UTMNorth	Gender	Marked	Recapture	Mark	Length cm	Width cm	Height cm
7/16/2011	493658	3537425	Male	Yes		10	13.5		
7/20/2011	493610	3537375	Female	Yes		20	13.5		
7/21/2011	493300	3537340	Female	Yes		30	13		
7/29/2011	493700	3537200	Female	Yes		100	13.8		
8/1/2011	493600	3537320	Male	Yes		70	13.6		
8/1/2011	493392	3538142	Male	Yes		200	12.8		
8/1/2011	493437	3538107	Male	Yes		300	14		
8/2/2011	494275	3537230	Male	Yes		1	14.7	12.3	7.2
8/2/2011	493738	3537132	Male	Yes		2	13.5	9.8	6.6
8/2/2011	493833	3537232	Male	Yes		400	14.1	10.8	
8/2/2011	494204	3537403	Male	No			8.5		
8/2/2011	494299	3537401	Male	No			8.5	6.8	3.8
8/2/2011	494344	3537363	Female	No					
8/2/2011	494369	3537383	Male	Yes		500	12.5	9.8	
8/3/2011	493634	3537448	Female	Yes		6	12.5	10	6.4
8/3/2011	493873	3537594	Female	No			12.6	9.8	0
8/3/2011	493600	3536710	Male	No			14	10	7.4
8/3/2011	493712	3537435	Female	Yes		5	11	8.6	6.9
8/3/2011	493824	3537574	Female	Yes		3	11.5	8.3	6.2
8/3/2011	493357	3536491	Male	Yes		11	12.5	9	6.4
8/3/2011	493596	3536471	Male	Yes		12	13.8	9.5	6.5
8/3/2011	493872	3537518	Male	Yes		8	12.5	9.6	6
8/3/2011	493854	3537468	Male	Yes		7	13.1	11.5	6.4
8/3/2011	493662	3537373	Male	Yes	Yes	10			
5/8/2012	494315	3537402	Male	No			13.5		
5/8/2012	494372	3537352	Female	No			12.8		
5/10/2012	493405	3537521	Male	Yes		14	12.7		
5/10/2012	493396	3537760	Male	Yes		13	12.2		
						All Turtles	12.7		
						Males	13.0		
						Females	12.6		

Table 8. Salinity of surface water or rehydrated soil (if depressions were dry).
Freshwater should have a salinity of 0. Tidal water has salinity of ~30 ppt.

	NAVD 1988		Water depth and salinity			
Site	Elev (ft)*	05/08/12	06/04/12	06/05/12	06/06/12	10/16/12
Yanxi	3 to 5 ft	brackish	13 cm/24 ppt	rain	23 to 42 cm/15 - 21 ppt	dry/0 ppt
Palmglade**	4 to 5 ft	brackish	17 cm/30 ppt		3 to 8 cm/20 to 23 ppt	
Benttree	4 to 5 ft	brackish	dry		4 to 11 cm/11 - 18 ppt	dry/0 ppt
Birdy	4 to 5 ft	brackish	dry		10 to 34 cm/12 - 14 ppt	1 to 5 cm/3 pp
VP3	3 to 4 ft	dry	dry		dry	dry/0 ppt

*Ground elevation determined from LiDAR derived digital terrain model
**Known tidal influence on some parts
Evening of June 4, High high tide at 8:51 pm. Checked sites during day and again between 8:30 and 9:30 pm. No tidal influence seen.

Bi-annual high tides occurred November 15, 2012. I watched tidal intrusion up ditches into depressions.

Monthly Tides SKIO; Uses datum of MLLW and range between 6 ft and 10 ft.

Table 9. Summary of number of canopy trees in 50 m diameter plot determine on ground, from aerial photos, and from LiDAR data.

	Ground	Air Photo		LiDAR	
Plot	# Trees	# Trees	% of Ground	# Trees	% of Ground
Pine Forest					
OTPine	59	26	44%	5	8%
Pine2	20	20	100%	6	30%
Pine3	45	25	56%	6	13%
VP21	33	23	70%	3	9%
Mixed Hardwood Forest					
VP10	34	21	62%	4	12%
VP16	47	27	57%	4	9%
VP2	46	31	67%	5	11%
VP3	21	17	81%	1	5%
VP7	8	27	338%	3	38%
VP9	26	22	85%	6	23%
Average	33.9	23.9	67%	4.3	16%

Table 10. Land use - land cover in 10 km buffer around Wormsloe in 1978 and 2008.
Data from Georgia Land Use Trends (GLUT).

Land Use/Land Cover	1978 Ha	1978 Acres	1978 % of Land	2008 Ha	2008 Acres	2008 % of Land	Change Ha*
Beach	65	161	0%	202	500	1%	137
Open Water	6,307	15,578		6,070	14,993	33%	(237)
Low Intensity Urban	5,516	13,625	30%	7,322	18,085	39%	1,805
High Intensity Urban	710	1,754	4%	3,263	8,059	18%	2,553
Clearcut	1,059	2,616	6%	97	240	1%	(962)
				9	22	0%	9
Forest, Deciduous	306	757	2%	835	2,061	4%	528
Forest, Conifer	7,245	17,895	39%	4,425	10,930	24%	(2,820)
Forest, Mixed	93	229	1%	344	849	2%	251
Agriculture	1,414	3,492	8%	562	1,388	3%	(852)
Wetland, Forest	2,089	5,160	11%	1,698	4,194	9%	(391)
Wetland, Saline	15,824	39,086		15,414	38,074	83%	(410)
Wetland, Freshwater	65	160		455	1,125	2%	391
							0
Total Area	40,693	100,513		40,696	100,519	219%	3
Land Area	18,432	45,528		18,554	45,827	100%	121

Percent Urban 34% 57%

*Numbers in ( ) is habitat loss
Gain in Wetland, Freshwater mostly from stormwater retention lakes