RESTORATION OF MARITIME HABITATS ON A BARRIER ISLAND USING THE PAINTED BUNTING (*Passerina ciris*) AS A FLAGSHIP SPECIES

A thesis submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

in

ENVIRONMENTAL STUDIES

by

SARAH ANN LATSHAW
August 2011

at

THE GRADUATE SCHOOL OF THE COLLEGE OF CHARLESTON

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ABSTRACT

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Habitat loss and degradation are major causes of the decline of many songbird species. One species, the Painted Bunting (*Passerina ciris*) has seen declines of over 60% from 1966-1995, according to Breeding Bird Surveys, mostly due to habitat losses. Because of this decline, the Painted Bunting has become high priority by many conservation organizations. Collaborating with the Kiawah Island Conservancy, and several Biologists, we used radio telemetry technology and vegetation sampling techniques to: 1) determine habitat use, 2) identify home range and territory size, and 3) create vegetation recommendations for the Kiawah Island Conservancy. We captured a total of 58 buntings representing all sexes and age classes between May-August 2007-2010, and tracked daily until the transmitter battery failed. Vegetation samples were also taken, measuring ground cover, midstory structure, and canopy cover. Buntings used maritime forest, maritime shrub, and developed land use types at significantly higher rates than the other land use types ($F = 65.6$, $df = 314$, $p = <0.001$). The top 10 substrates frequented most often by the buntings from 2007-2010 were: 1) Live Oak (*Quercus virginiana*), 2) Wax Myrtle (*Myrica cerifera*), 3) unknown, 4) Slash Pine (*Pinus elliottii*), 5) Eastern Red Cedar (*Juniperus virginiana*), 6) Loblolly Pine (*Pinus taeda*), 7) Seaside Oxeye (*Borrichia frutescens*), 8) snag, 9) shrubs, and 10) Yaupon Holly (*Ilex vomitoria*). Painted Buntings mean home range size (calculated from MCP) was 7.1 ± 1.1 ha, and mean territory (calculated from kernel density) was 0.3 ± 0.03 ha. Recommendations from our research may not only impact the local bunting population, as well as on other wildlife, they may also have major conservation implications both statewide and regionally by demonstrating the feasibility of homeowner-financed habitat restoration.

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INTRODUCTION

HABITAT LOSS

In the past 50 years, humans have made substantial changes to ecosystems, resulting in irreversible losses of biodiversity (Reid 2005). We have changed natural areas for use in agriculture, timber harvest, or other development, causing landscape-level habitat degradation and fragmentation. In the creation of these degraded and fragmented landscapes, native vegetation is removed, reduced, or isolated, vastly decreasing the biodiversity in the affected area (Reid 2005, Marzluff and Ewing 2001). These landscape changes and losses are the key reasons for species endangerment globally (Heinz Center 2008, Reid 2005, Wilcove *et al.* 1998).

More specifically, habitat loss and degradation worldwide are major causes for the decline of many songbird species (NABCI 2009; McKinney 2002; Chipley *et al.* 2003; Elphick *et al.* 2001; Marzluff and Ewing 2001; Ehrlich *et al.* 1988), leading to a total of 5% of all bird species being critically endangered or endangered (Baillie *et al.* 2004). Species that remain in degraded landscapes are exposed to increased risks through competition with exotic species, exposure to predators, mortality from human activity, and restricted or exposed corridors. Woods *et al.* (2003) illustrated the pressures of increased predator exposure in their research conducted in urban/suburban areas of Great Britain. Analyzing information derived from surveys of cat owners, they estimated that 92 (85-100) million individuals of native species (birds, reptiles, mammals, etc.) were killed in the United Kingdom by domestic cats (*Felis catus*) during the 5-month period of the study (Woods *et al* .2003).

Migratory bird species declines were originally blamed on habitat loss in the tropics (Chipley *et al.* 2003, Elphick *et al.* 2001). However, studies have shown that habitat loss and fragmentation on breeding grounds also play a substantial role (Elphick *et al.* 2001). Breeding grounds in wetland ecosystems, in particular, have suffered from habitat destruction (UNEP 2007), with more than half of all wetlands in the 48 contiguous United States degraded or converted (Ray and McCormick-Ray 2004).

Wetlands are one of the most productive ecosystems in the world (Stedman and Dahl 2008; Ray and McCormick-Ray 2004), providing resting, feeding, and breeding habitats for 75% of waterfowl and other migratory birds (EPA 2008). Additionally, wetlands contribute as much as 40% of Earth's ecosystem services while only covering about 1.5% of the planet (Zedler 2003). The ecosystem services, such as water filtration, flood mitigation, storm buffering, and seafood production, have actually been valued at over $13 trillion. Unfortunately, the failure to recognize the value of wetlands has led to their continued degradation (Stedman and Dahl 2008; Costanza *et al.* 1997).

Wetland areas have been significantly altered through changes in water flow, pollution, overfishing, and human development (Stedman and Dahl 2008, Ray and McCormick-Ray 2004), as they are often located near the fastest growing and developing areas (Crossett *et al.* 2004). United States counties located on the coast average 115 persons/km^2, over three times the national average of 38 persons/km^2. Compared to other coastal areas, the Southeast U.S. has had the most significant rate of human population growth with a 58% increase from 1998 to 2004 (Crossett *et al.* 2004). As a result of this growth, the Atlantic coast has lost 6,062 ha of wetlands between 1998 and 2004 (Stedman and Dahl 2008).

Islands are of particular concern because they often have the highest wildlife extinction rates (Ray and McCormick-Ray 2004). On the East Coast of the United States, about 300 major barrier islands stretch from Maine to Texas. The aesthetic and recreational appeal of these areas attracts people and can lead to overdevelopment (Ray and McCormick-Ray 2004), further degrading these important breeding areas. Protection and restoration of barrier islands are integral in mitigating for future ecological, commercial, economic, and recreation losses, especially when considering that humans' coastal populations are expected to continue to increase for many years to come (Stedman and Dahl 2008). Human influences on our landscapes are often damaging, as we remove high proportions of native vegetation to add permanent structures (Marzluff and Ewing 2001). These permanent structures (i.e. buildings, roads, etc.) prevent the regrowth of vegetation and lead to far greater species losses than is seen in areas (e.g. agricultural fields) that have been only partially degraded (Falk 2006). As human populations continue to increase and vie for resources, further habitat degradation will likely increase as well (Marzluff and Ewing 2001).

LAND PRESERVATION AND RESTORATION EFFORTS

In an effort to combat habitat loss and prevent further declines of migratory birds and other species, conservation groups, like the Nature Conservancy, have had success in purchasing lands to prevent future development and habitat destruction (Reid 2005, Caro *et al.* 2004, Ehrlich *et al.* 1988). The Millennium Ecosystem Assessment (Reid 2005) explains that there are over 100,000 protected land areas covering about 11.7% of the Earth. These nature preserves, national parks, and managed lands have been integral in our initial effort to conserve biodiversity and protect ecosystem services (Reid 2005), but setting aside large areas is often unrealistically expensive. Alternative modes for replacing lost habitat, through habitat restoration, must be considered if we are to maintain species diversity in fragmented landscapes.

The concept of ecological restoration is based on a series of values - ecological, personal, socioeconomic, and cultural – that promote restorative actions. A cultural example of restorative action is the work being done to save Sweet Grass (*Muhlenbergia filipes*) basket making in the South Carolina Lowcountry counties. Urbanization plays a key role in the vanishing technique of Sweet Grass basket making, a remnant artisan skill from the days of the African slave trade and still practiced today. As the population of the Lowcountry continues to increase, naturally growing Sweet Grasses disappears. Moreover, public areas where Sweet Grass was once harvested have now become privately owned. Sweet Grass is, however, planted as an ornamental grass in many neighborhoods, hotels, malls, etc. Efforts have been made to restore this dying trade by allowing basket-makers to harvest the grasses grown ornamentally in these private and gated communities (Hurley *et al.* 2008).

The Old Fort Bayou tract is a good example of successful wet prairie restoration in Mississippi. In the 1940s and 1950s much of this tract was converted from wet prairies to a pine plantation. The growth of these trees was too slow for commercial harvest, so much of the area was abandoned. The Nature Conservancy purchased the tract in the late 1990s and began restoration efforts to bring the land back to the wet prairie state seen in the 1940s. After removing timber and conducting several prescribed burns, the dormant rootstock and seedbank recovered along with the wet prairie (Clewell and Aronson 2007).

Restoration in developed areas can prove difficult, however, especially if landowners do not value the environmental resources available to them and are willing to substitute natural habitats with manmade structures (Bark *et al.* 2009). One strategy to overcome this difficulty is by the use of a surrogate species, to convince average citizens to invest in the conservation and restoration of an area (Favreau *et al.* 2006). A surrogate species that represents a community can be a "marketing tool" to draw in local support (Bowen-Jones and Entwistle 2002). A flagship species is a type of surrogate species that is charismatic and often chosen to encourage conservation awareness and action (Favreau 2006; Clucas *et al.* 2008; Caro *et al.* 2004; Bowen-Jones and Entwistle 2002; Walpole and Leader-Williams 2002; Simberloff 1998).

The premise behind using a flagship or surrogate species in conservation is that protecting the habitat for one species will also benefit the other species that share similar habitat preferences (Favreau *et al.* 2006). Using a flagship species aids in management efforts, as managing and monitoring a whole ecosystem is not always feasible (Simberloff 1998). In Africa, the lion (*Panthera leo*), leopard (*P. parducs*), buffalo (*Syncerus caffer*), elephant (*Loxodonta africanan*), and two species of rhinoceroses (*Ceratotherium simum* and *Diceros bicornis*) are considered important flagship species

(Williams *et al.* 2000). These species draw in tourists and donor funding because people want to view and protect them (Williams *et al.* 2000). Similarly, the Worldwide Fund for Nature and the National Audubon Society use the charismatic Giant Panda (*Ailuropoda melanoluca*) and the elegant Great Egret (*Ardea alba*), respectively, for their organization's logos.

The Painted Bunting was used as a flagship species for this study because of its significant decline (Lowther *et al.* 1999, Meyers 2004, Elphick *et al.* 2001) and charismatic appeal to the public. Moreover, it is thought to have a relatively small territory (Springborn and Meyers 2005), making meaningful habitat restoration feasible even on developed home sites. To restore bunting habitat on barrier islands such as Kiawah, we must understand specifically what the birds need. Therefore, in collaboration with the Kiawah Island Conservancy and several institutions, our specific goals in this study were to:

1) Determine habitat use of Painted Buntings in a maritime forest/scrub-shrub environment (including any tolerance of and/or preferences for developed areas).

2) Identify the home range and territory size of Painted Buntings.

3) Create vegetation recommendations, based on bunting habitat use, to guide the residents of Kiawah Island as they seek to restore their home sites to a semi-natural state.

Painted Bunting Natural History

Male Painted Buntings (Fig. 1a) are very colorful, having a blue head, red breast, greenish-yellow back, and red eye ring. Female and juvenile buntings (Fig. 1b & c) are greenish-yellow over their entire bodies, and are often referred to as “green birds”. There are two populations of Painted Bunting in the US (Fig. 2), the eastern and western (Duncan 1999, Lowther *et al.* 1999, Meyers 2004). The western population (*Passerina ciris palladior*) occurs primarily in Kansas, Oklahoma, Texas, Arkansas, and Louisiana, while the eastern population (*Passerina ciris ciris*) is limited to the coastal areas of North Carolina, South Carolina, Georgia, and northern Florida (Lowther *et al.* 1999).

The eastern population of Painted Buntings—the focus of this study—occurs along the Atlantic coast and depends on young understory growth for breeding and nesting, especially the scrub-shrub maritime habitat in coastal areas (Duncan1999; Meyers 2004). The female Painted Bunting builds a deep cup nest in a bush or shrub,

Figure 1. Painted Buntings (*Passerina ciris*) have different color phases depending on the sex and/or age of the bird. (a) Adult males look as if they are "painted" with a blue head, red belly, green back, and red eye ring. (b) Females are more cryptic, with greenish feathers throughout. (c) Young males have a similar appearance to females, until after their second year. Females and young males are also nicknamed “green birds”.

and occasionally in Spanish Moss (*Tillandsia usneoides*) or vines (Ehrlich *et al.* 1988; Meyers 2004; Parmelee 1959; unpubl. data). Nests are constructed with grasses, forbs, and leaves and lined with fine grasses or hair (Ehrlich *et al.* 1988). Nests are often placed near the main trunk of the shrub, approximately 1 to 2 meters above the ground (Meyers 2004, Parmelee 1959). Three to four eggs are incubated by the female for 11 days, and young fledge after 8 to 9 days of brooding (Parmelee 1959). During incubation, the male periodically visits the nest; however, it is unknown where males actually roost at night (Parmelee 1959). Once the fledglings leave the nest, the female will continue feeding while she builds a new nest close to the first and prepares to lay another clutch (Meyers 2004, Parmelee 1959, personal observation). Males will occasionally take over care of the fledglings when the female begins to renest (Parmelee 1959).

Figure 2. Map of the distribution of Painted Buntings (*Passerina ciris*), from Lowther *et al.* (1999). Note the two distinct populations, eastern and western.

Painted Buntings are primarily seed eaters (Ehrlich *et al.* 1988, Lanyon 1986, Meyers 2004, Parmelee 1959, Springborn & Meyers 2005). However, during the breeding/nesting season, adult Painted Buntings will often eat insects as well (Springborn & Meyers 2005, Meyers 2004, Lanyon and Thompson 1986, Parmelee 1959, personal observation). Young Painted Buntings feed solely on insects, especially grasshoppers (Meyers pers. comm., 2007, Parmelee 1959, personal observation). Approximately two weeks after fledging, their diet changes and they feed exclusively on seed and other vegetation, until they reach breeding age. Shallow pools and puddles of water are often visited for drinking and bathing (Parmelee 1959; personal observation).

Male Painted Buntings can be very territorial, defending their area from conspecifics of both sexes (Lanyon and Thompson 1984, Parmelee 1959, personal observation). The male bunting uses several threat displays. Non-mated female buntings that trespass in another bunting's territory will also be harassed. Although males can be aggressive, they peacefully co-exist as they eat from neighborhood bird feeders (personal observation). Researchers believe the males probably travel outside of their territories to visit bird feeders, which are utilized as a shared public area (Lex Glover, personal communication). Lanyon and Thompson (1986) found that Painted Buntings settle in territories on forest edges and interiors during the breeding season. They concluded that edge territories were of higher quality, because the edges were settled first and were highly defended. Lanyon and Thompson (1986) also showed that buntings were site faithful and would settle in familiar areas used in previous years.

According to research conducted by Springborn and Meyers (2005), territory size was the same for male and female buntings in understory maritime forest, with a mean of 3.1 ha (7.7 acres). However, in pine-oak forest with less understory, male Painted Bunting territory size increased to a mean of 7 ha (17.3 acres). This increase in territory size is thought to be due to the need to travel longer distances to reach better foraging areas, suggesting lower quality territories (Springborn and Meyers 2005; Lanyon and Thompson 1986; J. Meyers pers. comm.).

PAINTED BUNTING POPULATION

Declines in the Painted Bunting's population are thought to be due to habitat loss, parasitism from the Brown-headed Cowbird (*Molothrus ater*), and the trapping of male birds in Mexico for the pet trade (Ehrlich *et al.* 1988, Lowther *et al.* 1999, Rich *et al.* 2004). In fact, from 1984 to 2000, more than 100,000 buntings were captured for the domestic pet trade in Mexico (Iñigo-Elias *et al.* 2002). An estimated 6,000 buntings are exported to European and Asian countries each year (Iñigo-Elias *et al.* 2002, Fig. 3).

Currently, the eastern population of buntings is estimated at fewer than 100,000 birds, with 4,000 in North Carolina, 50,000 in South Carolina, 30,000 in Georgia, and 7,000 in Florida (Fig. 4, PIF 2007). Breeding Bird Survey data indicate that the eastern and western combined populations of Painted Bunting declined over 60% from 1966-1995 (Meyers 2004) or 3.5% annually (Sauer *et al.* 2007). The eastern population is believed to have declined as much as 2.58% annually from 1966-2002 (Sauer *et al.* 2007). Because of this decline, the Painted Bunting has been given "Focal Species" status by the US Fish and Wildlife Service (USFWS 2005), included on the National Audubon Society's WatchList (2007), identified as an 'extremely high priority' species in the Partners in Flight Bird Conservation Plan (Rich *et al.* 2004), and listed on the IUCN Red List as 'near threatened' (BirdLife International 2008).

Figure 3. Male Painted Buntings (*Passerina ciris*) for sale in a street market in Latin America. Photo taken by © Eduardo Iñigo-Elias.

Despite regional declines in Painted Bunting numbers, Kiawah Island, SC appears to be home to a stable population of these birds. Breeding Bird Surveys (BBS; Sauer *et al.* 2007) show a consistent population size of buntings on Kiawah Island since 1998 (Fig. 5). However, this may not be an accurate representation of the population on Kiawah Island because these numbers reflect a snap shot measuring only one day each year. Moreover, there is growing concern that continued development on the island may have negative impacts on the bunting population as their preferred understory habitat is removed.

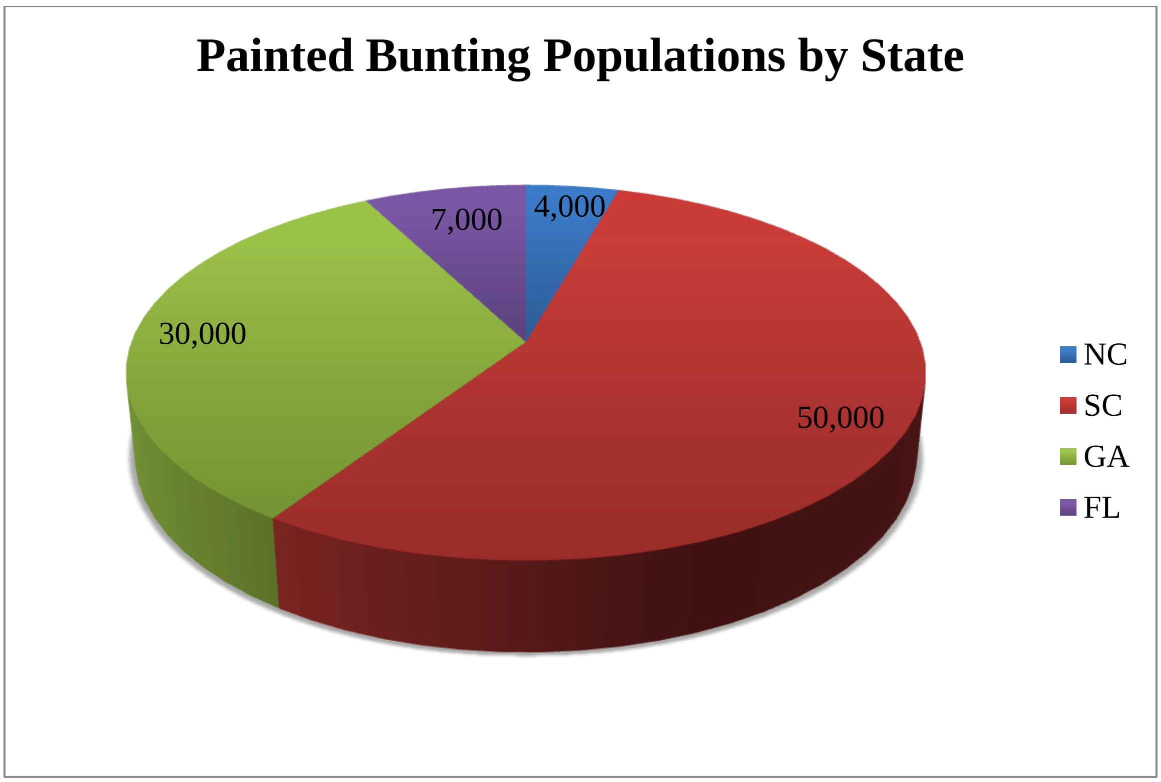


Figure 4. Estimated numbers of Painted Buntings (*Passerina ciris*) by state, in the eastern population. Figures are from the Partners in Flight Landbird Population Estimate Database (2007).

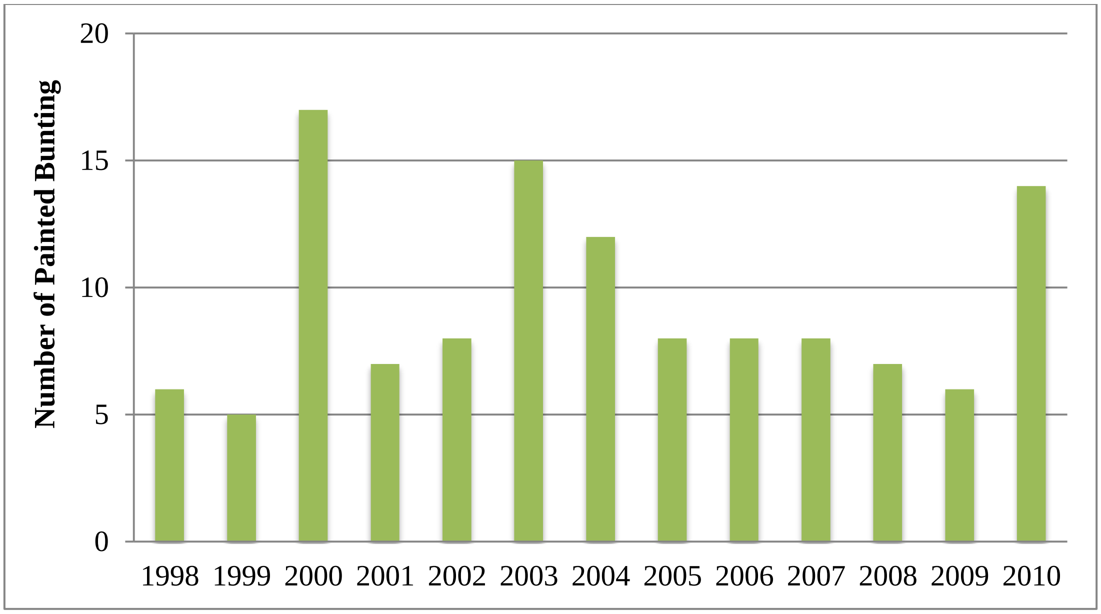


Figure 5. Annual number of Painted Buntings (*Passerina ciris*) seen or heard on the USGS Breeding Bird Survey conducted on Kiawah Island, SC from 1998-2010.

STUDY AREA

Kiawah Island is a barrier island roughly 32 km (20 mi) southwest of Charleston, South Carolina (Cobb 2006). The island is approximately 23 km (14 mi) long and 2.3 km (1.5 mi) across, at the widest point (Hayes and Michel 2008). A temperate climate dominates the island, which receives about 1.2 m of rain annually. The island is oriented with its longest axis running essentially east to west, and consists of approximately 1,335 ha of high ground and 1509 ha of marsh (Cobb 2006). The main ecosystems that dominate the island are: 1) beach/dune, 2) maritime forest, 3) estuary, and 4) freshwater (Hayes and Michel 2008; Cobb 2006).

The beach faces to the south and stretches the length of the island. As the beach builds northward toward the interior of the island, it begins to form the dunes system, with vegetation typically consisting of Sea Oats (*Uniola paniculata*), Sea Elder (*Iva imbricata*), *Croton sp.*, and Wax Myrtle (*Myrica cerifera*). As the dunes undergo succession over time, they form the maritime forest ecosystems. Those upland forests are dominated by Live Oaks (*Quercus virginiana*), Loblolly Pines (*Pinus taeda*), and Sabal or Cabbage Palmetto (*Sabal palmetto*). These species that grow closer to the beach experience harsh conditions from wind and salt, called salt pruning, preventing natural growth patterns (Hayes and Michel 2008). Expansive salt marshes and tidal creeks comprise the estuarine ecosystem that dominates most of the northern portion of Kiawah. This estuarine area is covered by a monoculture of Salt-marsh Cord Grass (*Spartina alterniflora*; Hayes and Michel 2008; personal observation). The freshwater ecosystems are primarily manmade (e.g. Willet and Ibis ponds, located on the eastern end of the island), but are very diverse (Cobb 2006), consisting of many of the same plant species found in the maritime forest ecosystem (personal observation).

According to the 2000 U.S. Census, there are 1,163 people living on Kiawah Island, and their median age is 61 y. The Census also reported 3,070 housing units with only 557 (17%) occupied by full-time residents. The remaining 2,513 (83%) units are for "seasonal, recreational, or occasional use" (U.S. Census 2000). This high percentage of non-permanent residents on Kiawah can make conservation measures difficult.

As of 2007, Kiawah Island had 3,250 home units, with 850 slated for development at a later date. Build-out of the island is estimated to have over 5,600 residential properties (TOKIEC 2007). Therefore, over 40% of the island is still designated for residential and/or resort development, leading to potential negative consequences for Painted Buntings and other wildlife that share similar habitat preferences. Furthermore, 83% of the human population only visits temporarily, adding unique challenges for restoration efforts.

METHODS

Data were collected during the breeding season for Painted Buntings during April-August, 2007-2010. Many of our field procedures (e.g. banding and radio-tagging) required research permits. Therefore, we relied on assistance from biologists who held state and federal permits to complete these tasks. We were also approved by the Institutional Animal Care and Use Committee at the College of Charleston (Approval code: IACUC-2009-017).

CAPTURE & BANDING

Buntings were captured with cage traps (Fig. 6). The cage traps contained a feeder full of white millet and were hung at the sites of bird feeders when buntings were regularly observed. When buntings flew into the traps to feed, they were unable to find their way back out. The feeders were located in three of the main habitat types on Kiawah Island: 1) maritime marsh, 2) maritime interior, and 3) seaside dunes.

We fitted each non-banded Painted Bunting with a numbered aluminum leg band (provided by the U.S. Geological Survey) and a unique combination of color bands (Fig. 7). We also measured body mass and recorded sex, age, and breeding phase based on plumage characteristics.

Figure 6. Painted Bunting (*Passerina ciris*) captured in a cage trap and foraging at a feeder.

Figure 7. Painted Bunting (*Passerina ciris*) with unique color band combination.

RADIO TRACKING

Once the birds were banded, we attached the radio transmitters (model A2426, Advanced Telemetry Systems, Inc., Isanti, MN, USA) using the technique of Rappole and Tipton (1991). Transmitter weight was 0.65 g, which was < 5% of the mean mass of 77 buntings banded by the PBOT (excluding egg-bound females). Buntings with a body mass < 13.0 g or egg-egg-bound females were not radio-tagged.

We used a variety of different thread types: thin, thick, and elastic sewing threads and catgut sutures. The thin thread was typically bitten through and removed by the bird within days to a week. The thick thread and catgut suture stayed on the longest. However, they were difficult to work with, increasing the time we had to hold the buntings. Moreover, the thick thread did not degrade quickly, as we had three buntings return the following years with their transmitters still intact. The elastic thread was the easiest and quickest to apply. While the buntings were still able to bite through the elastic thread, they were usually unable to remove the transmitters before the transmitter batteries died. The battery life of the transmitters was rated to last 36 days. Unfortunately, due to unknown circumstances, they almost never lasted past 23 days. Toward the end of each field season, we attempted to recapture radio-tagged buntings to recover the transmitter and prevent the bird from migrating with additional weight.

We used an ATS R410 Scanning VHF Receivers (and a Magnetic Mount SN150 Car antenna) with a 3-Element Folding Yagi antenna to locate and make visual contact with each radio-tagged bunting each day, sometimes multiple times per day, using the homing technique described by Samuel (1994). We also tracked the birds during different periods of the day to ensure that our estimate of each bird's home range was representative of its daily movement patterns. Each day was divided into multiple sampling periods between sunrise and sunset (e.g. 6-8am, 8-10am, 10-12pm, etc.). We attempted to sample each bird's location at least once during each of the time periods and before the transmitter battery died.

Once a bird was located, we recorded a number of variables describing its location (UTM) and activity (Table 1). The bunting's exact location was recorded using handheld GPS units (Magellan Meridian Gold Mapping and Garmin eTrex summit GPS units; Santa Clara, CA and Olathe, KS, respectively). We also noted information about the bird's behavior (e.g. singing, preening, foraging, etc.) and vegetation use (e.g. Live Oak, Slash Pine (*Pinus elliottii*), snag, etc.) at this location. The time of day and weather conditions were also noted. We assumed mortality of a bird if its transmitter was located and there were signs of predation, such as blood, tissue, or excessive numbers of feathers lost. Otherwise, we assumed the bird had been able to bite off or slip out of its harness. Attempts were made to relocate these birds that "escaped" from their harnesses or whose batteries died prematurely so we could verify they were still alive.

Table 1. Data recorded for each sighting of each radio-tagged Painted Bunting (*Passerina ciris*) on Kiawah Island from 2007-2010

Telemetry variable codes	**Variables**
Accuracy	Accuracy of GPS reading (m)
Activity:	Activity of Painted Buntings; activity codes listed below:
C	Capture
Co	Copulating
FdF	Feeding fledglings
FdN	Feeding nestlings
Fo	Foraging
I, Br	Incubating, brooding
M	Multiple activities
O	Other
Pr	Preening
ReC	Recapture
SG	Singing
TI	Territorial interactions
U	Unknown
Activity ht m.	Height of Painted Bunting during observation (m)
Activityhtm. mean	Mean of Activity height per bird
Age:	Age of Painted Bunting; age codes below:
ASY	After-second-year, adult Painted Bunting
SY	Second-year, juvenile Painted Bunting
HY	Hatch-year Painted Bunting
U	Unknown age of Painted Bunting
Bird id	Alphabetical code specific to each bird
Bird number	Telemetry frequency used in tracking
Bird number comment	Telemetry frequency comment noting when the same frequency was reused in a season
Date	Date (mm, dd, yyyy) data taken
GPS unit	Global Position System unit used to collect coordinates of observed Painted Buntings

Lat	UTM reading of easting coordinates
Long	UTM reading of northing coordinates
Plant species	Plant species Painted Bunting was observed
Sex:	Sex of Painted Bunting:
F	Female
M	Male
U	Unknown
Time	Time data was recorded (24-hour clock)
Visual	Visual of Painted Buntings (yes or no)
Weather Reading:	Weather variables taken at the sight where Painted Bunting was observed
Ave wind mph	Average wind speed (mph)
Cloud coverage	Percent of cloud coverage
Humidity	Percent Humidity
Precipitation	Precipitation (yes or no)
Temp	Temperate (C) at time of Painted Bunting sighting

To evaluate Painted Bunting's use of vegetation and habitat types on Kiawah Island, we focused on: 1) land use types, 2) substrates used, and 3) home range and territory sizes.

LAND USE

We used a land use map layer created by the Town of Kiawah Island (Fig. 8; digitized by the Town of Kiawah Island) to determine in which land use type Painted Buntings were observed most often, the distance they were from the various land use types, and the distance they were from the edge of the land use types. Land uses were classified as: 1) developed, 2) maritime forest, 3) golf courses, 4) marsh, 5) open/altered, 6) beaches/dunes, 7) roads, 8) scrub/shrub, and 9) water. However, the dune and beach land use types were removed because our focus was on the marsh-side and interior parts of the island. All telemetry data were added to this land use layer to allow for analysis in ArcGIS (ESRI, Redlands, CA).

We used the ArcGIS *Near* analysis tool to calculate the distance from each telemetry point (representing a bunting's location) to each land use type within a 350 m radius. We derived that distance - intended to identify all land use types within the bunting's home range - by rounding up from 315 m, identified separately as the radius of the largest home range observed in this study. A zero was recorded for the land use type in which a bunting was located; if the bunting was > 350 m from a particular land use type, the value for that type was calculated as 351 m.

Similarly, we used the *Near* analysis tool and the same land use layer to estimate a buntings' mean distance from an edge. For each observation of a bunting, we measured the distance to the nearest edge that fell within a 350 m radius.

Figure 8. World imagery of Kiawah Island, SC displaying the dominant land use types of the island. Land use layer was digitized and provided courtesy of the Town of Kiawah Island, SC. Map created by Emma 'Lu' Paz, July 2011.

SUBSTRATE

PLANT SPECIES - Plant species refers to the species of plant a Painted Bunting was observed using. A total of 33 substrate types were recorded as used by buntings. The term *shrub* was used when we observed buntings using multiple species of understory vegetation or when an understory plant species could not be identified. Similarly, we used the term *unknown* when we could not identify the actual plant species the bunting was using because we were unable to observe it clearly.

For each bird, we identified the number of times it was seen on specific plants. Because the number of times we observed each bunting varied, the individual counts of plant species used by the buntings may over-represents some plant species. Therefore, we calculated and report the proportion of times we observed each bird in each of the plant species it used, rather than simply reporting the absolute number of times a given bird was seen in a particular plant species.

VEGETATION PLOTS - Within each bunting's territory, we measured the ground cover, mid-story, and canopy layers using a modified version of the BBIRD Protocol (Martin *et al.* 1997; Table 2). We revisited each bird's location at some point after observing it (≤ 3 months, with mean of 44 days elapsed between documenting the sighting and sampling the vegetation) and used that coordinate as the center point for our vegetation sampling protocol. From the center point, we measured out circles with 5 m and 11.3 m radii (Fig. 9). In areas where nests were found, we carried out the standard vegetation sampling protocol (outlined below), but also conducted a more thorough measurement of the nest and nest patch itself. Exact methods for carrying out ground, mid-story, and canopy layer samples are as follows:

Table 2. Microhabitat variables measured at sites where radio-tagged Painted Buntings (*Passerina ciris*) were observed on Kiawah Island, SC from 2009-2010.

Vegetation variable codes	**Variable**
DBH	Diameter breast height (cm), measured at 137 cm high on the plant species
Plant species height	Height of plant species being measured (m)
Ground Cover Variables:	
bare ground	Percent of open ground not covered by leaf litter
boardwalk/dock	Percent of ground covered by a boardwalk or dock
brush	Percent of ground covered by small dead woody vegetation less than 50 cm above the ground
fern	Percent of ground covered by ferns below 50 cm
forb	Percent of ground covered by broad-leafed non-woody plants below 50 cm tall
grass	Percent of ground covered by grasses, sedges, or rushes below 50 cm in height
green	Percent of ground covered by green vegetation that is below 50 cm in height
house	Percent of ground covered by house or other large man-made structure
leaf	Percent of ground covered by leaf litter
log	Percent of ground covered by downed logs >12 cm diameter
marsh	Percent of ground covered by marsh vegetation
moss	Percent of ground covered by moss
other	Percent of ground covered by variable not listed (i.e. lumber, cactus)
road/driveway	Percent of ground covered by paved road or driveway
rock	Percent of ground covered by rocks
shrub	Percent of ground covered by woody perennial plants that are below 50 cm tall
snag	Percent of ground covered by snags (standing dead tree) below 50 cm
trail	Percent of ground covered by man-made, unpaved trail or dirt road
vine	Percent of ground covered by vines
water	Percent of ground covered by standing water (fresh, brackish, or salt)
Midstory Variables:	

SWS	Number of small diameter (< 6 cm) live stems of species found within the 5 m plot circle
LWS	Number of large diameter (6-20 cm) live stems of species found within the 5 m plot circle
Midstory	Total number of small and large diameter stems of live species found within the 5 m plot circle
SWS %	Percent of small diameter stems of species found within the 5 m plot circle ((# SWS/Midstory)*100)
LWS %	Percent of large diameter stems of species found within the 5 m plot circle ((# SWS/Midstory)*100)
Midstory aveht	Estimated mean height of Midstory per 5 m plot
Canopy Variables:	
scanopy	Number of small diameter (20-58 cm) live tree stems of species found within the 11.3 m plot circle
mcanopy	Number of medium diameter (58-96 cm) live tree stems of species found within the 11.3 m plot circle
lcanopy	Number of large diameter (> 96 cm) live tree stems of species found within the 11.3 m plot circle
canopy	Total number of small, medium, and large tree stems of species found within the 11.3 m plot circle
canopy aveht	Estimated mean height of canopy trees per 11.3 m plot
densiometer	Percent canopy cover ((# dots covered/96)*100)
Snag#	Number of snags (with a diameter of ≥ 20 cm and standing ≥ 1 m tall) within the 11.3 m radius plot

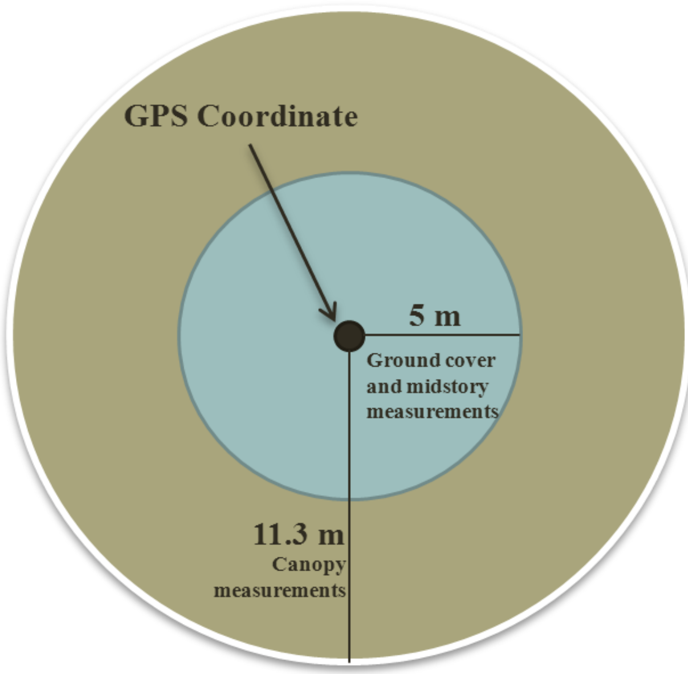


Figure 9. Example of a horizontal plot layout used for vegetation measurements.

Ground Cover – We measured the horizontal vegetation structure within the 5 m radius. To quantify ground cover we estimated percentages of green cover, grasses/sedges/rushes, shrubs, brush cover, forbs, ferns, mosses, leaf litter, fallen logs, rocks, water, marsh vegetation, bare ground, vines, trails, roads/driveways, snags, houses, boardwalks/docks, and other cover. We also listed the three most common ground cover species within the 11.3 m radius.

Initially, we analyzed each of the 20 ground cover types to identify any differences in these ground cover types between sexes and age classes. Later, we reduced the 20 ground cover variables into four distinct categories likely to represent different ways in which the buntings use their environment. Those categories were : 1) live vegetation (grass, shrubs, forbs, ferns, marsh, moss, and vines), 2) dead vegetation (brush, leaf litter, fallen logs, water, bare ground, and snag), 3) manmade materials (boardwalk/dock, house, road/driveway, rock, and trail), and 4) other. This grouping of variables helped reduce our chances of having a Type I error.

Mid-story – Within the 5 m radius, we measured the vertical structure of the mid-story layer by counting all woody stems with a height of 0.5 m - 5 m. Using a diameter tape, we classified these stems as either small woody stems (SWS; <6 cm in diameter) or large woody stems (LWS; 6 to 20 cm in diameter) and estimated the mean height of all woody stems combined. We also listed the three most common mid-story species within the 11.3 m radius.

To estimate basal area, we used the formula: Basal Area (m^2) = 0.00007854 * dbh^2. Because all stems were placed into a category and not individually recorded, we used the midpoint of the SWS (3.18 cm) and LWS (13 cm) categories when estimating overall basal area.

Canopy Trees – Within the 11.3 m radius, we counted all trees that were $\geq$ 5 m in height and $\geq$ 20 cm in diameter. Using a diameter tape, we evaluated each tree counted and placed it into one of three categories based on its diameter at breast height (dbh): 1) 20-58 cm dbh, 2) >58-96 cm dbh, or 3) > 96 cm dbh and then estimated the overall mean height. We also listed the three most common canopy trees within the 11.3 m radius. Finally, we measured canopy coverage using a concave densiometer. These readings were taken at chest height, from the central point of the circle and were read four times, at angles 0, 90, 180, and 270.

We used the formula mentioned previously to calculate the basal area of the canopy trees in the area surrounding a bird's observed location. Because all trees were placed into a category and not individually recorded, we used the midpoint values of the small canopy (39 cm), medium canopy (77 cm), and large canopy (115 cm) categories to estimate overall basal area. We then calculated the mean basal area of the small, medium, and large canopy trees for each bird.

ACTIVITY VARIABLES

There were 13 *Activity Variables* used (see Table 1) to describe the behaviors observed when we located individual birds, including their activity height. The activity height refers to the height at which we encountered a bunting. We estimated these heights using comparison with objects of known height, with a 3 m pole, or with a clinometer.

HOME RANGE & TERRITORY

We calculated home range and core range by using the minimum convex polygon (MCP) and kernel density tools (respectively) in ArcGIS. The MCP tool connects the outer most telemetry points for each bird, thereby including all telemetry points within the polygon. Kernel density identifies areas where points are clustered, and therefore more closely identifies the bunting's core range. This tool calculated the density per unit area of the telemetry points and produced a raster layer with a smoothed estimation of the bird's territory (Fig. 10; Worton 1989, Aebischer *et al.* 1993). For both the home range and territory analysis, we removed telemetry points where buntings were captured while foraging at feeders. We also removed the birds that had fewer than 6 observations.

Figure 10. Calculation of a Painted Bunting's (*Passerina ciris*) home range, using the minimum convex polygon technique (MCP; yellow line) and core range, using the kernel density technique to identify the area used ≥ 50% of the time. Note how MCP can overestimate home range sizes because it includes areas not visited by the bunting. Map created by Sarah Latshaw, June 2011.

STATISTICAL ANALYSIS

Statistical analyses were performed in Minitab statistical software (Minitab Inc. 2010; State College, PA). Because of the variability in the number of Painted Buntings caught each year (including sex and age class variability), we pooled the data for all the years. To reduce pseudoreplication, we only used the data collected on a bunting from one year, even if we caught it in multiple years.

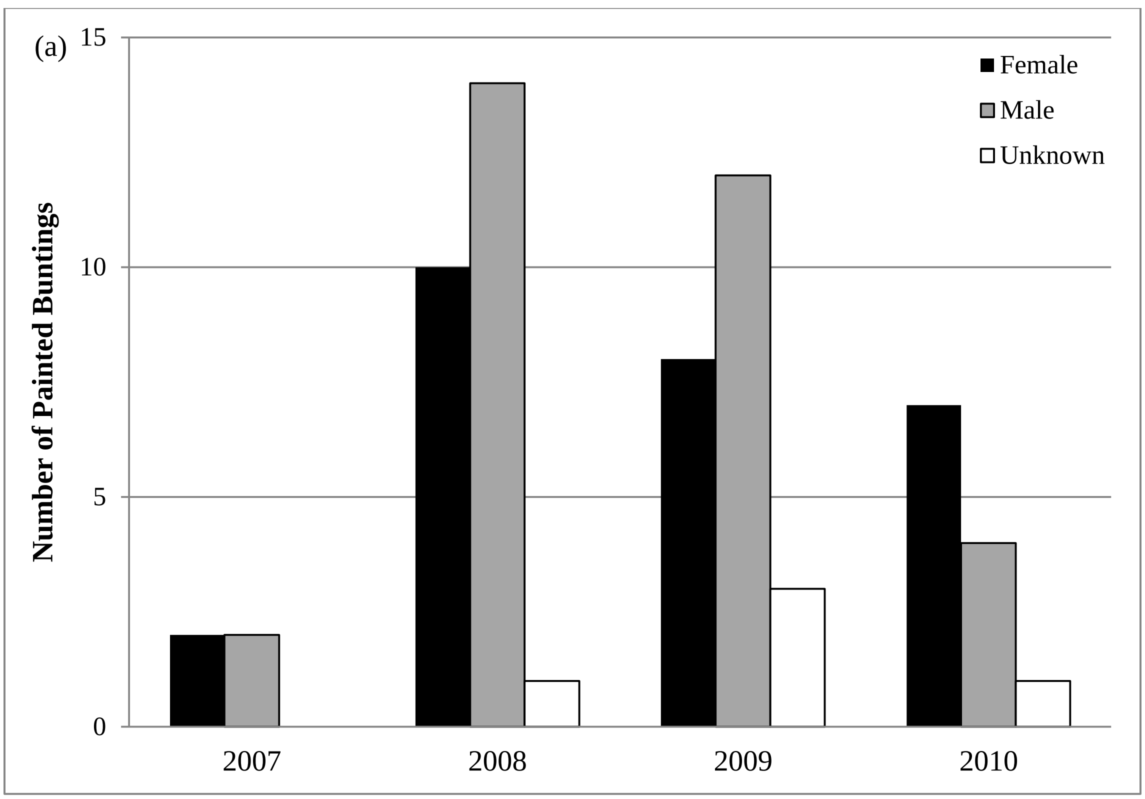
Likewise, to reduce pseudoreplication in comparisons between birds, we used the means of each variable per bunting. This was done because each bunting had a different number of data points. We used the mean values for each bunting to make comparisons between sexes (Male, Female, and Birds of Unknown Sex) and age classes (ASY – After-second-year, SY – Second-year, and HY – Hatch-year). Any buntings that had fewer than six observations were removed from our assessment.

We used ANOVA to compare variables between sex and age classes, with $\alpha \leq 0.05$ used to identify significance. For analysis with a high number of variables (ground cover and plant species), we applied a Bonferroni correction to correct for issues of multiple comparisons, and to reduce the likelihood of a Type I error.

All variables were tested for normality, and we used standard logarithmic transformation when necessary to achieve a normal distribution of the data. For ease of clarity, tables reflect the non-transformed data. Moreover, an "*" denotes when reported values are the log-transformed values.

RESULTS

During the 2007-2010 field seasons, we caught, radio-tagged, and tracked 64 Painted Buntings (Fig. 11) on Kiawah Island, SC. We recaptured and radio-tagged six buntings one year later. For any given recaptured bird, we excluded from analysis the year with the least data (therefore n = 58 individuals).



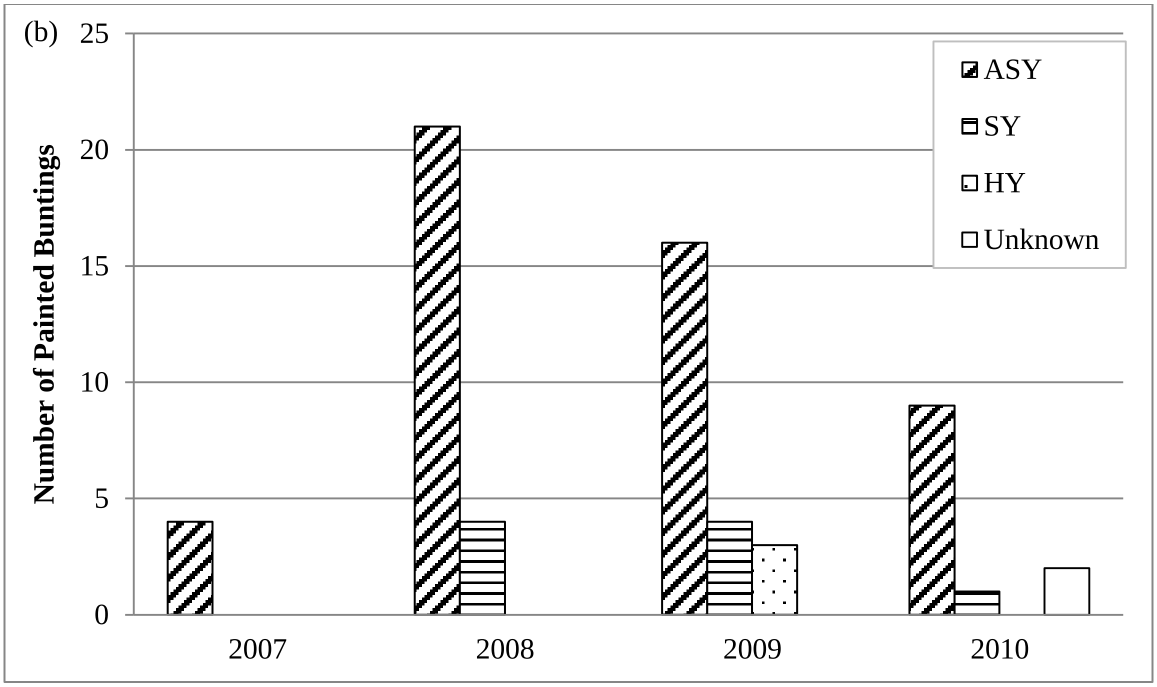


Figure 11. Painted Buntings (*Passerina ciris*) captured from 2007-2010 by (a) sexes and (b) age classes (ASY – After Second Year, SY – Second Year, and HY – Hatch Year).

Figure 12 depicts the number of birds caught in each habitat type. It proved difficult to track the birds we caught on the seaside part of the island in 2008 and to assess the characteristics of their preferred vegetation because they used dense, often impassable, dune vegetation. Therefore in 2009 and 2010, we focused our trapping efforts on bird feeders located on the marsh side and interior parts of the island. Marsh feeders were, on average, 9 m (range 5 -12 m) from the marsh edge, while inland feeders averaged 540 m (range 206 - 1085 m) from the marsh edge.

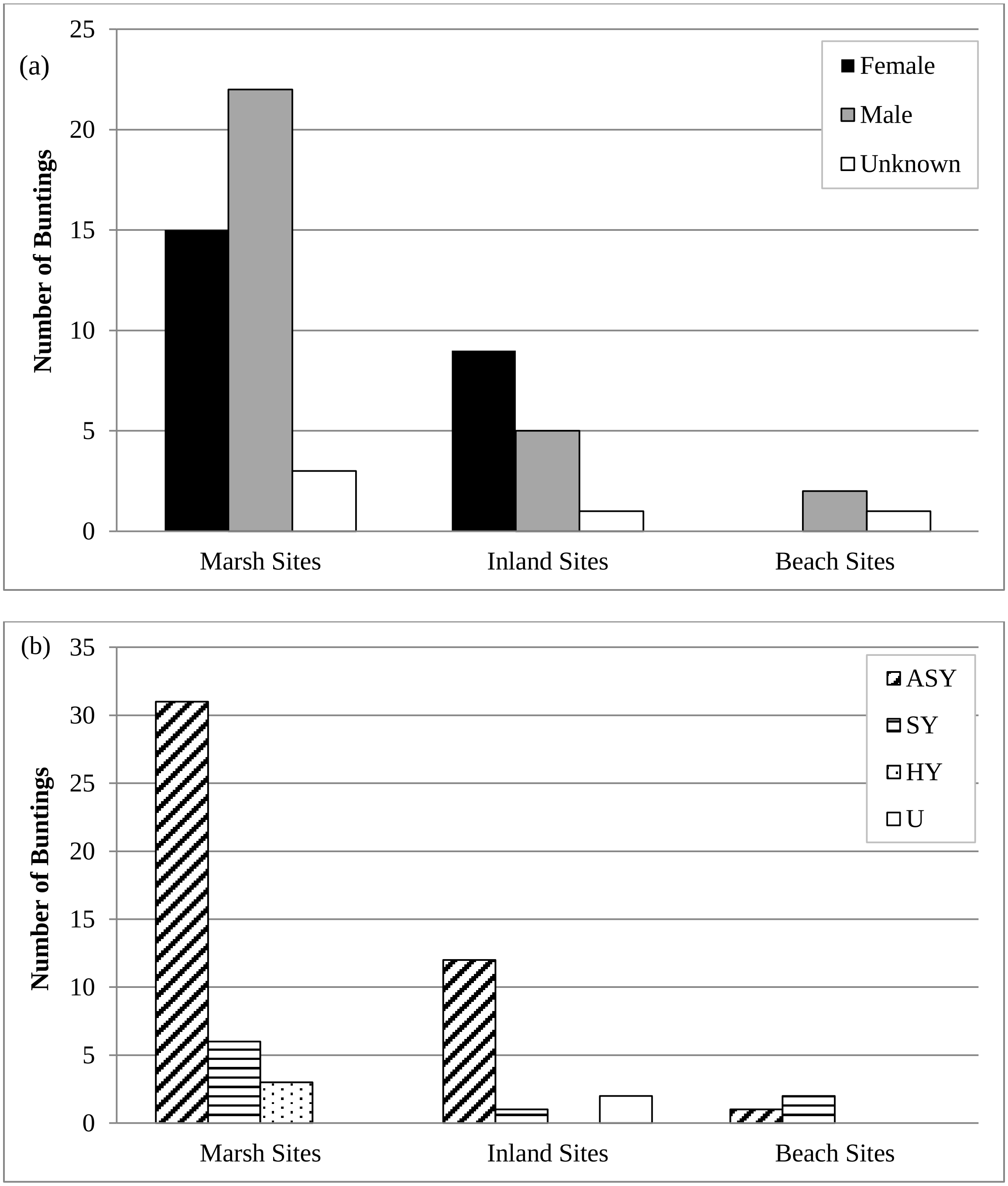


Figure 12. Painted Buntings (*Passerina ciris*) caught at marsh, inland, and beach feeders distributed into (a) sex and (b) age classes (ASY – After Second Year, SY – Second Year, and HY – Hatch Year).

We relocated radio-tagged buntings (Fig. 13) 1,303 times (mean ± SD; 26.1 ± 16.8), after removing those birds with fewer than six observations. There was no significant difference in the rates at which we found males (28.7 ± 18.6, n = 26), females (22.6 ± 14.1, n = 20), and birds of unknown sex (26.3 ± 18.2, n = 4; F = 0.74, df = 49, p = 0.49). Similarly, there was no significant difference in the rates at which we found ASY (24.4 ± 15.2, n = 38), SY (38.5 ± 22.5, n = 8), and HY buntings (17.7 ± 7.2, n = 3; F = 2.15, df = 49, p = 0.11).

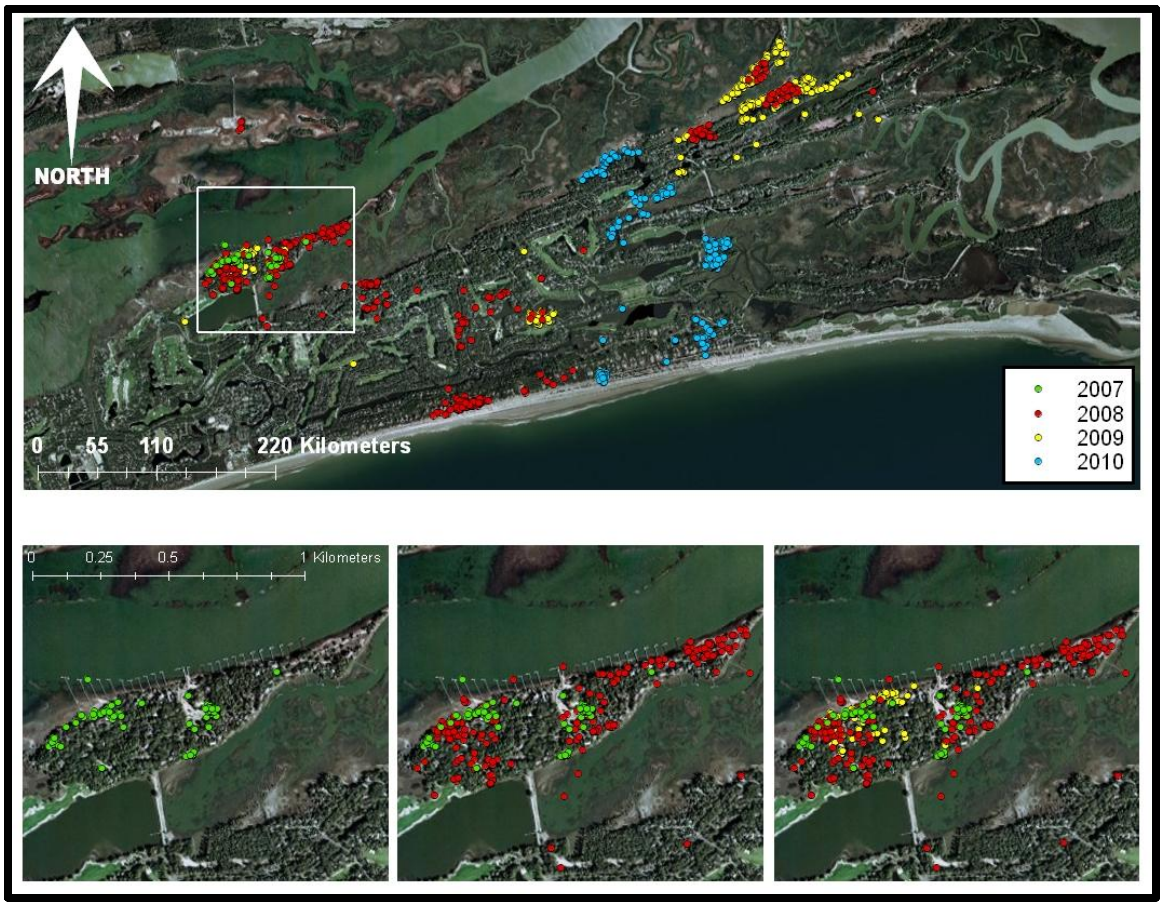


Figure 13. Painted Buntings (*Passerina ciris*) tracked on Kiawah Island, SC, from 2007-2010 (top). Each color represents a year (green = 2007, red = 2008, yellow = 2009, and blue = 2010) and each dot represent one observation of one bird at one particular time of day. The map series below depicts a zoomed in view of a neighborhood on Kiawah Island (Rhett's Bluff).

Of the 58 birds in our sample, we removed those that had fewer than 6 observations (therefore n = 50). From that sample size, we revisited the core areas used by 20 of those buntings to record more detailed vegetation characteristics (Fig. 14; see Table 2 for vegetation variables recorded). We visited a total of 283 plots (14.2 ± 6.14 plots per 20 bunting). There were no significant differences in the mean number of plots measured for males (15.4 ± 4.4, n = 11), females (17.6 ± 11.7, n = 7), or buntings of unknown sex (11.5 ± 5.0, n = 2; F = 0.5, df = 19, p = 0.6). Similarly, there were no significant differences in the mean number of plots measured for ASY (16.6 ± 8.1, n = 16), SY (13.5 ± 5.0, n = 2) or HY buntings (11.5 ± 5.0, n =2; F = 0.46, df = 19, p = 0.6).

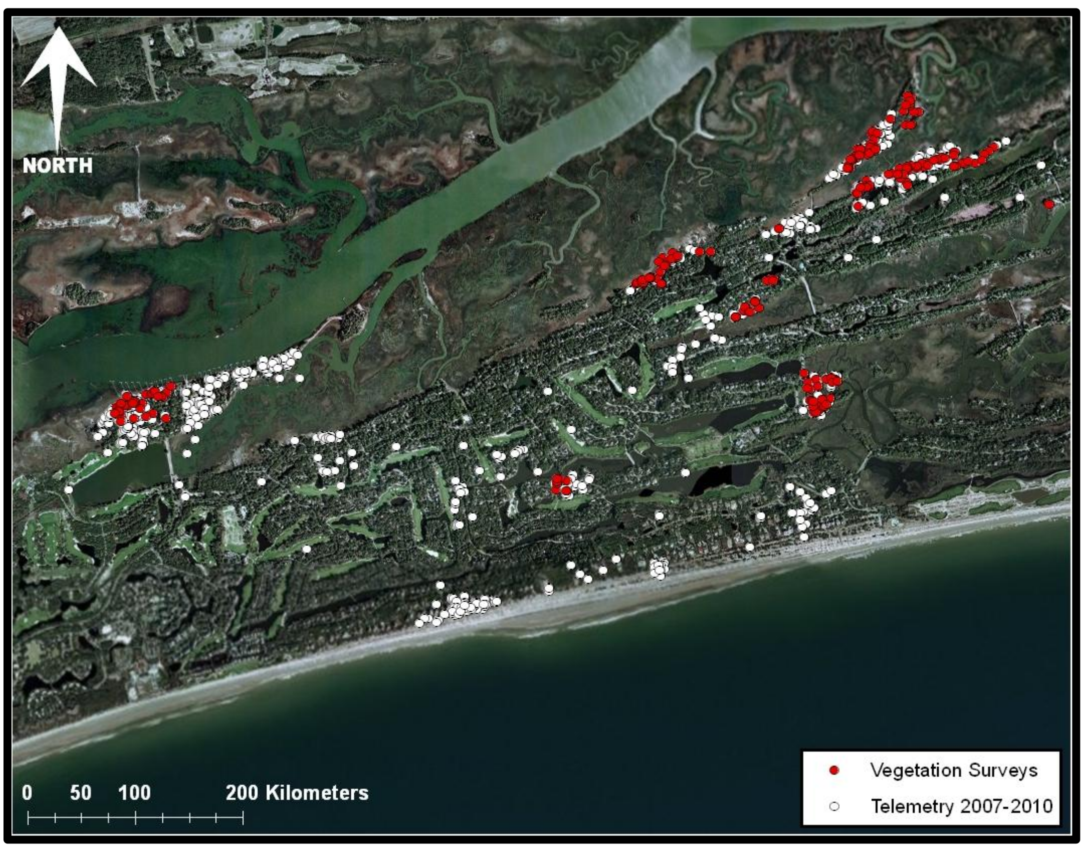


Figure 14. Subset of vegetation surveys (red) taken from Painted Bunting (*Passerina ciris*) observations (white).

LAND USE

Of the dominant land use types on Kiawah Island, SC (Fig. 15), Painted Buntings were observed significantly closer to maritime forests (mean ± SD = 20.7 ± 22.4 m), scrub/shrub (51.9 ± 89.4 m), and developed (25.6 ± 25.9 m) land use types, compared to road (44.1 ± 19.6 m), marsh (77.0 ± 100.3 m), fresh water (203.2 ± 89.7 m), and golf courses (244.2 ± 104.4 m; F = 65.6, df = 314, p = <0.001*; Fig. 16).

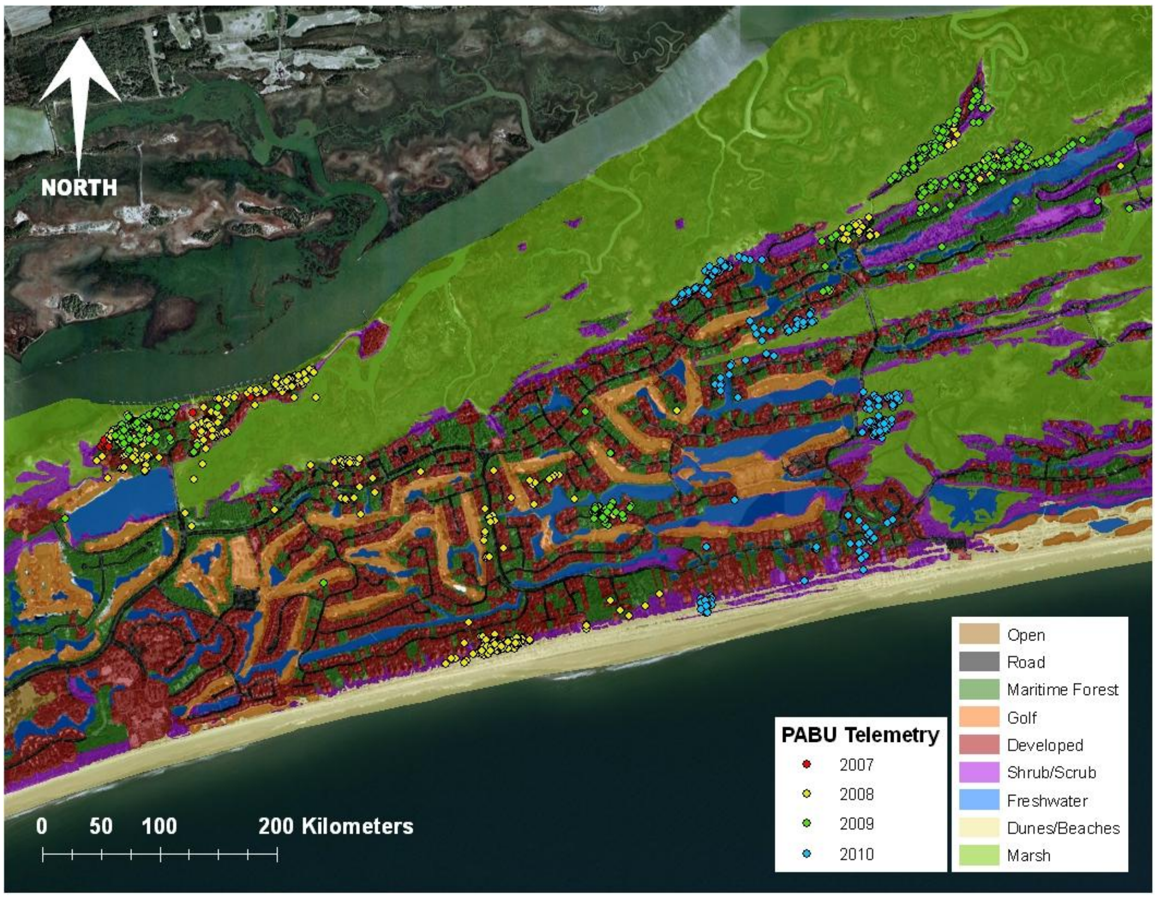


Figure 15. The dominant habitat types of Kiawah Island, SC. Locations at which Painted Buntings (*Passerina ciris*) were observed from 2007-2010 indicated by filled circles. Note the use of areas near habitat edges, as well as proximity to marshes. This data layer was digitized and given to us courtesy of the Town of Kiawah Island. Map created by Emma 'Lu' Paz, July 2011.

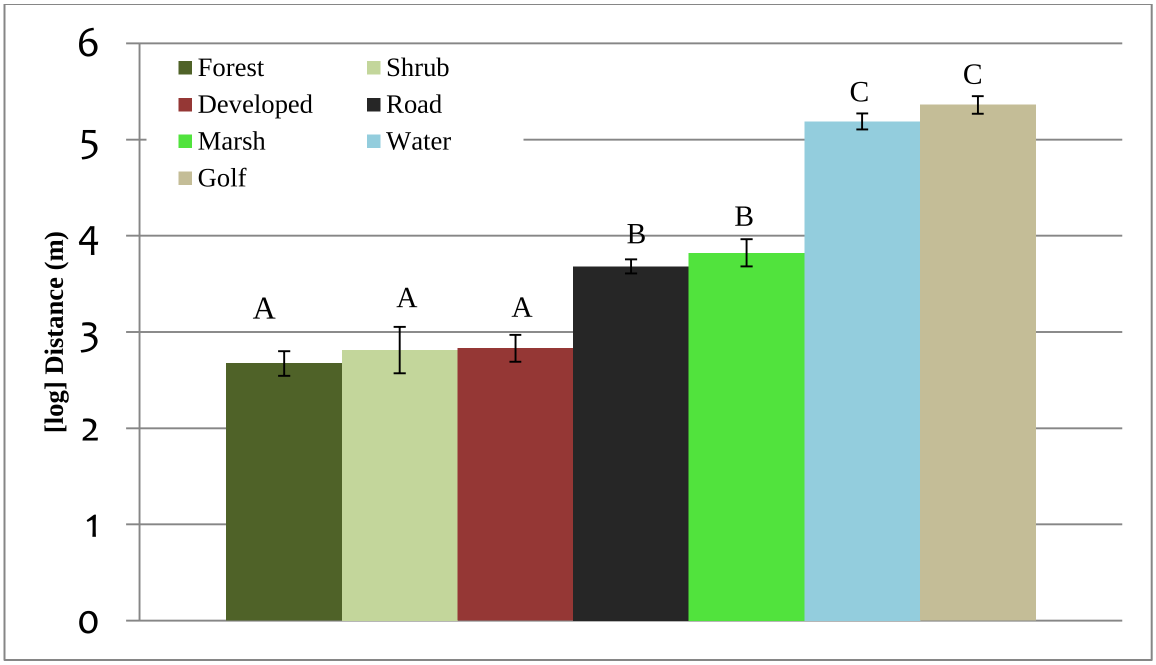


Figure 16. Mean [log] distances ± SE (m) of Painted Buntings (*Passerina ciris*). Observations from 3 of 10 land use types (beach, dunes, and open/altered land uses) are not displayed because those areas were out of the range of the buntings in our study. Means with different letters are significantly different.

Between the sexes, Painted Buntings showed no preference in land use types (Table 3). However, there was a non-significant trend for females to be observed closer to the road more often than birds of unknown sex, but not more often than males ($F = 3.01$, $df = 49$, $p = 0.06$*). ASY buntings were found closer to roads than SY buntings, but were not significantly closer to the road than HY buntings ($F = 3.85$, $df = 48$, $p = 0.03$*). SY buntings were found closer to the beach/dunes than ASY and HY buntings ($F = 5.77$, $df = 48$, $p = 0.01$).

Table 3. Comparison of the mean distances that Painted Buntings (*Passerina ciris*) were observed from each of the primary land use types on Kiawah Island, SC, from 2007 to 2010.

				Sex			Age		
	Mean		**StDev**	**F**	**df**	**p**	**F**	**df**	**p**
Forest	21.4	±	21.6	0.5	49	0.60*	0.53	48	0.59*
Developed	24.7	±	24.6	2.1	49	0.13*	2.47	48	0.10*
Scrub/shrub	48.2	±	84.9	2.4	49	0.10*	2.18	48	0.12*
Road	50.5	±	30.0	3.0	49	0.06*	3.85	48	0.03*
Marsh	97.0	±	117.9	0.1	49	0.91	1.47	48	0.24
Water	197.7	±	86.8	2.6	49	0.09	0.7	48	0.50
Golf	249.1	±	99.6	3.0	49	0.06	2.43	48	0.10
Beaches dunes	321.7	±	89.2	1.2	49	0.32	5.77	48	0.01

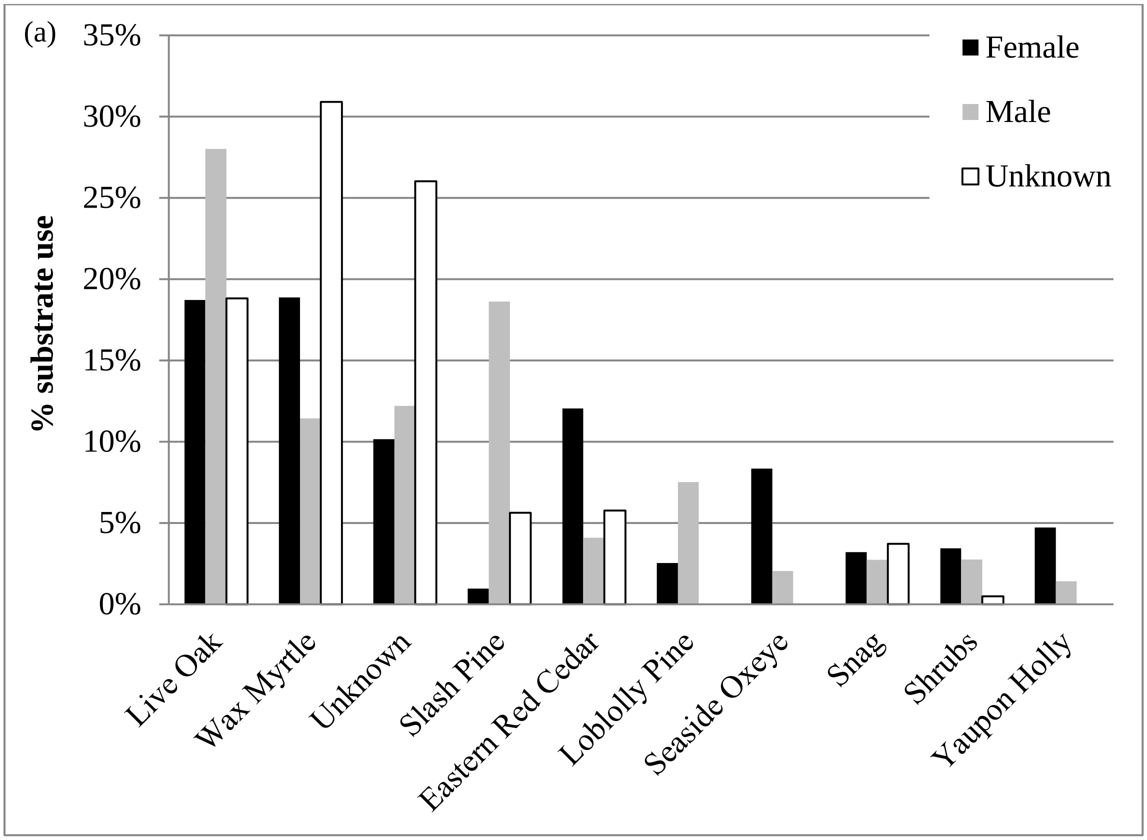
Painted Buntings were found at a mean (± SD) distance of 7.42 ± 2.75 m from the edge of whichever land use type they were in when we relocated them. There were no significant differences in the mean distance from edge for males (7.5 ± 2.2 m, n = 26), females (7.4 ± 3.3 m, n = 20), or birds of unknown sex (5.7 ± 3.7 m, n = 4; F = 0.74, df = 49, p = 0.48). Likewise, there were no significant differences in the mean distance from edge for ASY (7.5 ± 2.8 m, n = 38), SY (8.2 ± 1.7 m, n = 8), or HY buntings (4.0 ± 1.6 m, n = 3; F = 2.9, df = 48, p = 0.07).

Substrate Use

Plant Species - We observed the buntings using a total of 33 substrates, primarily vegetation, but occasionally the birds were seen on inanimate structures (e.g. bird box, boardwalk, feeder, ground, and house) as well. The top 10 (in order from highest to lowest) substrates frequented most often by the buntings from 2007-2010 were: 1) Live Oak, 2) Wax Myrtle, 3) unknown, 4) Slash Pine, 5) Eastern Red Cedar, 6) Loblolly Pine, 7) Seaside Oxeye (*Borrichia frutescens*), 8) snag, 9) shrubs, and 10) Yaupon Holly (*Ilex vomitoria*).

Comparing use of these 10 plant species between sexes (Fig. 17a) and between age classes (Fig. 17b), we identified some significant differences. Female buntings were observed in Eastern Red Cedar at higher frequencies than male buntings (F = 6.66, df = 25, p = 0.01, Table 3), but not at significantly higher rates than birds of unknown sex. Females were seen on Wax Myrtle at marginally higher rates than males (F = 3.08, df = 41, p = 0.06, Table 3). Male buntings were observed on Slash Pine more frequently than were female buntings (F = 6.15, df = 22, p = 0.02, Table 3). Moreover, ASY buntings were observed more often on Yaupon Holly than SY Buntings (F = 8.17, df = 11, p = 0.02, Table 5).

***Number of Different Substrates Used* –** Substrate use did not differ significantly between males (7.12 ± 3.08, n = 26), females (7.00 ± 1.75, n = 20), and birds of unknown sex (7.25 ± 2.22, n = 4; F = 0.02, df = 49, P=0.98). Similarly, substrate use did not differ significantly between ASY (6.82 ± 2.22, n = 38), SY (8.63 ± 3.77, n = 8), and HY (6.33 ± 1.53, n = 3; F = 1.88, df = 48, P = 0.16) birds.



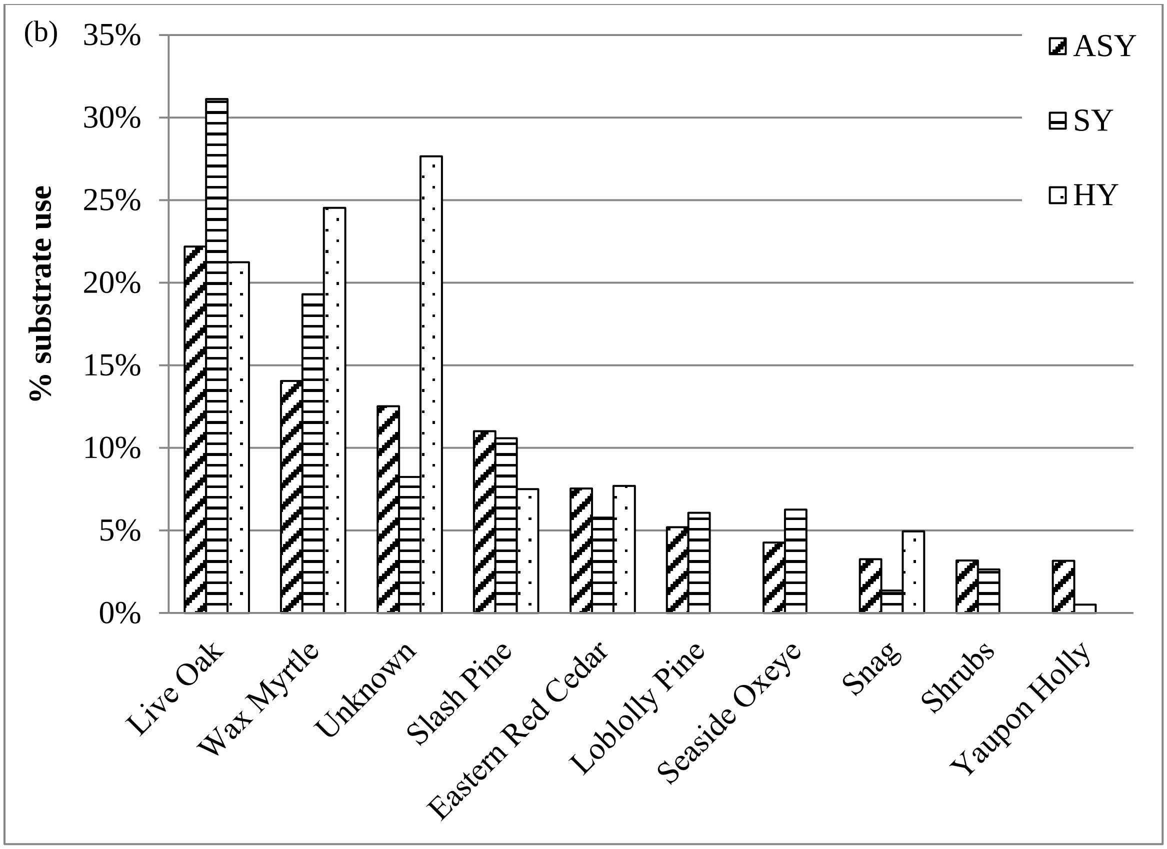


Figure 17. Vegetation use by Painted Buntings (*Passerina ciris*) of different (a) sexes and (b) age classes, showing the top 10 (of 33) species in which buntings were observed on Kiawah Island, SC, 2007-2010.

Table 4. Plant species used most frequently by radio-tagged Painted Buntings (*Passerina ciris*, n = 20 females, 26 males, and 4 birds of unknown sex) on Kiawah Island, SC from 2007-2010, showing the top 10 (of 33) species in which buntings were observed. Values represent the mean proportion of time buntings of different sexes and age classes, were observed in a particular plant species. Mean ± SD are shown untransformed for clarity, but the df, F, and p values reported are from the transformed data.

	Plant species use frequency			df	F	p		Plant species use frequency			df	F	p
Redbay													
Female	8%	±	7%				ASY	4%	±	6%			
Male	2%	±	4%	22	6.16	0.02*	SY	6%	±	9%	21	0.37	0.549*
Unknown	0%	±	0%				HY	0%	±	0%			
Yaupon Holly													
Female	5%	±	9%				ASY	3%	±	7%			
Male	1%	±	3%	12	3.05	0.11*	SY	1%	±	1%	11	8.17	0.017*
Unknown	0%	±	0%				HY	0%		0%			
Eastern Red Cedar													
Female	12%	±	18%				ASY	8%	±	14%			
Male	4%	±	6%	25	6.66	0.01*	SY	6%	±	9%	14	0.63	0.541*
Unknown	6%	±	7%				HY	8%	±	8%			
Wax Myrtle													
Female	19%	±	15%				ASY (n = 31)	14%	±	14%			
Male	11%	±	11%	41	3.08	0.057*	SY (n = 8)	19%	±	17%	40	0.30	0.742*
Unknown	31%	±	19%				HY (n = 3)	25%	±	18%			
Slash Pine													
Female	1%	±	2%				ASY (n = 16)	11%	±	18%			
Male	19%	±	22%	22	6.15	0.02*	SY (n = 5)	11%	±	23%	22	1.42	0.264*

Unknown	6%	±	7%				HY (n = 2)	8%	±	8%			
Loblolly Pine													
Female	3%	±	5%				ASY (n = 11)	5%	±	11%			
Male	8%	±	13%	15	0.41	0.53*	SY (n = 5)	6%	±	7%	15	0.61	0.45*
Unknown	0%		0%				HY (n = 0)	0%		0%			
Live Oak													
Female	19%	±	24%				ASY (n = 30)	22%	±	23%			
Male	28%	±	23%	40	0.63	0.54*	SY (n = 7)	31%	±	25%	39	0.38	0.689*
Unknown	19%	±	5%				HY (n = 3)	21%	±	2%			
Shrubs													
Female	3%	±	7%				ASY (n = 11)	3%	±	6%			
Male	3%	±	5%	13	1.75	0.22*	SY (n = 3)	3%	±	5%	13	0.61	0.449*
Unknown	0%	±	1%				HY (n = 0)	0%	±	0%			
Snag													
Female	3%	±	6%				ASY (n = 13)	3%	±	6%			
Male	3%	±	6%	16	0.02	0.98*	SY (n = 2)	1%	±	3%	16	0.32	0.73*
Unknown	4%	±	4%				HY (n = 2)	5%	±	4%			
Unknown species													
Female	10%	±	10%				ASY (n = 28)	13%	±	13%			
Male	12%	±	15%	37	1.73	0.19*	SY (n = 7)	8%	±	7%	37	2.58	0.09*
Unknown	26%	±	5%				HY (n = 3)	28%	±	5%			

VEGETATION PLOTS

Ground Cover - Ground cover measurements represent the mean percentages of ground in a study plot covered by each of 20 different substrate types (see Table 2). Of these 20 types of substrate, only 2 (brush cover and snags) showed any significant differences in their abundances on plots used by the different sexes or age classes. Males were found in areas with a higher percentage of brush cover than females, but not birds of unknown sex ($F = 7.09$, $df = 19$, $p = 0.01$*). SY buntings were found in areas with a higher percentage of snags than ASY and HY buntings ($F = 7.06$, $df = 7$, $p = 0.04$*). However, there were no significant differences between sexes or age classes in relative abundances of any of the substrates, when using the Bonferroni corrected $\alpha = 0.0025$.

To reduce the number of variables, ground cover variables were grouped into 4 categories: live, dead, man-made substrates, and unknown. There were no significant differences between the sexes or age classes in the abundance of any of the ground cover categories. However, female buntings seemed to choose areas with less dead vegetation (category 2) than did the males and birds of unknown sex ($F=3.28$, $df = 19$ $P=0.06$*). Yet, when we applied the Bonferroni corrected $\alpha = 0.0125$ we were unable to detect any significant differences between the sex and age classes in the abundance of live, dead, or man-made substrates in the locations they chose.

Midstory - Midstory analysis included the mean number and the mean basal areas of SWS and LWS. There were no significant differences between sexes or age classes in the mean number of midstory stems (SWS and LWS) or mean basal areas of the area they chose. However, the mean basal area of SWS was significantly larger than the basal area of LWS (n = 20; t = 5.83, p-value = <0.001)

Canopy – Canopy analysis included the mean number and mean basal areas of small, medium, and large canopy trees. Moreover, the mean percent of canopy closure was also assessed. There were no significant differences between sexes or age classes for any of the canopy measurements (Table 5).

Table 5. Mean measurements of canopy variables in vegetation plots used by Painted Buntings (*Passerina ciris*) on Kiawah Island, SC, from 2007 to 2010.

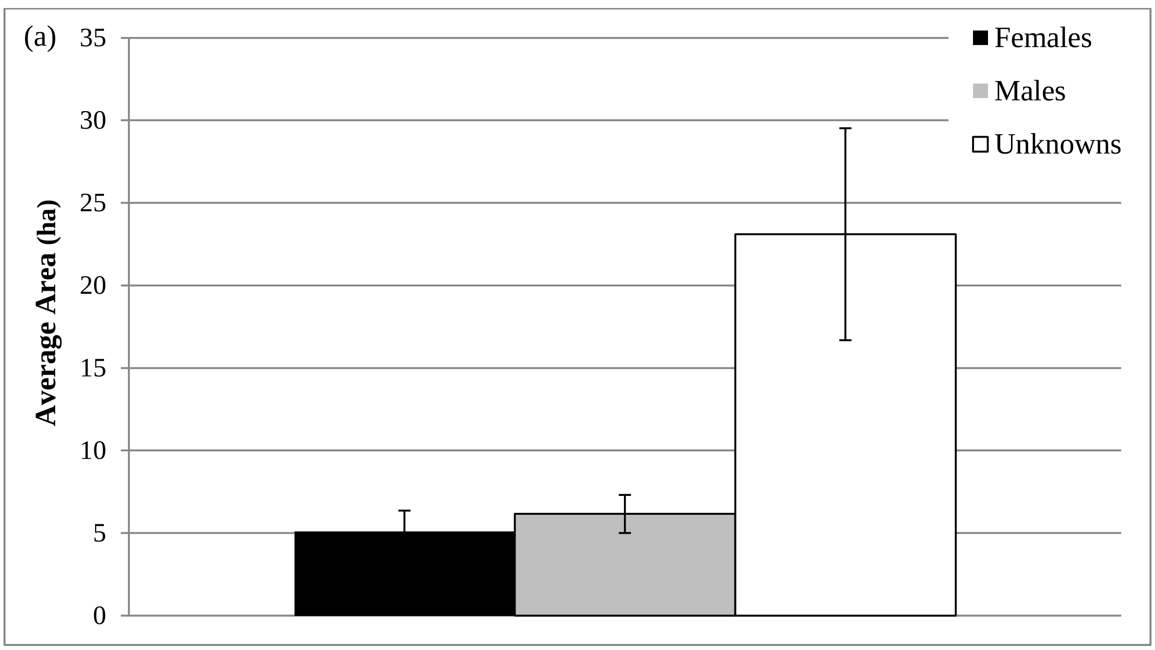
				SEX			AGE		
Canopy Variables	**Mean**		**StDev**	**df**	**F**	**p**	**df**	**F**	**p**
small canopy dbh (cm)	6.9	±	4.1	19.0	0.2	0.79	19.0	0.8	0.47
medium canopy dbh (cm)	5.2	±	1.8	19.0	0.2	0.85	19.0	0.5	0.60
large canopy dbh (cm)	1.9	±	1.6	19.0	0.3	0.71	19.0	0.2	0.86
total canopy dbh (cm)	14.1	±	5.2	19.0	0.4	0.69	19.0	0.3	0.77
canopy height (m)	28.2	±	5.5	19.0	0.1	0.90	19.0	0.7	0.49
basal area small canopy (m^2)	9.0	±	5.2	19.0	0.3	0.75	19.0	0.9	0.43
basal area medium canopy (m2)	24.9	±	7.9	19.0	1.1	0.35	19.0	0.7	0.51
basal area large canopy (m2)	21.7	±	18.4	19.0	0.3	0.72	19.0	0.2	0.86
total basal area (m2)	55.6	±	21.7	19.0	1.0	0.38	19.0	0.3	0.75
densiometer (%)	67.7	±	13.2	19.0	0.9	0.42	19.0	0.5	0.60

HEIGHT OF ACTIVITY

Buntings were observed at an overall mean (± SD) height of 4.26 ± 1.88 m (n = 49) above the ground. Males were observed highest in the vegetation (5.5 ± 1.3 m, n = 26), followed by birds of unknown sex (3.0 ± 0.7 m, n = 4) and females (2.9 ± 1.6 m, n = 19). Moreover, males showed a significant preference for activity higher in the canopy (F = 16.2, df = 35, p = ≤ 0.001). There were no significant differences in the height of activity of ASY (4.5 ± 2.0 m, n = 38), SY (3.4 ± 0.7 m, n = 8), and HY buntings (3.2 ± 0.7 m, n = 3; $F = 1.3$, df = 34, $p = 0.3$).

HOME RANGE & TERRITORY SIZES

The mean home range sizes (calculated from MCP) for Painted Buntings on Kiawah Island were 7.1 ± 7.9 ha. There were large differences in home range size between the sexes and age classes (Fig. 18). Birds of unknown sex had the largest home ranges (23.1 ± 12.8 ha, n = 4), followed by males (6.2 ± 5.9 ha, n = 26) and females (5.1 ± 5.6 ha, n = 20). The home ranges of birds of unknown sex were significantly larger than those of females or males (F = 3.98, df = 49, p = 0.025*). Hatch-year birds had the largest home ranges (29.5 ± 2.2 ha, n = 3), followed by ASY (5.7 ± 5.7 ha, n = 38) and SY (5.5 ± 6.3 ha, n = 8). The home ranges of hatch-year birds were significantly larger than those of ASY and SY buntings (F = 5.08, df = 48, p = 0.01*).



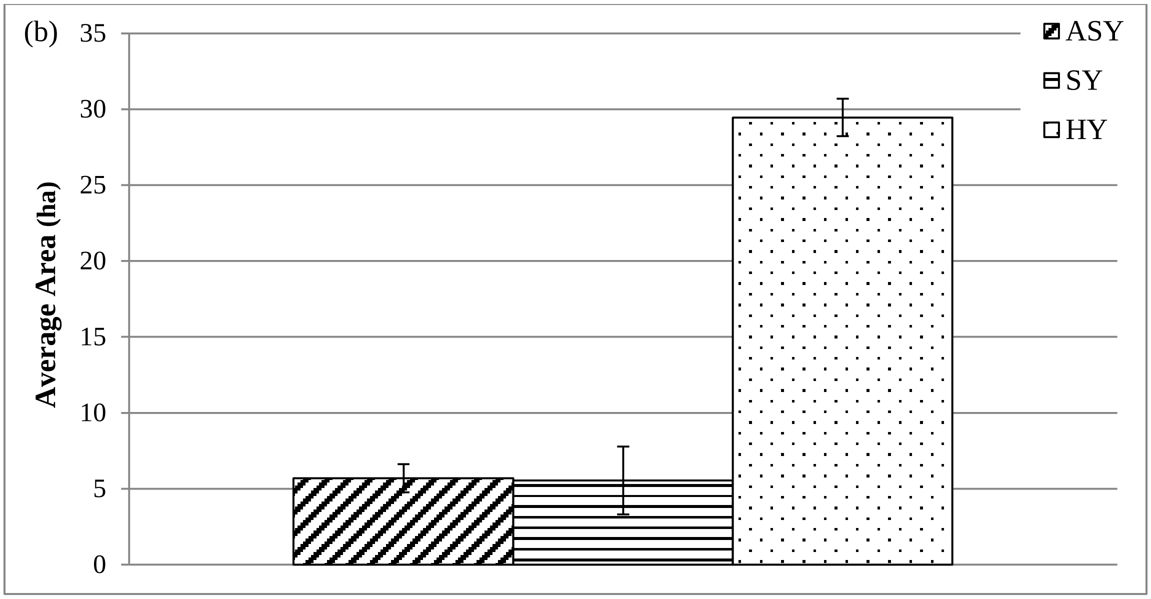


Figure 18. Mean (± SE) minimum convex polygon home range size (ha) for (a) sexes (n = 20 females, 26 males, and 4 birds of unknown sex) and (b) age classes (n = 38 ASY, 8 SY, and 3HY) of Painted Buntings (*Passerina ciris*) on Kiawah Island, SC, 2007-2010.

The core areas of the Painted Buntings were predictably smaller than their home ranges (Fig. 19). The mean territory size was 0.3 ± 0.2 ha. Birds of unknown sex had the largest territories (0.6 ± 0.4 ha), followed by males (0.3 ± 0.2 ha) and females (0.2 ± 0.1 ha; Fig. 20a). Furthermore, HY buntings had the largest territories (0.7 ± 0.4 ha), followed by ASY (0.2 ± 0.2 ha) and SY (0.2 ± 0.1 ha, Fig. 20b). Territory sizes of the buntings (of different sexes and age classes) did not differ. However, there is a non-significant trend for HY buntings to have larger territory sizes than ASY and SY Buntings ($F = 2.67$, $df = 48$, $p = 0.06$*).

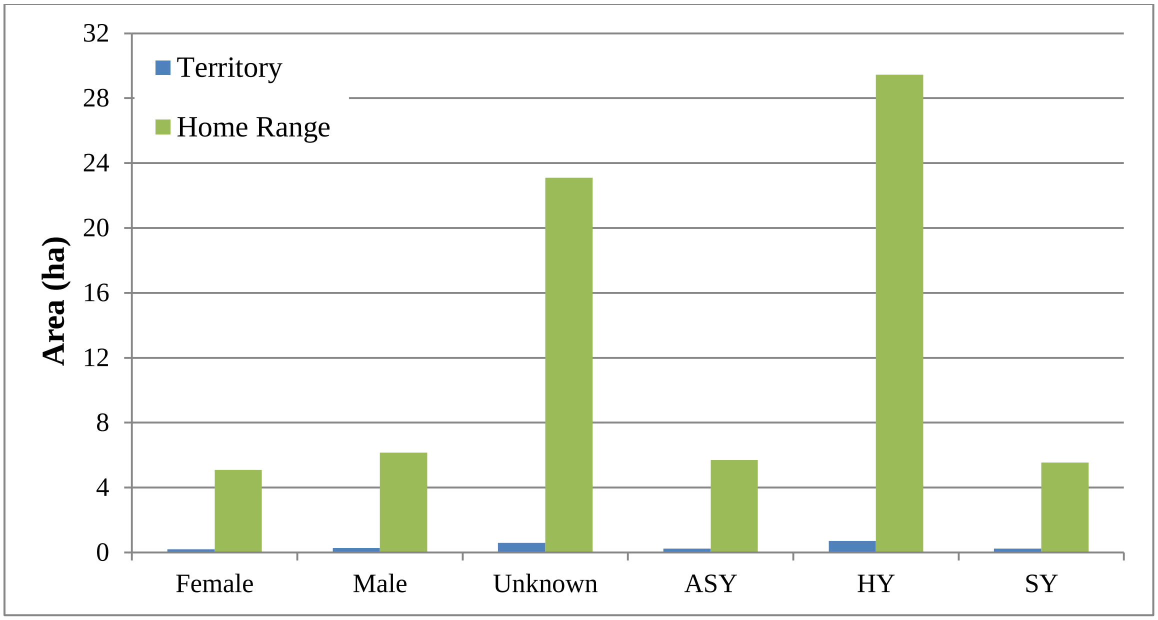
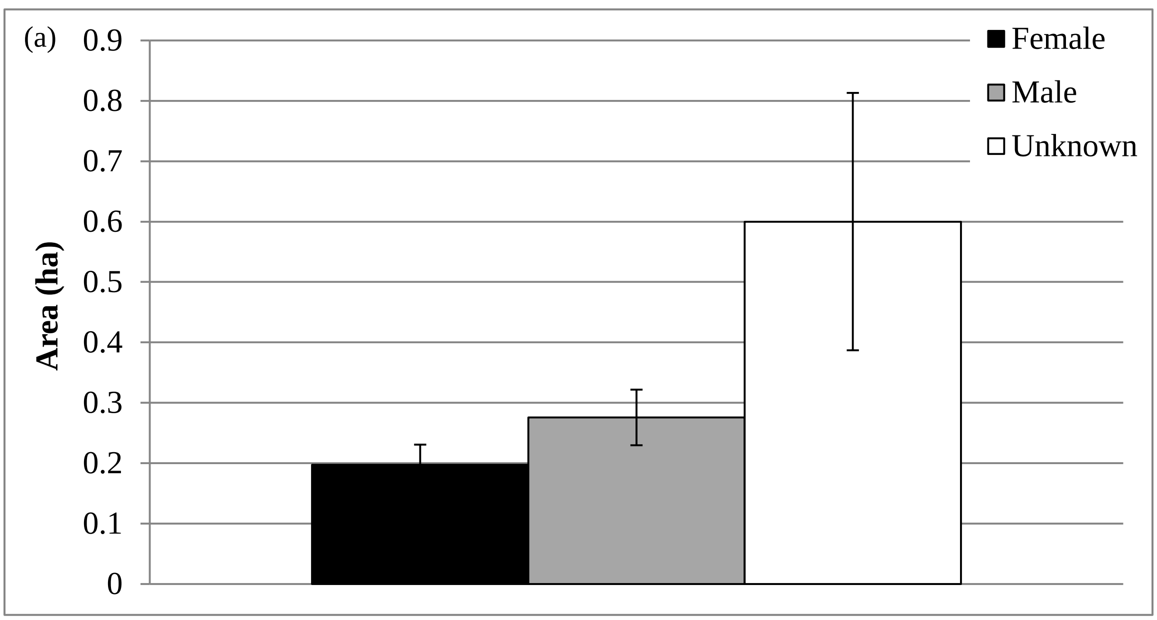


Figure 19. Comparison of mean territory (blue) and home range (green) sizes of Painted Buntings (*Passerina ciris*) on Kiawah Island, SC, 2007-2010.



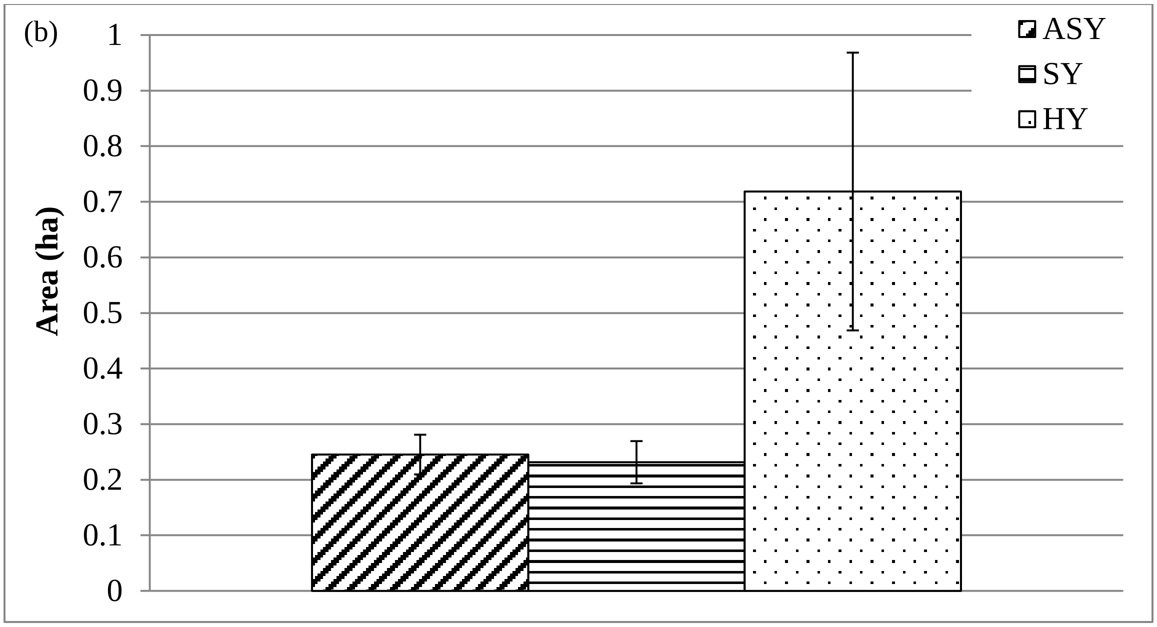


Figure 20. Mean (± SE) kernel density territory size (ha) for (a) sexes (n = 20 females, 26 males, and 4 birds of unknown sex) and (b) age classes (n = 38 ASY, 8 SY, and 3HY) of Painted Buntings (*Passerina ciris*) on Kiawah Island, SC, 2007-2010.

DISCUSSION

GOAL 1: DETERMINE HABITAT USE

Our results indicate few differences in substrate use between sexes and age classes of Painted Buntings. Buntings, whether male or female, adult or juvenile, appear to use areas with a similar make up of ground cover, midstory, and canopy vegetation. Moreover, buntings do seem to use areas with a higher density of SWS that take up more area, as compared to the area occupied by LWS. High densities of small woody stems are typical of areas that buntings inhabit and even nest in.

While the buntings seem to prefer similar vegetative structures, there was, however, a significant difference in the types of vegetation they used and the heights at which they were active. Males were found to be active significantly higher in the vegetation than females and birds of unknown sex. We often observed male buntings in the canopy while females and birds of unknown sex were found mostly in the understory.

This difference in height preference may be related to the types of vegetation the buntings prefer. Females used Eastern red cedar and wax myrtle significantly more than males, and these species typically do not grow to great heights in this environment. The dense foliage of these two species may provide safety and camouflage to a green female and her nest. In contrast, males used slash pine significantly more than females. Pine species grow straight and tall, with sparse needles toward the ends of the branches. These trees provide high song perches for the colorful males. Lowther *et al.* (1999) noted that male buntings observed in Georgia were observed over 50% of the time singing on exposed perches after females arrived. Singing on these exposed perches allows the males to be heard and seen and is thought to be for territorial defense or self-advertisement (Lowther *et al.* 1999).

Adult buntings used Yaupon Holly at higher rates than non-adult buntings. This may be due to the large gap in sample sizes between the ages (ASY = 38, SY = 8, HY = 3). However, Yaupon Holly is an erect growing species with tiny leaves. This species is relatively open compared to Wax Myrtle and Eastern Red Cedar. Therefore, young buntings may avoid this species as it may not provide adequate protection.

Land Use

Painted Buntings were typically found in close proximity to maritime forests, maritime shrub, development, roads, and marsh land use types. This is to be expected because these habitat types are all in close proximity to one another on our study site. Houses and roads are built in the maritime forests and/or maritime shrub habitats along the edge of marshes.

Additionally, the majority of the captured buntings established home ranges in maritime forests or maritime shrub habitats. Although we tried to capture an equal number of buntings in both habitat types, we were largely unsuccessful at catching many in the interior section of the island. Moreover, even when the birds were caught at interior feeders, they were often found to have established territories on the marsh edge. For example, 15 birds were caught at “inland sites”. However, only five actually used more interior parts of the island; the other ten moved from the feeders to areas on the marsh edge.

The trend of the radio-tagged buntings using maritime areas may also reflect the higher quality habitats preferred by buntings on the island. Many hours were spent attempting to capture buntings at inland feeders, yet we were highly unsuccessful. For example, in 2010, we had traps open at inland sites for approximately 130 hours of that field season, and we caught 0 buntings. The buntings just didn't seem to be present at these sites.

Similarly, bird surveys from the Assistant Town Biologist on Kiawah also reflect lower abundance of buntings using interior areas of the island (Fig. 21). Of the 238 point stations located throughout Kiawah Island, buntings were heard or seen at 111 of them from 2009-2011. Note, in Figure 21, that most of the point stations where Painted Buntings were seen or heard (yellow dots) were located along the marsh or dune edge. The biologist did not detect buntings (blue dots) in a large portion of the interior part of the island (unpublished data).

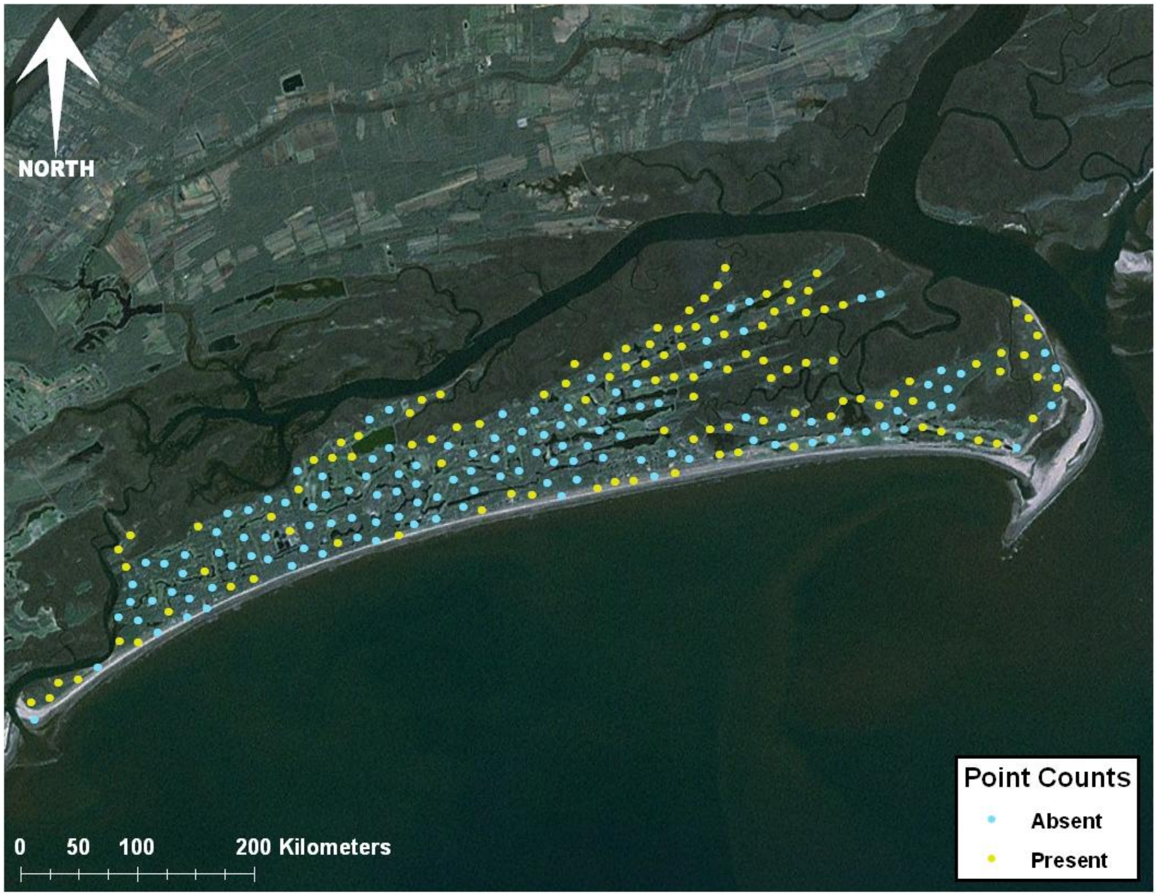


Figure 21. Point count surveys for Painted Bunting (*Passerina ciris*), conducted by the Town of Kiawah Island, SC. The dots represent the point stations where the surveys were conducted. Buntings were seen or heard at the yellow point stations and were absent at the blue point stations.

GOAL 2: IDENTIFY HOME RANGE AND TERRITORY SIZE

The mean home range size of Painted Buntings on Kiawah Island was 7.1 ha, with buntings of unknown sex having significantly larger home ranges than females or males, and HY buntings having significantly larger home ranges than ASY and SY buntings. The home ranges of our unknown-sex and HY buntings were approximately twice the size of the home ranges of male and female and ASY and SY buntings. The home ranges of unknown-sex and HY buntings were similar because three of the four birds of unknown sex were HY buntings. The home range of birds of unknown sex and HY buntings may have been less significant in size if our sample size was larger.

Yet, this large home range could have occurred because young buntings do not have established territories, so they travel throughout the territories of other buntings. It is not uncommon for young birds to have larger ranges than those of their adult counterparts. A study of juvenile Wood Thrushes (*Hylocichla mustelina*) in Missouri found, for example, that their home ranges varied from 2.6 to 24.8 ha, much larger than an average adult Wood Thrush home range of 0.08 to 2.8 ha (Anders *et al.* 1998).

A study of Painted Bunting home ranges on Sapelo Island, GA provided an interesting contrast to our observations on Kiawah. The home ranges of female and male buntings were larger on Kiawah than those of the buntings studied in the maritime shrub habitats on Sapelo Island, GA. However, Kiawah buntings had smaller home ranges than those of the buntings using the managed pine-oak habitats on Sapelo Island, GA (Springborn and Meyers 2005). Kiawah Island is a developed and developing island, so buntings must extend their ranges, around homes and roads, to find necessary resources.

Sapelo Island, on the other hand, is mostly undeveloped. Therefore, buntings in maritime scrub habitats may possibly have a larger home range on Kiawah than those on Sapelo Island because of habitat degradation related to development.

The territory size is notably smaller than the home range. This is because the MCP tool estimates home range and includes areas the buntings do not use. Kernel density estimates the intensity of use, and establishes core areas. These core areas had a mean size of 0.3 ha and provide important information on the sizes of areas necessary to support Painted Bunting populations.

The fact that we had such a difficult time capturing birds at inland and dune feeders, yet had little difficulty capturing buntings at marsh feeders may indicate that marsh habitats are of higher quality and buntings are therefore found in higher numbers near the marsh. This idea may also be supported by the three years of point count data from the Town of Kiawah Island, showing a lack of bunting presence in the interior habitats (unpublished data). Similarly, in their study on Painted Buntings on St. Catherines Island, GA, Lanyon and Thompson (1986) found edge territories to be settled first and more heavily defended than inland territories. They suggest these marsh edges are recognized, by the buntings, as higher quality. Our data are consistent with that hypothesis.

Goal 3: Recommendations

As Painted Buntings and humans continue to vie for similar habitats, the bunting population will probably continue to decline. Moreover, as development removes understory and opens more land, Brown-headed Cowbird numbers may increase further. Habitat restoration could improve habitat quality for buntings, decrease cowbird parasitism, and promote successful nesting – potentially preventing a further decline of the population on Kiawah Island and other areas where restoration is undertaken.

Plant Understory Vegetation - Understory vegetation provides vital habitat to Painted Buntings. Kiawah Island, SC has been developed in a more environmentally sensitively manner compared to other similar islands, however, much of the understory vegetation, has been removed. Our data suggest that this vegetation layer (usually vegetation from 0-5 m high) is extremely important for Painted Buntings' survival and reproduction.

Plant Native Vegetation - Preventing the removal of native vegetation when developing or designing the landscape will reduce the need for later habitat restoration. However, when restoration is needed, it is important to use native species. Native species often require less maintenance, less water, little to no fertilizer/pesticide use, and are more likely to survive harsh conditions (Welker and Green 2003). The top native species used by Painted Buntings were Live Oak, Wax Myrtle, Slash Pine, Eastern Red Cedar, Loblolly Pine, Seaside Oxeye, snags, and Yaupon Holly.

Remove Invasive Species - Invasive species should be removed when possible, as they displace native shrub species. Two of the most troublesome species on Kiawah Island, SC are Chinese Tallow Tree (*Triadica sebifera*; or Popcorn Tree) and Autumn-olive (*Elaeagnus umbellata*).

Save the Snags - Male buntings often use snags, or standing dead trees, for perching and singing and female buntings were sometimes observed perching on snags to feed fledglings. Snags are important for many wildlife species. They provide shelter for cavity nesters, areas for perching, and food sources including the insects and fungi that decompose these trees. Removing snags can cause many of the cavity nesting and insectivorous birds to leave the area. This may result in an increase of insect populations, as their main predators have departed.

Prevent Pruning - Pruning can promote healthy growth, allow for the maintenance of a desired shape and size, prevent overcrowding, or remove damaged vegetation. However, pruning is not always necessary. Pruning can cause a plant to be less desirable to some wildlife because it reduces cover and makes them more vulnerable to predation. When possible, vegetation should be left to grow and prune itself naturally. For plants that need to be pruned, they should be pruned before or after the nesting season of the Painted Bunting (or other bird species; Fig. 22).

Reduce Lawn Sizes - Painted Buntings were rarely seen using open areas of sod. These areas should be minimized and planted with understory vegetation when possible. The ARB also discourages large areas of sod as well (Kiawah ARB 2007).

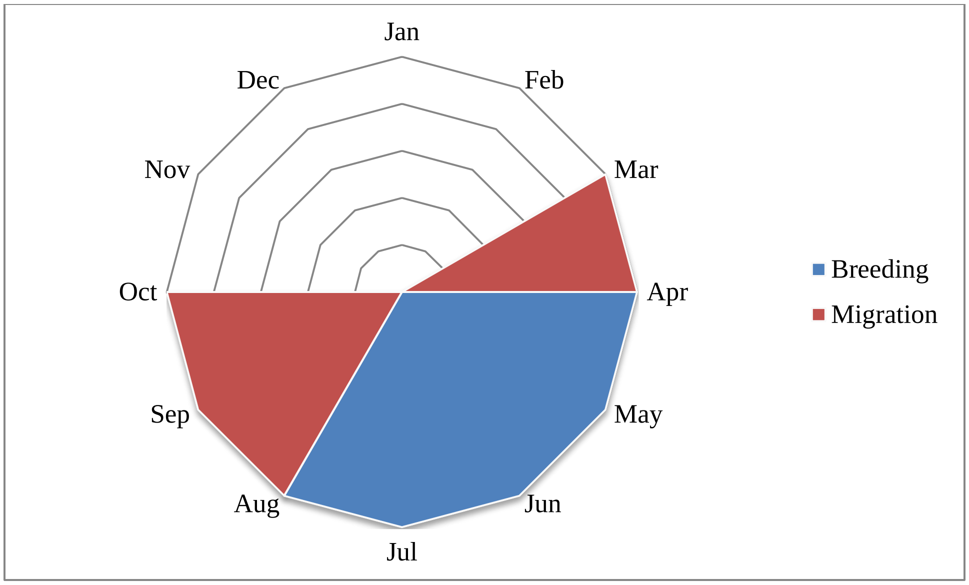


Figure 22. Breeding and migration timeline of Painted Bunting (*Passerina ciris*); created by Sarah Latshaw

CONCLUSION

CONSERVATION IMPLICATIONS

Locally - By identifying habitat preferences for the buntings, conservation groups can provide management examples to homeowners and land managers hoping to have a positive impact on the local wildlife. Because buntings have small territories, a single homeowner could potentially impact most or all of a bird's territory, and thereby have a tremendous effect on habitat availability for buntings. Protecting their preferred shrub/scrub habitat will, in turn, benefit other species that have similar preferences. If multiple, neighboring residents changed their landscape practices to benefit buntings, then they could create a contiguous block of understory habitat, possibly also aiding species such as the bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), Wood Thrush (*Hylocichla mustelina*), etc. Our habitat management recommendations for Kiawah may not only have an impact on the local bunting population, as well as on other wildlife, they may also have major conservation implications both statewide and regionally by demonstrating the feasibility of homeowner-financed habitat restoration.

Statewide - Painted Bunting populations exhibit one of the most localized distributions in the Southeastern U.S. and show some of the steepest declines in population size, leading to their designation as a high priority species by the South Carolina Department of Natural Resources (SCDNR). South Carolina is thought to support 50-60% of the total breeding population of Painted Buntings in the Southeast. That number is more than North Carolina, Georgia, and Florida combined; South Carolina also has substantial acreage in barrier islands similar to our study site, giving broad applicability to our recommendations. Findings from this project may guide the state biologists in future conservation efforts for this species.

Along with habitat losses globally, most barrier islands also face increasing land losses as development rapidly progresses. As land increasingly disappears, it is imperative that we preserve habitat throughout these islands. Unfortunately, due to the high costs of land purchase, it is difficult to preserve even a fraction of what's being destroyed. Therefore, habitat restoration is a feasible alternative to reverse vegetation losses that have already occurred through development.

Research focusing on a flagship species, such as the Painted Bunting, may help to spark residents' interest in restoring habitat on their home sites if such actions offer hope of attracting this bird. This type of conservation works in the favor of governmental and non-governmental conservation groups because it 1) increases available habitat for a diverse flora and fauna and 2) externalizes the financial burden by placing restoration costs on the residents themselves.

Moreover, an understanding of the value of the ecosystem services provided by a barrier island with a healthy, resilient ecosystem will only strengthen conservation and preservation efforts. It can be difficult and controversial to give economic values to ecosystem goods and services (Keating 1995). However, ecosystems, like those on Kiawah Island, yield definite benefits by providing wildlife habitat, nurseries for many saltwater and freshwater fishes and shellfish, flood prevention, water filtration, nutrient recycling, and recreation and wildlife viewing opportunities (USFWS 2009). Giving a value to these benefits can provide a tool for directing policy and land use decisions (Dodds *et al.*2008).

Kiawah Island has approximately 607 ha of wetlands. Using the estimate from Costanza *et al.* (1997) on global ecosystem services, Kiawah's wetlands provide approximately $5 million in ecosystem services per year; extrapolating this value to the other sea islands throughout the coastal range of Painted Buntings illustrates the potentially high economic value of maintaining habitat structure that will also support buntings. Provision of these ecosystem services is extremely valuable to the human residents and wildlife alike, and may result from using the Painted Bunting to promote restoration efforts and prevent further land loss.

FUTURE RESEARCH

The results reported in this thesis offer insight into the habitat use of Painted Buntings. However, to understand the habitat preferences of the buntings, for more accurate restoration recommendations, a random point analysis is needed in which the areas used by the birds are compared a random selection of the areas that were available to them. Therefore, a random point analysis will be conducted and compared to the painted bunting data collected in our study. Results from this analysis will be submitted for publication in a peer-reviewed journal. Nest characteristic data collected in our study, will be analyzed and submitted for publication, as well.

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