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History, Nesting Population, Migration, Home Range and Habitats Used by Louisiana Bald Eagles

Nickolas Ryan Smith

Louisiana State University and Agricultural and Mechanical College

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HISTORY, NESTING POPULATION, MIGRATION, HOME RANGE AND
HABITATS USED BY LOUISIANA BALD EAGLES

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The School of Renewable Natural Resources

by
Nickolas R. Smith
B.S., South Dakota State University, 2008
August 2014

This work is dedicated to the memory of Thomas Hess, who devoted much of his career to the Bald Eagles of Louisiana. His dedication and hard work have been a big influence on my life and was a major factor in making this research possible. His life exemplified the meaning of pursuing your dreams and living your passion. That passion he had for wildlife and Louisiana touched so many lives and will live on in future generations of wildlife biologists and outdoor enthusiasts to come.

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ABSTRACT

The population of Bald Eagles (*Haliaeetus leucocephalus*) nesting in Louisiana reached precariously low numbers in the early 1970's, and although the population has since increased markedly, resident eagles remain a species of conservation concern in Louisiana. Using statewide aerial nest survey data from 1975–2008, I documented the history and quantified the recovery of the nesting population in Louisiana. Known active nests increased exponentially from 7 to 387 during this period, exhibiting a mean annual rate of increase of $11.1 \pm 0.3\%$ per year with no indications of slowing. By 1990, the nesting population in Louisiana had exceeded all goals of the Southeastern States Bald Eagle Recovery Plan. I used nest location and status data from the most recent year (2007–2008) of the nest monitoring program to examine landscape level nest site selection and success. Success of a nest was not greatly influenced by the physical characteristics around a site, whereas the initial selection of a nest site was most influenced by distance to the historical nest centroid and the proportion of open water and agricultural land within 3 km. Bald Eagles nest during the winter in Louisiana, but they are rarely observed in the state during summer. Therefore, I used satellite GPS transmitters to provide evidence of their undocumented summer migrations and examined parameters such as timing of departure and arrivals, stopover use, routes used, and seasonal and annual variations in these parameters. Marked eagles flew relatively direct routes, exhibiting high route fidelity going between Louisiana and their summering areas, which were spread out across much of Canada and south to Illinois. Using locations from their winter and summering areas, I estimated home range and core area size. Home ranges varied from 19.7–1,997.7 km², but nesting Bald Eagles had smaller home ranges, on average, than did non-nesting birds. The sex of an individual can play an important role when considering variations in movements, home ranges,

and habitat use. Accordingly, I evaluated the published field technique for sex determination of Bald Eagles, and upon documenting misclassifications, I developed a new formula applicable to Louisiana and other southern regions.

CHAPTER 1. GENERAL INTRODUCTION

1.1 INTRODUCTION

The Bald Eagle (*Haliaeetus leucocephalus*) experienced a marked population decline throughout the continental United States in the mid-1900's, reaching an estimated low of 417 pairs in 1963 (Sprunt and Ligas 1964). The continental population began to increase after the ban on DDT in 1972 and federal listing of the Bald Eagle as an endangered and threatened species in 1978 (Buehler 2000). By 2007, the species was removed from the federal list of endangered and threatened wildlife but continues to be protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act (U.S. Fish and Wildlife Service 2007).

In the early 1900's, Bald Eagles were described as common in Louisiana (Bailey 1919) and reported as nesting in various parts of the state, but mainly near the coast (Beyer 1900, Beyer et al. 1908). The nesting population subsequently declined, with only 6 or 7 active nests reported in 1972 (Lowery 1974). Similar to the continental population, the decline in Louisiana was believed to be linked to DDT, habitat destruction, and human persecution (Murphy 1989, U.S. Fish and Wildlife Service 2007). The continental decline prompted the listing of the Bald Eagle as an endangered species throughout its southern range and subsequent conservation efforts were focused at increasing the nesting population (U.S. Fish and Wildlife Service 1987).

In 1984, a collective recovery plan (Murphy 1989) was compiled for the southeastern region which included Louisiana. The goals of the recovery plan were to achieve a collective 3 year average of >0.9 young per active nest, >1.5 young per successful nest, and >50% of nests successful in raising at least 1 young, as well as document population vigor and establish that adequate habitat exists. Numbers of active nests in Louisiana began to increase, due in large part to protection by law enforcement and decreased use of chemicals such as DDT (Louisiana

Department of Wildlife and Fisheries 2007, U.S. Fish and Wildlife Service 2007). The Bald Eagle remains a species of conservation concern in Louisiana despite the marked increase in the nesting population (Lester et al. 2005).

Bald Eagles nest primarily in the south central portion of Louisiana, but are expected to move into other habitats as the population expands (Louisiana Department of Wildlife and Fisheries 2007). Historically, nests were located primarily in bald cypress (*Taxodium distichum*)/water tupelo (*Nyssa aquatic*) swamps adjacent to marshes, rivers, canals, bayous, ponds, or lakes (Harris et al. 1987). Nest sites have not been quantitatively examined since the population has expanded. Understanding nest site selection and factors contributing to nest success may allow managers to make informed decisions about effects of future developments, conservation activities, and human use. Currently, nest sites are protected by the Bald and Golden Eagle Protection Act, but little consideration has been given for the preservation of habitats outside of nest sites (Mojica et al. 2008).

Considered a resident species of Louisiana in the early 1900's (Beyer et al. 1908), the Bald Eagle was later classified as an uncommon resident and rarely observed in the state during June, July and August (Lowery 1974). The cause of the seasonal decline in observations from Louisiana has not been documented. Resident Bald Eagles from other southern regions exhibit summer migrations, flying to northern states and returning in the fall to nest (Broley 1947, Mabie et al. 1994, Linthicum et al. 2007, Mojica et al. 2008, Hunt et al. 2009). In Florida, banding records have shown a summer migration as far north as Prince Edward Island in Canada (Broley 1947).

Banding data and very high frequency (VHF) radio transmitters have been used to document migrations but are limited in their ability to track long-distance movements. Satellite

telemetry provides regular, less biased location data over large landscapes, which can be used to document migration routes, stopover sites, and summering areas (Bloom et al. 2007, Mojica et al. 2008, Bridge et al. 2011). With the added technology of solar power and a Global Positioning System (GPS), satellite transmitters provide timely and accurate location data, which is advantageous in determining the timing of movements and identifying important use areas (Soutullo et al. 2007).

Solar-powered transmitters also provide the opportunity to collect a large number of locations over prolonged periods, making them advantageous when trying to depict usage of an eagle's breeding and non-breeding areas and the comparison between them (Kie et al. 2010, Walter et al. 2011). Understanding the size and distribution of an animal in space and time provides insight into the relationship between that animal and its environment. Estimates of home range size vary markedly for Bald Eagles depending upon season, age, and sampling technique (Gerrard et al. 1992, Garrett et al. 1993, Watson 2002, Mojica 2006). Brownian bridge movement models take advantage of the large number of temporally related locations provided by this new technology, depicting its movement path rather than individual locations (Horne et al. 2007, Fischer et al. 2013), which should provide better estimates of home range and core area size than do techniques previously used for Bald Eagles.

Sex is an important biological factor to consider when conducting research on species that are sexually dimorphic in size (Andersson and Norberg 1981, Krüger 2005), such as Bald Eagles (Bortolotti 1984a, b, Garcelon et al. 1985). Results may be biased if sex ratio is ignored when sampling. Bortolotti (1984b) developed a formula which correctly classified 98.1% of the birds sampled from northern United States and Canada, but the accuracy of his formula has not

been tested for southern Bald Eagles. Misclassified birds would indicate a need for an updated morphometric formula to accurately sex Bald Eagles in Louisiana and other southern locations.

Accordingly, I analyzed historical nesting data collected from 1975–2008, and deployed satellite GPS transmitters on Louisiana Bald Eagles. My study provides quantitative information on habitat use, migratory patterns, home ranges and history of the nesting population of Bald Eagles, allowing identification of possible risks and threats to the population. In Chapter 2, I document the history and analyze the recovery of Louisiana’s nesting population. In Chapter 3, I examine factors influencing landscape level nest site selection and success. In Chapter 4, I examine migration chronology, routes, stopover sites and summering areas of Louisiana Bald Eagles. In Chapter 5, I examine winter and summer home ranges and core areas of Louisiana Bald Eagles. Finally, in Chapter 6, I evaluate a morphometric technique for determining sex in Bald Eagles from Louisiana. Chapters 2–6 are organized as separate manuscripts to be submitted to scientific journals; thus, some duplication of information and text occurs.

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CHAPTER 2. HISTORY AND NESTING POPULATION OF BALD EAGLES IN LOUISIANA

2.1 INTRODUCTION

The Bald Eagle (*Haliaeetus leucocephalus*) experienced a marked population decline throughout the continental United States in the mid-1900's, reaching an estimated low of 417 pairs in 1963 (Sprunt and Ligas 1964). The continental population began to increase after the ban on DDT in 1972 and through the federal listing of the Bald Eagle as an endangered and threatened species in 1978 (U.S. Fish and Wildlife Service 1978, Buehler 2000). By 2007, the species was removed from the federal list of endangered and threatened wildlife (U.S. Fish and Wildlife Service 2007); however, it continues to be protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act, and remains a species of conservation concern in Louisiana (Lester et al. 2005).

In the early 1900's, Bald Eagles were described as common in Louisiana (Bailey 1919) and nesting in various parts of the state, but mainly near the coast (Beyer 1900, Beyer et al. 1908). The nesting population subsequently declined, with only 6 or 7 reported active nests in 1972 (Lowery 1974). Similar to the continental population, the decline in Louisiana was believed to be linked to DDT, habitat destruction, and human persecution (Murphy 1989, U.S. Fish and Wildlife Service 2007).

The continental decline prompted the listing of the Bald Eagle as an endangered species throughout its southern range and subsequent efforts were focused at increasing the nesting population (U.S. Fish and Wildlife Service 1978). In 1984, a collective recovery plan (Murphy 1989) was compiled for the southeastern region which included Louisiana. The goals of the recovery plan were to achieve a collective 3 year average of >0.9 young per active nest, >1.5

young per successful nest, and >50% of nests successful in raising at least 1 young, as well as document population vigor and establish that adequate habitat exists.

Aerial nest monitoring has been used throughout the southeastern region (Murphy 1989, Jenkins and Sherrod 2002), specifically in Louisiana since 1975 (Payne 1975), to document population changes of Bald Eagles and evaluate their management. My objectives were to document the recovery of Louisiana's nesting population of Bald Eagles, using data collected during the nest monitoring program. Finally, I assessed the population increase in Louisiana with regard to the overall recovery of the Bald Eagle in the southeastern region.

2.2 METHODS

Aerial survey data were collected annually for known Bald Eagle nests in Louisiana from 1975–2008 (1974-75 to 2007-08 winter nesting seasons). Reports of nesting activity and nests were provided by private individuals, state and federal agencies, and the media. Additionally, other nests were found during nest monitoring activities and incorporated into subsequent surveys. From 1975–1985, statewide nest surveys were conducted by U.S. Fish and Wildlife Service; surveys were continued from 1985–2008 by Louisiana Department of Wildlife and Fisheries using the same protocols. Attempts were made to survey known nests twice annually, using a Bell Jet Ranger Model 206B helicopter or a fixed wing aircraft, such as a Cessna 210 or Cessna 185 float plane. Aerial survey techniques used were similar to methodologies reported by Grier et al. (1981) for fixed-wing aircraft and Watson (1993) for helicopters. Coordinates (latitude and longitude) of nests sites were recorded using Loran C navigation equipment until 1992 after which Global Positioning System (GPS) equipment was used.

Using the standard 2-flight method (Fraser et al. 1983), the first survey flight was conducted annually during the egg laying and incubation periods (October-January) to determine

activity of known nests and locate new nests. Nests were classified as active by the presence of at least one of the following: (1) one or more adults in or near a nest with signs of nest refurbishment (i.e., presence of fresh nesting material); (2) an adult sitting low in the nest presumably incubating; or (3) the presence of eggs or young. Within the same nesting season, active nests were revisited during a second flight survey, conducted during January–May, to assess annual nest success, productivity, and mean brood size (collectively termed production). Nests were recorded as successful if a minimum of one young, eight weeks of age or greater, was observed. Annual nesting success was defined as the proportion of successful nests per active nests with known outcomes. Productivity was the mean number of young produced per active nests with known outcomes. Mean brood size was the mean number of young produced per successful nest.

From 2004–2008, complete sampling of all nests for productivity was logistically impossible because the nesting population had expanded over a large geographic area. Therefore during this period, all nests were sampled during the first flight survey, as done in previous years, but only a subsample of active nests were revisited during the second flight survey to determine productivity. Nests with complete production data were used to estimate, with 95% confidence, the number of young produced from all active nests. Prior to 2004, the percentage of known active nests in which productivity was not determined within the same nesting season was considered minimal ($< 3\%$) and therefore ignored in my calculations.

2.2.1 Statistical Analysis

For each year from 2004–2008, I used PROC MEANS (SAS Institute Inc. 2011) to estimate, with 95% confidence, the mean number of young produced per active nests with known

outcomes. Means were then multiplied by the total number of active nests within that nesting season in order to estimate the total young produced annually from 2004–2008.

I used general linear mixed models (PROC GLIMMIX; SAS Institute Inc. 2011) to examine the annual rate of change in (1) numbers of active nests, (2) numbers of successful nests, (3) numbers of young produced, (4) nest success, (5) productivity, and (6) brood size. Sample sizes were small when surveys were initiated and increased throughout the monitoring period; thus, I weighted each model to account for annual changes in sample size during the entire nest monitoring period. Active nests, successful nests, and number of young produced were weighted by their total for each year, whereas nest success and productivity were weighted by the number of active nests, and brood size was weighted by the number of successful nests. Inclusion of intercept only, linear, and curvilinear models were used to test whether rates had changed over the monitoring period and if so, whether that change was consistent or variable. Various distributions (binomial, gamma, Gaussian, Poisson, etc.) were tested to determine the best fit within each model. However, distributions considered for testing were only those considered to be applicable for each model, such as for models with a response variable that was between zero and one. Selection of a distribution and model was based on Akaike's information criteria, corrected for sample size (AIC_c), where distributions and models that best supported the data had the lowest AIC_c (Burnham and Anderson 2002). Goodness-of-fit of a model was evaluated with relation to an intercept only model using ΔAIC_c . This was done because of the lack of application of traditional goodness-of-fit methods like R^2 which are not applicable due to the use of pseudo-likelihoods in calculating generalized mixed models (Liu et al. 2008, Bolker et al. 2009).

2.3 RESULTS

From 1975-2008, the number of known active nests increased exponentially from 7 to 387 (Figure 2.1, Table 2.1), exhibiting a mean annual rate of increase of $11.1 \pm 0.3\%$ per year ($F_{1,32} = 1856.75$, $P < 0.01$). As numbers of known active nests increased, locations of nests expanded from 3 parishes (Terrebonne, Jefferson, and St. Charles) to 38 parishes throughout Louisiana; however, the majority of nesting still occurs in the region surrounding the 3 original parishes (Figure 2.2). Numbers of successful nests and total young produced increased exponentially at relatively similar rates as for active nests, respectively ($9.8 \pm 0.5\%$, $F_{1,32} = 371.12$, $P < 0.01$ and $11.4 \pm 0.3\%$, $F_{1,32} = 1331.31$, $P < 0.01$; Figure 2.1).

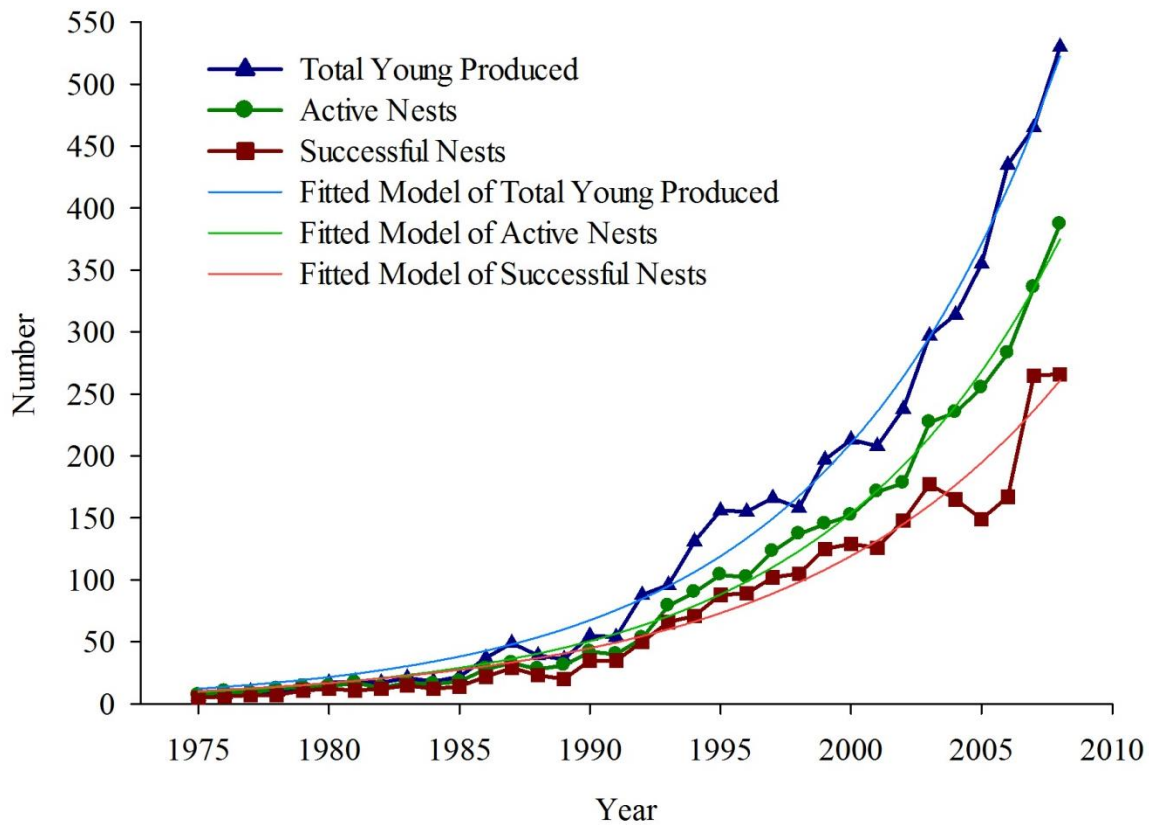


Figure 2.1. Numbers of known active nests, successful nests and total young produced by Louisiana Bald Eagles from 1975–2008 with fitted exponential models weighted by sample size (Active Nests = $e^{(0.111 \cdot \text{Year} - 217.41)}$, Successful Nests = $e^{(0.098 \cdot \text{Year} - 190.85)}$, Total Young Produced = $e^{(0.114 \cdot \text{Year} - 222.10)}$).

Table 2.1. Summary of Bald Eagle nesting in Louisiana from 1975–2008.

Year	Active Nests	Successful Nests	Total Young Produced ^a	Nest Success	Productivity	Mean Brood Size
1975	7	5	6	0.71	0.86	1.20
1976	10	6	8	0.60	0.80	1.33
1977	9	7	10	0.78	1.11	1.43
1978	12	7	10	0.58	0.83	1.43
1979	14	11	12	0.79	0.86	1.09
1980	14	12	17	0.86	1.21	1.42
1981	17	11	18	0.65	1.06	1.64
1982	13	12	17	0.92	1.31	1.42
1983	17	15	21	0.94	1.31	1.40
1984	16	12	18	0.75	1.13	1.50
1985	18	14	22	0.78	1.22	1.57
1986	28	22	37	0.79	1.32	1.68
1987	33	29	49	0.88	1.48	1.69
1988	28	23	39	0.82	1.39	1.70
1989	31	20	36	0.67	1.20	1.80
1990	42	35	55	0.83	1.31	1.57
1991	40	35	54	0.88	1.35	1.54
1992	53	50	88	0.94	1.66	1.76
1993	79	66	96	0.84	1.22	1.45
1994	90	71	131	0.79	1.46	1.85
1995	104	88	156	0.85	1.51	1.77
1996	102	89	155	0.88	1.53	1.74
1997	123	102	166	0.83	1.35	1.63
1998	137	105	158	0.78	1.17	1.50
1999	145	125	197	0.89	1.40	1.58
2000	152	129	213	0.85	1.41	1.65
2001	171	126	208	0.86	1.41	1.65
2002	178	148	238	0.88	1.41	1.61
2003	227	177	297	0.80	1.34	1.68
2004	235	165	314 ±26	0.81	1.34	1.65
2005	255	149	355 ±28	0.86	1.39	1.62
2006	283	167	435 ±28	0.91	1.54	1.69
2007	336	265	465 ±28	0.86	1.38	1.60
2008	387	266	530 ±33	0.84	1.37	1.62

^a From 2004–2008, production could not be determined for 20.9% of active nests (n = 1946); thus, a subsample of nests were used to estimate, with 95% confidence, total young produced. Prior to 2004, the number of active nests in which production could not be determined was considered minimal (2.6%, n = 1901); therefore, total young produced was an actual count.

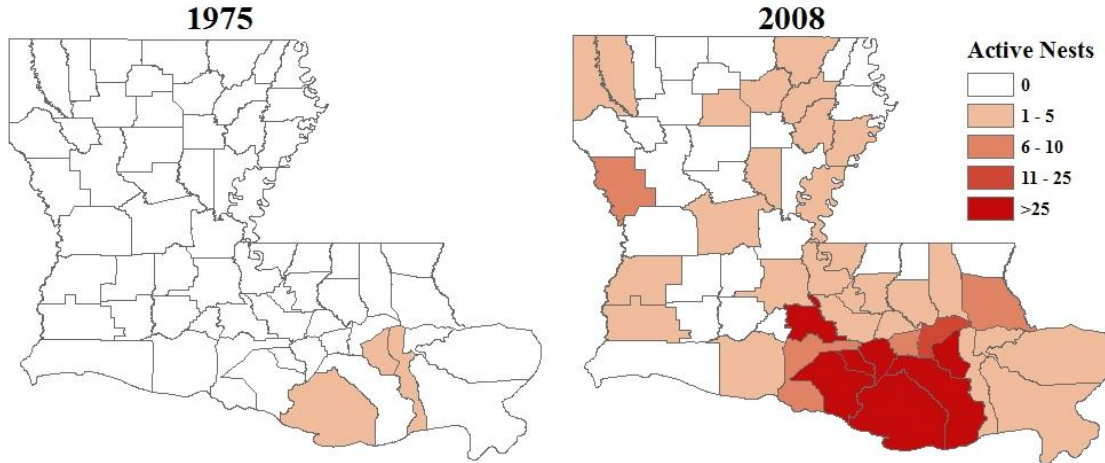


Figure 2.2. Numbers of known active nests by parish in Louisiana in 1975 and 2008.

Nest success increased $1.8 \pm 0.8\%$ per year over the monitoring period ($F_{1,32} = 5.11$, $P = 0.03$; Figure 2.3). Model selection using AIC_c showed that nest success was best described using a linear model with a binomial distribution and logit link function ($y = 0.0181x - 34.534$; $AIC_c = 179.49$). The intercept only model was greater than 2 ΔAIC_c from the top model ($\Delta AIC_c = 4.70$, weighted mean = 0.84 ± 0.01).

Productivity exhibited a slight annual increase ($0.5 \pm 0.2\%$ per year, $F_{1,32} = 5.35$, $P = 0.03$), best described using a gamma distribution and log link function ($\text{Log}(y) = 0.005x - 9.489$; $AIC_c = -30.03$; Figure 2.3). The next best-fitting model was the intercept only model ($\Delta AIC_c = 2.65$) with a ΔAIC_c slightly greater than 2, indicating that there was weak evidence that productivity changed over the monitoring period.

Brood size showed little evidence of change; the intercept only model was the best-fitting model ($AIC_c = -42.28$, weighted mean = 1.63 ± 0.02 ; Figure 2.3). The second best-fitting model was curvilinear with a gamma distribution and log link function ($\Delta AIC_c = 0.98$) which produced a slightly increasing curvilinear trend similar to that observed for productivity.

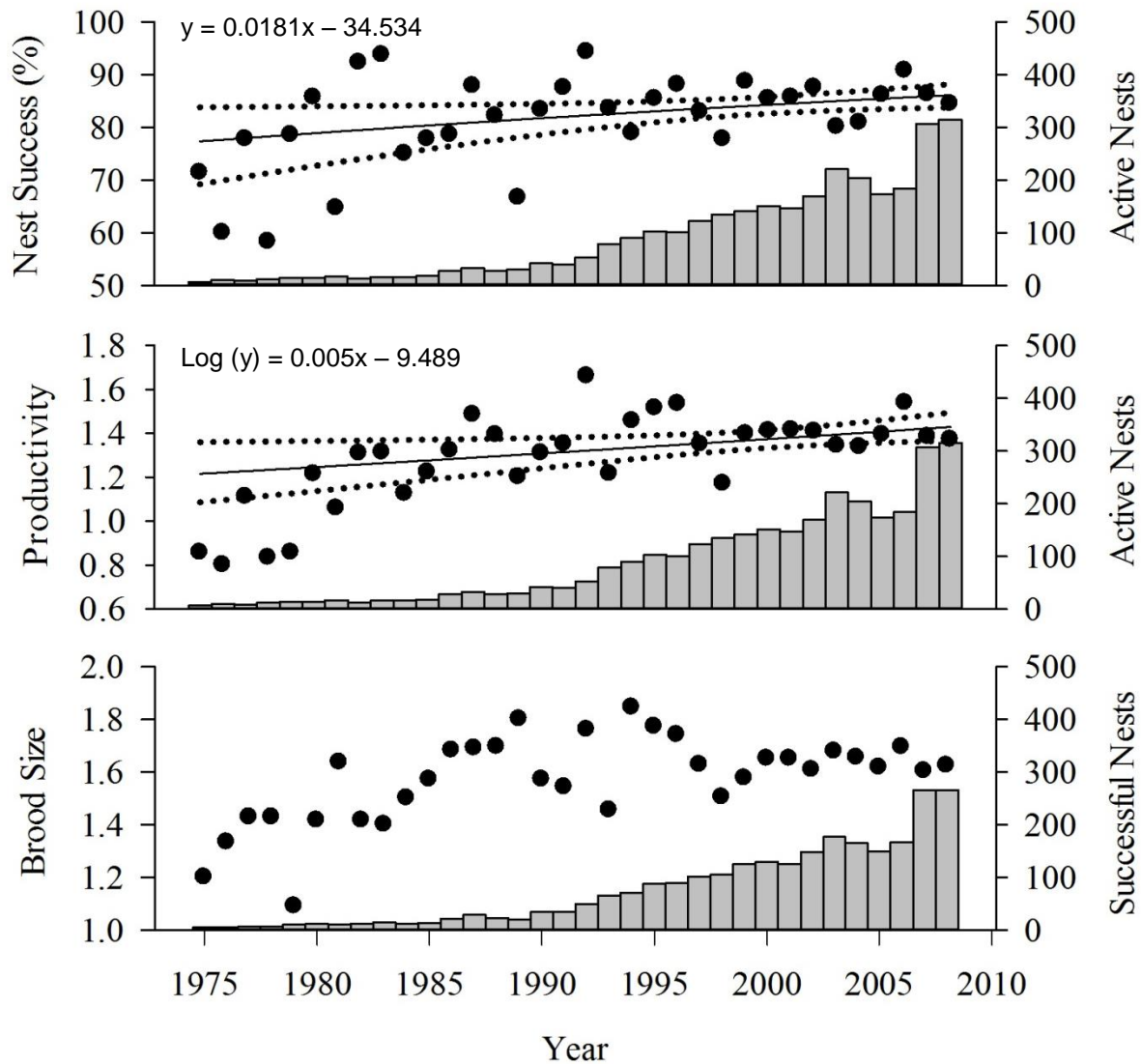


Figure 2.3. Nest success, productivity, and brood size of Louisiana Bald Eagles from 1975–2008 with best fitted models weighted by number of active nests (solid lines) and 95% confidence intervals (dashed lines). Brood size was best represented by the intercept only model (weighted mean = 1.63 ± 0.02).

2.4 DISCUSSION

Observed increases in nest success and productivity in Louisiana were not as large as those reported in other studies (Grier 1982, Watts et al. 2008), wherein previous authors suggested that early increases in production may have resulted from reduced use of contaminants. These studies, however, did not control for increasing sample sizes, which may

have resulted in them showing a larger change in production over time than that documented in my study. Production rates such as nest success, productivity, and brood size remained relatively constant in Texas from 1971–2005 (Saalfeld et al. 2009), despite rates of change for total number of active, successful and young produced being similar to those in Louisiana. Saalfeld et al. (2009) speculated that the lack of change in Texas could have been due to the population being less effected by DDT than other regions or having recovered from its effects prior to 1971.

Less clear are factors potentially influencing the observed yearly variation in production in Louisiana. Hurricanes have destroyed a large proportion of nests, but affected nest sites often were rebuilt and showed no substantial effect on productivity (Hess et al. 1994). Other factors such as inclement winter weather and low prey availability may play a role in yearly variation, but potential effects of these have not been investigated for Louisiana eagles.

The number of nesting Bald Eagles in Louisiana increased exponentially from precariously low numbers in 1975 to a minimum of 387 nesting pairs by 2008. Mean annual rates of increase for total active nests, successful nests, and young produced (11.1, 9.8, and 11.4%, respectively) in Louisiana are indicative of a healthy and expanding population (Buehler et al. 1991a). These increases are reflective of the general recovery of nesting Bald Eagles across much of the United States as exhibited by many other studies in different states and regions (Nesbitt et al. 1990, Driscoll et al. 1999, Watson et al. 2002, Jenkins and Sherrod 2005, U.S. Fish and Wildlife Service 2007, Watts et al. 2008, Saalfeld et al. 2009).

Even though results of the modeled variables parallel each other, there are inherent biases in using infrequent aerial surveys. For example, some of the increase in active nests observed over the progression of my study may be a result of increased observer expertise and discovery of existing, but previously undocumented nests, as noted for other aerial nest surveys (Nesbitt et

al. 1998, Saalfeld et al. 2009). Nesting activity also may have been underestimated due to active nests being abandoned prior to a second survey flight. Likewise, my production estimates may have been biased high (Nesbitt et al. 1998) because young in some nests, which were recorded as successful prior to actual fledging, may not have survived to depart from the nest. Conversely, nests in which young could have fledged prior to a second survey flight were excluded from analysis of production, which could have underestimated production. However, I believe that production biases were minimal in my study and provided relatively consistent estimates between years as suggested by others (Nesbitt et al. 1998). Therefore, my survey results should represent a minimum estimate of nesting activity and are expected to reflect the general trend in production for the population.

The Southeastern States Bald Eagle Recovery Plan (Murphy 1989) outlined goals for the southeastern region which included Florida, Georgia, South Carolina, North Carolina, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Texas, and Louisiana. The plan considered that recovery was achieved when, along with documentation of population vigor and adequate habitat, a collective 3 year average of >0.9 young per active nest, >1.5 young per successful nest, and $>50\%$ of nests successful in raising at least 1 young was reached. The Louisiana population already exceeded goals for nest success and young produced per active nest when the recovery plan was first drafted in 1984; and the three year average for young produced per successful nest was >1.5 by 1986.

The recovery plan also had an objective of 600 active nests distributed across at least 75% of their historical range which represented approximately 40 nests in Louisiana. From 1992-1994, efforts were made to expand the Louisiana population into new areas using an eagle hacking program, as recommended in the Southeastern States Bald Eagle Recovery Plan

(Murphy 1989) and considered a successful technique in other states (see Nesbitt et al. 1998, Jenkins and Sherrod 2005). During these three nesting seasons, 33 eaglets were transported from nests in southern Louisiana to a hacking tower at Lake Ophelia National Wildlife Refuge in central Louisiana. A total of 32 young were successfully fledged from the hacking tower. A nest was found on the refuge in 1995, but unfortunately it was not determined whether any of the hacked eagles ever established nesting territories in the area or if the rate of nesting population increase was greater in this area compared with surrounding areas. However, prior to the hacking program there were already >40 known active nests in Louisiana. Thus, the nesting population in Louisiana has exceeded all recovery criteria since 1990 and the Bald Eagle was removed from the list of threatened and endangered species in 2007 (U.S. Fish and Wildlife Service 2007).

The Endangered Species Act mandates continued monitoring after the delisting of any species. Accordingly, the United States Fish and Wildlife Service developed a post-delisting management plan for the Bald Eagle population with a statistical goal of an 80% probability of detecting a 25% or greater change in the number of occupied nests when surveyed every 5 years (starting in 2009) over a 20 year period (U.S. Fish and Wildlife Service 2009). The plan criteria for defining occupied nests are the same as that used to define active nests in the Louisiana survey. The plan design uses a dual-frame estimate with a list frame (list of known nests) and an area frame (set of survey plots) to estimate the continental population.

Watts and Duerr (2010) expressed concerns about the adequacy of the dual-frame approach if the list frame is not properly maintained. Decreased priority in nest monitoring by states would cause deterioration in the list frame, which could degrade the viability of the dual frame approach, specifically in the latter stages of this monitoring plan. However, continued

maintenance of the list frame is costly, whereas the dual-frame approach was developed with consideration for cost and logistics. Sauer et al. (2011) suggest that the dual-frame approach is still more effective and logistically feasible than an area-only sample but also encouraged maintenance of a nest list.

Accordingly, wildlife managers in Louisiana and elsewhere may want to consider updating nest list frames through periodic statewide aerial surveys during post-delisting monitoring. An alternative option would be to incorporate a citizen based nest reporting system, which allows for the addition of new nests to the nest list and provides an update on the status of existing nests. Several states (e.g., Colorado, Iowa, Texas, New Jersey, Pennsylvania) use citizen based reporting systems of various types, consisting of forms, online reporting, and notifying a local game warden (Gross and Brauning 2011, Smith and Clark 2012). A citizen based nest reporting system may be more cost effective than a statewide aerial survey, but would require verification for each site and quality control to ensure that a nest is not recorded more than once. Such an effort to maintain nest lists would be in line with the suggestions of a state based effort for continued updating and management of the nest list as presented in the post-delisting monitoring plan (U.S. Fish and Wildlife Service 2009) and Sauer et al. (2011).

The Bald Eagle is listed as a species of conservation concern (shows evidence of or the potential for population decline) in Louisiana (Lester et al. 2005); however, this status may require periodic re-evaluation as the population increases. If the species were to be considered secure or apparently secure, ≥ 100 extant populations as defined in Louisiana's Comprehensive Wildlife Conservation Strategy (Lester et al. 2005), it may no longer warrant conservation concern. A change in the state status may not endanger or inhibit the protection of Bald Eagles,

their young, or their nests as these are afforded coverage under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act.

Long-term monitoring has documented the recovery of the Bald Eagle, and as of 2008, the increase of the nesting population had not slowed in Louisiana. However, future research examining regional population trends may reveal that the most populated region in southeastern Louisiana may be approaching or have reached local carrying capacity, which may favor dispersal and promote nesting in other regions of the state. Habitat loss and human development may be the most important limiting factors in the expansion of the Bald Eagle in Louisiana. As eagle numbers grew, so did Louisiana's human population, which increased by about 25% from 1970 to 2010 (U.S. Census Bureau. 2010). In the past, human activity has been a strong predictor of Bald Eagle nest site selection (Andrew and Mosher 1982, Buehler et al. 1991b, Saalfeld and Conway 2010). Eagles may select areas away from human activity to nest, but as populations expand, they could alter their preferences and move into more populated areas (Guinn 2013). In Florida and Chesapeake Bay, there has been no apparent effect on productivity for birds nesting in human dominated settings (Millsap et al. 2004, Watts 2006). Thus, the continued stability and growth of the nesting population may depend on the ability of Bald Eagle's to cope with human activity and the protection of current and future nesting habitats.

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CHAPTER 3. FACTORS AFFECTING LANDSCAPE LEVEL NEST SITE SELECTION AND SUCCESS OF LOUISIANA BALD EAGLES

3.1 INTRODUCTION

A critical step to managing a species is management of habitat wherein that species lives. To better understand factors that may be influencing the selection of a site, many studies compare characteristics that make up the area where a species is found to the areas that are available (Jones 2001). Habitat selection occurs at hierarchical levels (Johnson 1980), wherein an animal first selects a geographical range, then a home range within, and then further selects a place to nest within that home range. Selection may vary at these different levels (Thompson and McGarigal 2002, Saalfeld and Conway 2010), but identifying habitat selection at a landscape level facilitates broad management implications while still providing direction for more refined management on a local level. Modeling nest site selection to understand the disproportionate use of habitats, especially when related to the success of a site, will help to achieve the ultimate goal of understanding the relationship that selection has to the reproductive fitness for the individuals involved (Jones 2001).

Nest site selection on a local level has been extensively studied, indicating that Bald Eagles (*Haliaeetus leucocephalus*) typically select nest sites in large mature trees (McEwan and Hirth 1979, Andrew and Mosher 1982, Harris et al. 1987, Anthony and Isaacs 1989, Wood et al. 1989, Saalfeld and Conway 2010) and within close proximity to open water (McEwan and Hirth 1979, Andrew and Mosher 1982, Harris et al. 1987, Anthony and Isaacs 1989, Wood et al. 1989). Other factors implicated in influencing nest site selection include size of water bodies (Gerrard et al. 1975, Anthony and Isaacs 1989, Dzus and Gerrard 1993), prey availability (Isaacs et al. 1983, Gende et al. 1997), human activity/disturbance (Andrew and Mosher 1982, Anthony

and Isaacs 1989, Buehler et al. 1991, Saalfeld and Conway 2010, Guinn 2013, Mundahl et al. 2013), habitat surrounding a site (McEwan and Hirth 1979, Andrew and Mosher 1982, Anthony and Isaacs 1989, Wood et al. 1989, Buehler 1995, Saalfeld and Conway 2010, Mundahl et al. 2013), and philopatry (Wood 2009).

Harris et al. (1987) examined nest site characteristics at a local level in south central Louisiana, during 1977–1980, and reported nests were primarily in bald cypress (*Taxodium distichum*)/water tupelo (*Nyssa aquatic*) swamps adjacent to marshes, rivers, canals, bayous, ponds, or lakes. Since then, the Louisiana nesting population has grown exponentially with no indications of slowing since at least 2008 (see Chapter 2). Although Louisiana Bald Eagles still nest primarily in the south central portion of the state, they are expected to move into other habitats as the population expands (Louisiana Department of Wildlife and Fisheries 2007). Understanding nest site selection and factors contributing to nest success, especially after major expansion in number of nests and distribution, may allow managers to make informed decisions about potential effects of future developments, conservation activities, and human use.

Accordingly, I used nest data collected during the most recent Louisiana nest survey to: (1) describe habitats used by nesting Bald Eagles in Louisiana; (2) examine factors influencing landscape level nest site selection and success; and (3) identify areas with high potential for future nest sites.

3.2 STUDY AREA

Bald Eagles establish territories and nest throughout Louisiana, but their nests are unevenly distributed within the state (Chapter 2). Louisiana can be subdivided into six distinctive ecoregions (Figure 3.1; Daigle et al. 2006), of which the Mississippi Alluvial Plain covers 38% of the state but contained 91.7% of active nests during the 2007-2008 nesting

season. The Mississippi Alluvial Plain is mostly a flat alluvial plain largely comprised of agricultural and wetland habitats. Crop production consists mainly of sugarcane, soybeans, and pasture in the southern part and cotton, corn, soybeans, pasture, and rice in the rest of the region. The South Central Plains cover 40% of the state and are primarily comprised of forested or woodland habitats, with less than 20% of the region in cropland. Comprising 13% of the state, the Western Gulf Coastal Plain is a relatively flat area with fertile soils making rice and soybean production the primary land uses in the region. The Southeastern Plains, Mississippi Valley Loess Plains, and Southern Coastal Plain together encompass only 9% of the state and are similarly comprised of a mosaic of cropland, pasture, wetland, forested, and woodland habitats.

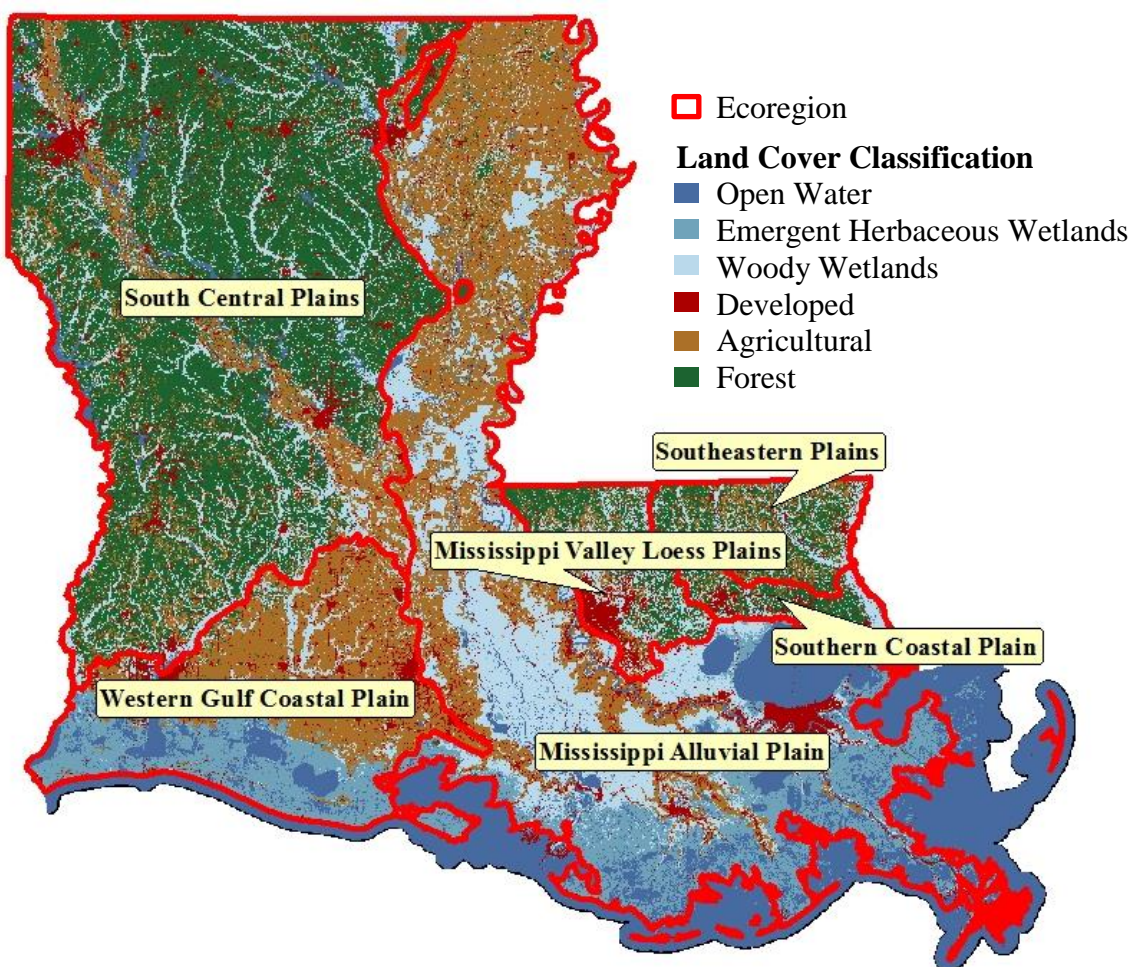


Figure 3.1. Land cover map of Louisiana showing six geographic ecoregions.

3.3 METHODS

I used GIS and remote sensing to compile variables that were known or hypothesized to influence nest site selection and success (Table 3.1). For variables in which data were not available for 2007, selection of data sources from 2006 and 2010 (see Table 3.1) were assumed to be most representative of the values during the 2007-2008 winter nesting season. To guide the development of factors to consider, I compiled information from previous studies on Bald Eagles (McEwan and Hirth 1979, Peterson 1986, Harris et al. 1987, Buehler 1995, Wood 2009, Saalfeld and Conway 2010, Zehnder 2012). Separate consideration was given for the biological basis of each variable for both nest site selection and nest success.

3.3.1 Nest Site Selection

I used nest location data collected during the 2007–2008 winter nesting season (most recent available statewide survey) to examine landscape level nest site selection. Louisiana Department of Wildlife and Fisheries maintained records of known nest locations (see Chapter 2). Multiple nests may occur within a nesting territory; thus, nests not classified as active were excluded from analysis to reduce pseudoreplication. Nests were classified as active by the presence of at least one of the following: (1) one or more adults in or near a nest with signs of nest refurbishment, i.e., presence of fresh nesting material; (2) an adult sitting low in the nest presumably incubating; or (3) the presence of eggs or young. My analysis of nest site selection is based on a total of 387 active nest locations.

Table 3.1. Summary of data used to model landscape level nest site selection and success.

Variable	Biological Indicator	Data	Source
Nest Sites		Winter 2007-2008 nest locations and status	LDWF ^a
Roads	Human Disturbance	TIGER/line Roads (2006)	U.S. Census Bureau
Houses per km ²	Human Disturbance	2010 population – census block group	U.S. Census Bureau
		2010 census block group	U.S. Census Bureau
Nearest Nest	Nest Density	Winter 2007-2008 nest locations	LDWF
Distance to Historical Nest Centroid	Philopatry	Winter 1974-1975 nest locations	LDWF
Water	Foraging Habitat	High-resolution NHD ^b – linear (1:24,000)	U.S. Geological Survey
		High-resolution NHD – discrete (≥ 8 ha)	U.S. Geological Survey
		NLCD ^c 2006 (30m) – discrete (≥ 8 ha)	MRLC Consortium ^d
Land cover (0.5 and 3 km)	Habitat	NLCD 2006 (30m)	MRLC Consortium
Open Water			
Woody Wetland			
Emergent Herb Wetland			
Developed			
Agricultural			
Forest			

^a Louisiana Department of Wildlife and Fisheries

^b National Hydrography Dataset

^c National Land Cover Database

^d Multi-Resolution Land Characteristics Consortium

To facilitate comparisons between nest sites and available habitat, I generated 387 random locations (Figure 3.2). Random sites were stratified by ecoregion to correspond to the number of active nests occurring within each ecoregion. Within ecoregions, random sites were restricted to areas considered to be suitable habitat. Criteria for determining suitable habitat were based on variables associated with nest sites (Gerrard et al. 1975, McEwan and Hirth 1979, Andrew and Mosher 1982, Harris et al. 1987, Anthony and Isaacs 1989, Wood et al. 1989, Dzus and Gerrard 1993, Saalfeld and Conway 2010) and used in the modeling of suitable habitat in other studies (Andrew and Mosher 1982, Grier and Guinn 2003, Watts et al. 2008, Saalfeld and Conway 2010); however, specific values were reflective of characteristics from Bald Eagle nests

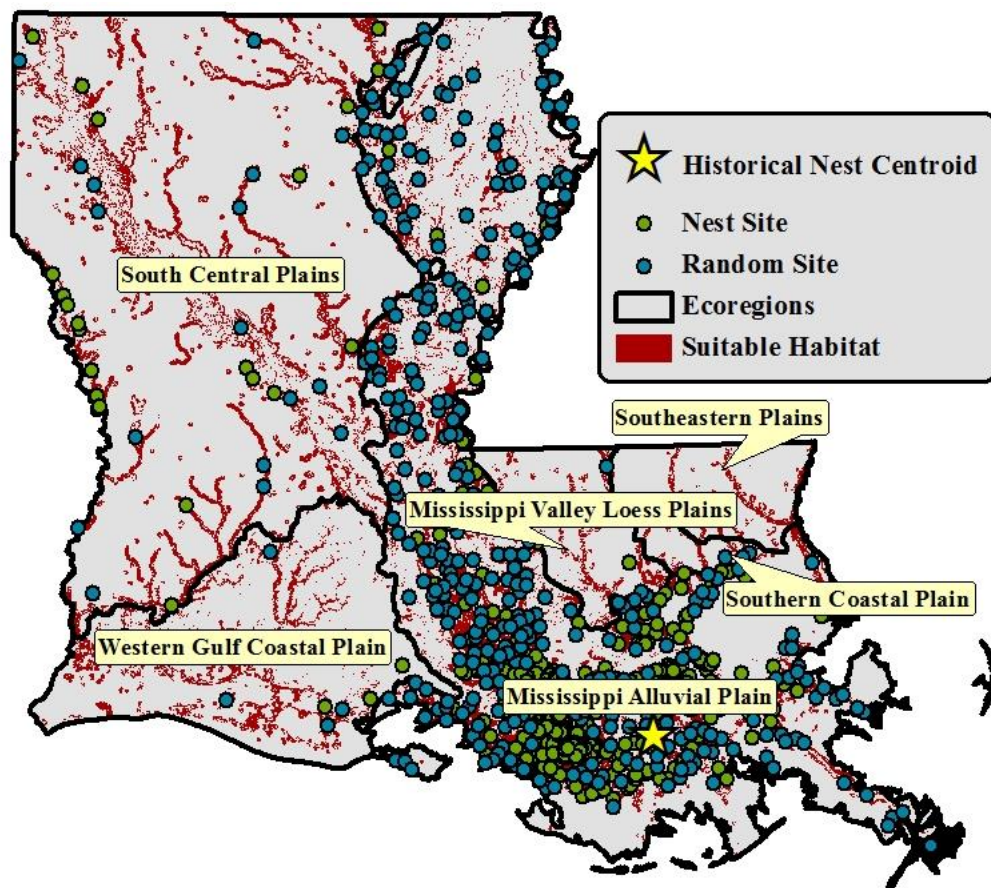


Figure 3.2. Map of Louisiana Bald Eagle nests sites from winter 2007-2008 ($n = 387$) with corresponding random sites ($n = 387$) stratified by ecoregion and restricted to suitable habitat.

in Louisiana. Specifically, suitable habitat was classified as: (1) less than 1 km (representative of distance to water for nest sites) from open water (discrete water body ≥ 8 ha or linear water body represented as polygon at 1:24,000 scale), (2) at least 3 km (representative of the observed distance between nests) from another nest or random point, and (3) within suitable land cover. Suitable land cover types were restricted to emergent herbaceous wetland, woody wetland, and forest (see Appendix A) because these types were most likely to have trees that could support a nest. I further restricted emergent herbaceous wetland land cover type to the area within 1 km of at least one other suitable land cover type. I did this to remove large herbaceous wetlands with the lowest probability of containing suitable nest trees, such as coastal marshes. Random sites were restricted to these land cover types because almost all nests (95%) were located within these land covers.

Human disturbance, around nests and random points, was indexed using distance to nearest road and houses per square kilometer. I assumed that sites closer to roads and with more houses per square kilometer experienced more human disturbance. In Texas, distance to human disturbance was the best predictor of landscape level nest site selection (Saalfeld and Conway 2010), but absolute distance to human structures may be misleading as tolerance to human presence may be effected by visual buffers and habituation (Andrew and Mosher 1982, Millsap et al. 2004). Because of these varying results, I included two human disturbance indexes to assess whether they had an effect on Louisiana Bald Eagles.

Locations of roads were identified using TIGER/line shapefiles created in 2006. A spatial join was then used to calculate the Euclidian distance from a site to the nearest road. Density of houses was calculated using 2010 census data. Number of houses and total area within each census block group were used to calculate houses per square kilometer.

Land cover has been included in most studies of nest site selection for Bald Eagles (Gerrard et al. 1975, McEwan and Hirth 1979, Andrew and Mosher 1982, Peterson 1986, Harris et al. 1987, Anthony and Isaacs 1989, Wood et al. 1989, Dzus and Gerrard 1993, Curnutt and Robertson 1994, Buehler 1995, Saalfeld and Conway 2010, Zehnder 2012, Guinn 2013). Accordingly, I hypothesized that the composition of habitat around a site influences site selection with some land cover types being more influential than others. Land cover was classified using 2006 NLCD (see Appendix A; Fry et al. 2011), wherein similar cover types were combined to reduce the number of variables to six cover types (open water, woody wetland, emergent herbaceous wetland, developed, agricultural, and forest). I determined the proportion of land cover types at two spatial scales, 500 m and 3 km, around each site. Area within 500 m was selected to correspond to U.S. Fish and Wildlife Service (1987) primary management zone and the immediate area surrounding the sites. A 3 km scale was selected to represent the observed home range size of nesting Bald Eagles in Louisiana (see Chapter 4). I calculated the proportion of each land cover type within 500 m and 3 km of each site using the *isectplyrst* tool in Geospatial Modeling Environment (GME; version 7.2.0).

Distance to the historical nest centroid was used to evaluate the hypothesis that the expansion of the population may be affected by philopatry because Bald Eagles are a philopatric species, returning to relatively the same area in which they were hatched (Mabie et al. 1994, Saalfeld et al. 2009, Wood 2009). The historical nest centroid was calculated as the mean northing and easting of the 7 known active nests from winter 1974-1975. Distance from each site to the centroid was then calculated using *pointdistance* tool in GME.

Roads are unevenly distributed across Louisiana with fewer roads located near the historical nest centroid. The area around the historical nest centroid, which encompasses much

of the southern portion of the Mississippi Alluvial Plain, is largely comprised of wetland habitats (Daigle et al. 2006), wherein few roads cross some of the large wetland areas (Figure 3.3).

Distance to road is more variable within about the first 100 km from the historical nest centroid; however, farther from the nest centroid distance to road appears to be restricted to within about 2.5 km to the nearest road. The distribution of roads in Louisiana may not allow for sites to be more than a few kilometers from the nearest road except for in the south and eastern part of the state. Thus, the importance of distance to the nearest road may vary as distance to the historical nest centroid increases. Therefore, I included a first order interaction of distance to road x distance to historical nest centroid in my analysis.

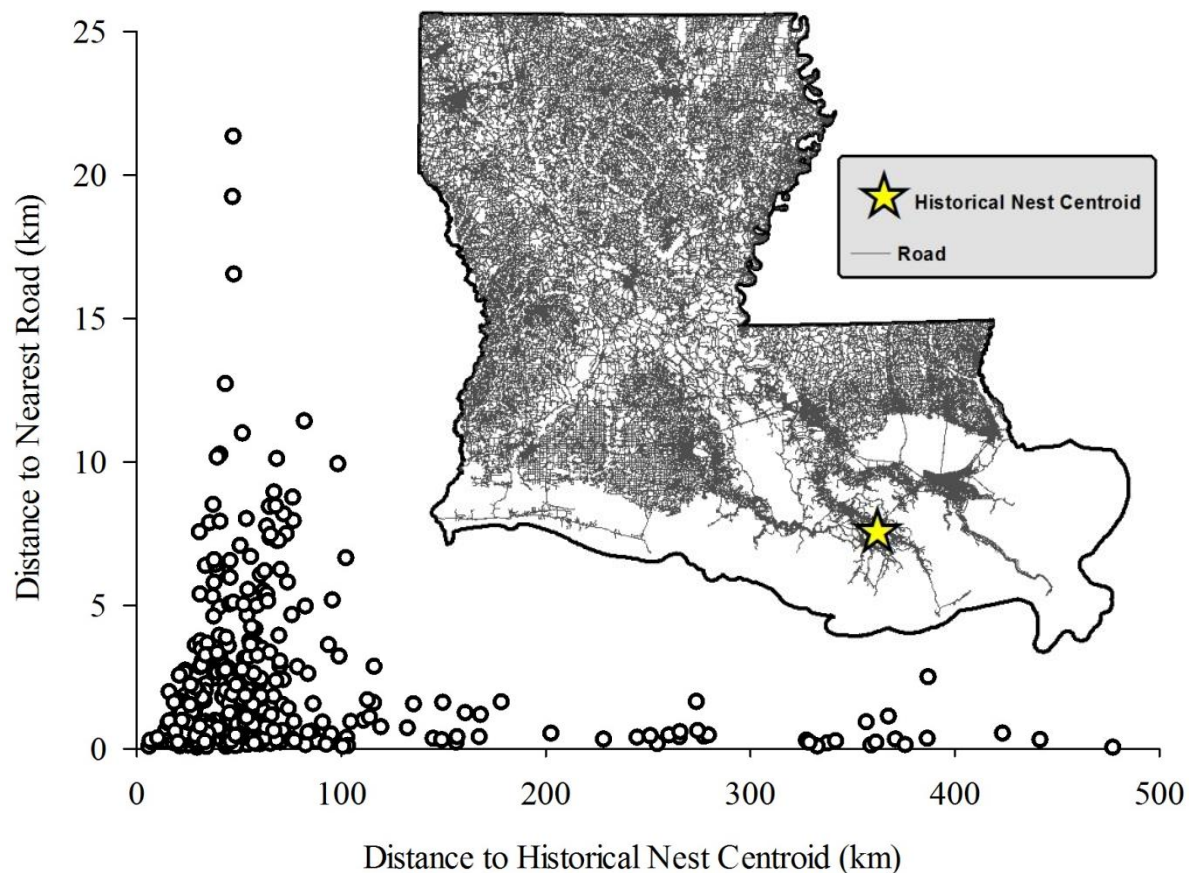


Figure 3.3. Plot of distance to historical nest centroid x distance to nearest road with inset map depicting distribution of nests within Louisiana.

General habitat characteristics also change in relation to the distance to the historical nest centroid. Emergent herbaceous wetlands are more abundant near the historical nest centroid, whereas areas become more dominated by agricultural and forested land cover types as distance to historical nest centroid increases (Figure 3.4). Likewise, there is relatively more variation in the percent of emergent herbaceous wetland near the historical centroid but less variation for agricultural and forested land cover types. Conversely, there is relatively more variation in the percent agricultural and forested land cover types further from the historical nest centroid but less variation in the percent emergent herbaceous wetland land cover (Figure 3.4). Therefore, I included three first order interactions: (1) proportion emergent herbaceous wetland x distance to historical nest centroid, (2) proportion agricultural land cover x distance to historical nest centroid, and (3) proportion forested land cover x distance to historical nest centroid. All three of these land cover types x historical centroid interactions were used to depict the change in general land cover from the historical nest centroid; thus, all three interactions were either included in a model or all were excluded from a model.

In summary, I considered the following explanatory variables in my analysis of landscape level nest site selection: (1) distance to road, (2) houses per km², (3) distance to historical nest centroid, (4) land cover, (5) distance to road x distance to historical nest centroid interaction, (6) distance to historical nest centroid x proportion of forest land cover type interaction, (7) distance to historical nest centroid x proportion of agricultural land cover type interaction, and (8) distance to historical nest centroid x proportion of emergent herbaceous wetland land cover type interaction.

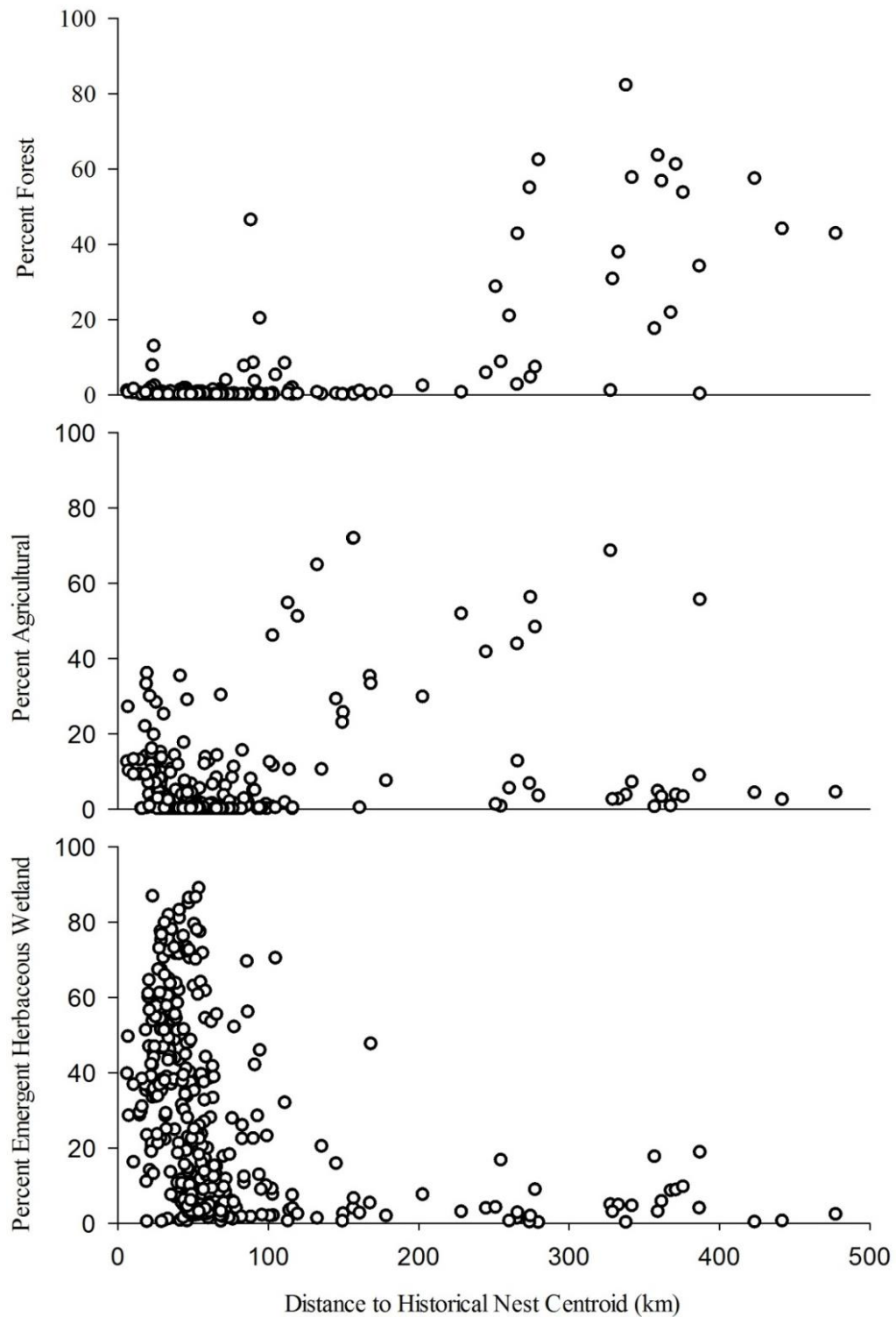


Figure 3.4. Plot of percent forest, percent agricultural, and percent emergent herbaceous wetland within 3 km of a nest site versus distance to historical nest centroid (km), depicting interactions between land cover types and distance to historical nest centroid.

3.3.2 Nest Success

Status data for active nests in the survey were used to classify nests as successful or unsuccessful, with nests recorded as successful if a minimum of one young, eight weeks of age or greater, was observed. Only those nests in which a status could be determined were used in my nest success analysis. Thus, this analysis is based on a total of 315 nests of which 266 (84%) were successful and 49 (16%) were unsuccessful.

I used the same eight explanatory variables in my nest success analysis as used in the nest site selection analysis. I considered hypotheses from the nest site selection analysis to have similar effects on nest success, e.g., a variable hypothesized to have a negative effect on the probability of a site being selected for nesting would also have a negative effect on the probability of a nest being successful. The only exception was that the variable, distance to the historical nest centroid, was considered for nest success because a relatively high density of nests still occurs around the area where the 7 historical nests occurred, suggesting the nesting population expanded geographically from those historical nests. Therefore, it may be expected that nests further from the historical centroid would be relatively newer and have less experienced pairs. Accordingly, I hypothesized that nests further from the historical nest centroid would experience lower nest success.

In addition to the eight explanatory variables used in the analysis of nest site selection, I also included distance to open water and distance to nearest nest for my analysis of nest success. Distance to open water was used to index distance to foraging areas. Fish and water birds comprise the majority of a Bald Eagle's diet (Dugoni et al. 1986, Buehler 2000); therefore, I hypothesized that successful nest sites would be closer to areas that provide such food sources.

Many other studies have reported that nests were close to water (McEwan and Hirth 1979, Andrew and Mosher 1982, Harris et al. 1987, Anthony and Isaacs 1989, Wood et al. 1989, Buehler 2000), and that eagles prefer larger water bodies over smaller ones (Gerrard et al. 1975, Anthony and Isaacs 1989, Dzus and Gerrard 1993), but smaller water bodies may also provide suitable foraging opportunities, especially when located near other water bodies (Peterson 1986).

I considered open water to be large discrete water bodies ≥ 8 ha in size (e.g., lakes, ponds, and reservoirs) as well as large linear water bodies which were represented as polygons rather than lines at a 1:24,000 scale (e.g., rivers, streams, and canals). I used National Hydrography Dataset (NHD) High Resolution Discrete and Linear Waterbody layers, wherein I removed all water bodies that did not meet the size requirement. I also removed swamp/marsh water types from the NHD Discrete Waterbody layer because these were to be represented by land cover types and were not truly representative of unobstructed open water. The NHD had some data gaps wherein large water bodies or parts of large rivers, such as parts of the Mississippi River, were not represented; therefore, I supplemented these files with open water from the 2006 National Land Cover Database (NLCD; Fry et al. 2011). The NLCD raster files open water land cover class was clipped to remove coastal water, and then a region group was used to calculate water body size, wherein areas < 8 ha in size were removed. I did not consider distance to open water in models of nest site selection because random sites were restricted to areas within 1 km of open water.

I used distance to nearest nest as an index of nest density. I evaluated the hypothesis that nesting density would affect nest success (Dzus and Gerrard 1993, Elliott et al. 2011). Using the pointdistance tool within GME, I calculated the Euclidean distance to the nearest active nest.

In summary, I considered the following explanatory variables in my analysis of nest success included: (1) distance to road, (2) houses per km², (3) distance to water, (4) distance to nearest nest, (5) distance to historical nest centroid, and (6) land cover, (7) distance to road x distance to historical nest centroid interaction, (8) distance to historical nest centroid x proportion of forest land cover type interaction, (9) distance to historical nest centroid x proportion of agricultural land cover type interaction, and (10) historical nest centroid x proportion of emergent herbaceous wetland land cover type interaction.

3.3.3 Statistical Analysis

I used logistic regression (PROC LOGISTIC; SAS Institute Inc. 2011) to evaluate the influence of multiple explanatory variables on the probability of a nest site being selected and the probability of a site being successful or unsuccessful. Site characteristics were included as explanatory variables and the classification of a site (nest/random, successful/unsuccessful) was the response variable. A set of 18 *a priori* candidate models were developed for the evaluation of landscape level nest site selection. For the analysis of nest success, 16 *a priori* candidate models were developed. Model selection was based on Akaike's information criteria, corrected for sample size (AIC_c), where models that best supported the data had the lowest AIC_c. I evaluated parameters from the top model/models using a 85% confidence interval (CI) of the parameter estimates to be consistent with an AIC approach (Arnold 2010). Only those parameters that did not overlap zero were considered to be influential in nest site selection or success.

Multicollinearity was inherent due to the nature of the data (Graham 2003). For example, the percent of one land cover type present within a buffer influenced the percent of all other land cover types within that same buffer as well as the percent land cover in the smaller/larger buffer,

because buffers were inclusive. For this reason, in the nest site selection and nest success analyses, all land cover types at a single spatial scale were either included or excluded together from a model and were represented as the variable “land cover” with 6 levels. I separately tested which spatial scale was most influential in nest site selection and nest success by running the full model from each analysis with land cover within 500 m and then running the full model again with land cover within 3 km. The full model that performed best, as determined by the lowest AIC_c, was then considered the most influential spatial scale. In these preliminary analyses, land cover within a 3 km radius of sites had a greater influence in nest site selection and nest success than that within a 500 m radius and therefore was used for all candidate models subsequently analyzed. To test for multicollinearity in all other variables, I used a correlation matrix (PROC CORR; SAS Institute Inc. 2011); wherein variables with Pearson correlation coefficients ≥ 0.7 were considered highly correlated (Dormann et al. 2013); however, none of the variables I considered were found to be highly correlated.

3.4 RESULTS

Nests within 100 km of the historical nest centroid were located, on average, 2.4 km from the nearest road (range = 0.0-21.3 km) and nest >100 km from the historical nest centroid were located, on average, 0.8 km from the nearest road (range = 0.0-6.6 km; Figure 3.3). Nest sites were, on average, 4.7 km from the nearest nest (median = 2.0, range = 0.1–52.2 km) with 97% of nests being at least 400m of the nearest nest (Figure 3.5). All but 1 nest were within 3 km of a substantial body of open water with the average distance 466 ± 26 m (Figure 3.6). Woody wetland made up the largest proportion of land cover types within 3 km of nests ($\bar{x} = 44.1\%$) with emergent herbaceous wetland being the second most abundant land cover type ($\bar{x} = 26.0\%$; Figure 3.7).

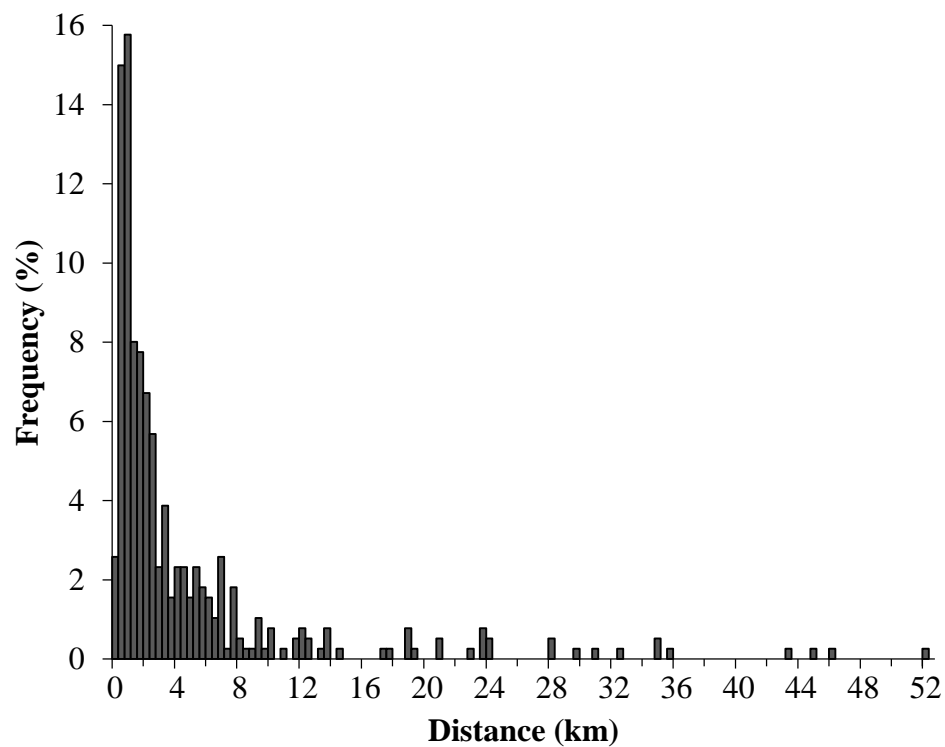


Figure 3.5. Distribution of distances from a nest to the next nearest nest.

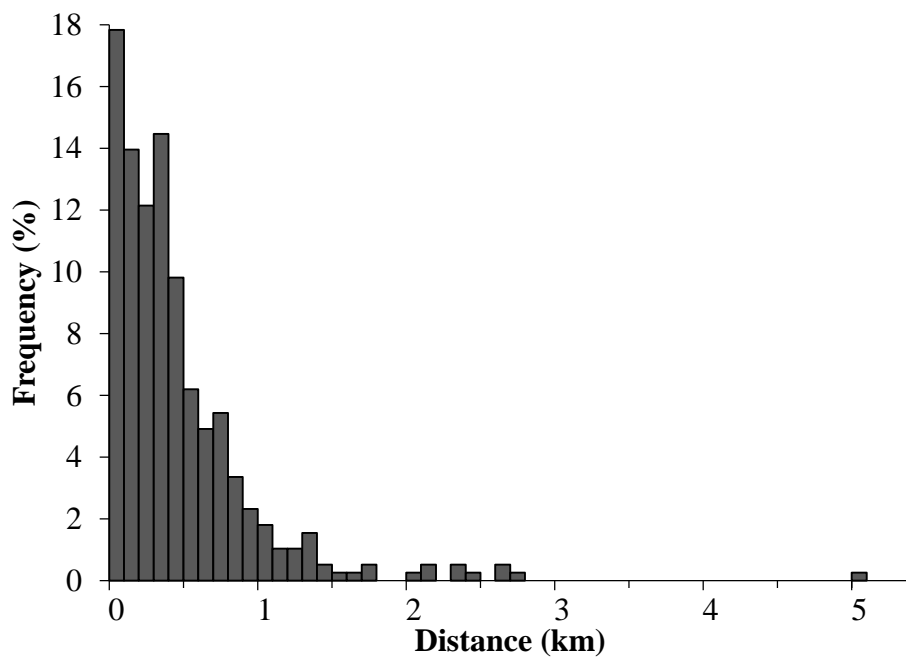


Figure 3.6. Distribution of distances from a nest to the nearest open water.

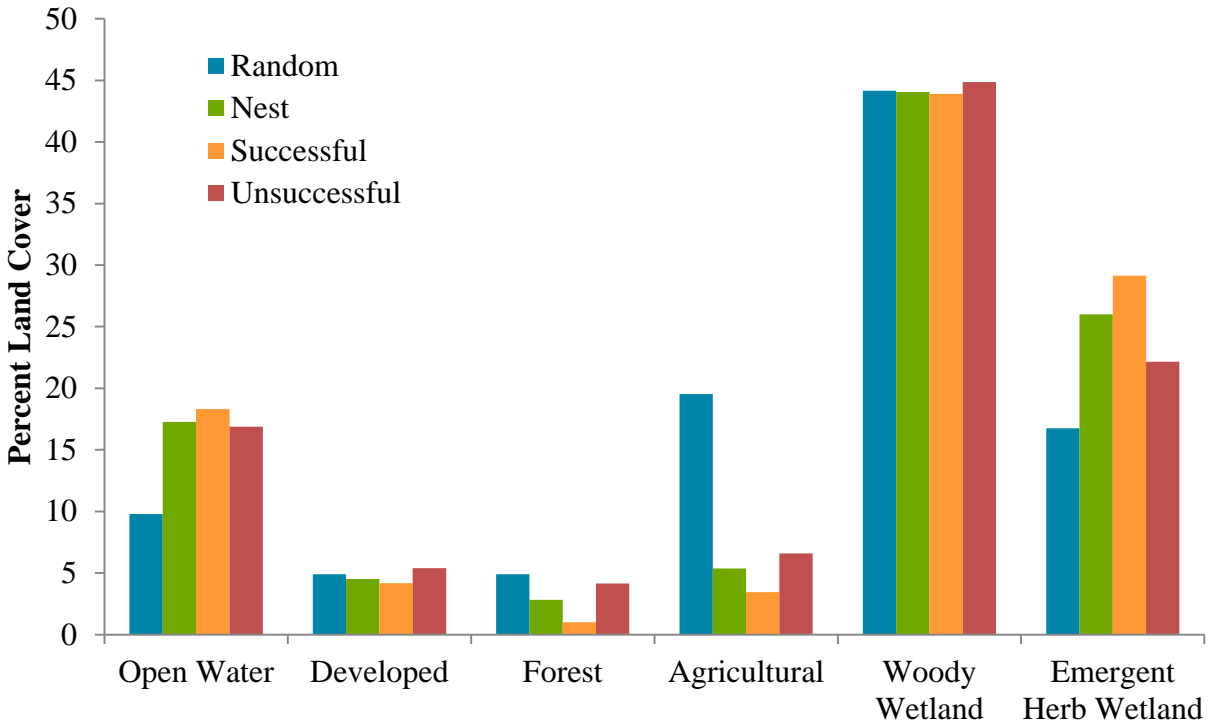


Figure 3.7. Percent of 6 land cover types within 3 km of random sites, known active nests, and successful and unsuccessful nests of Louisiana Bald Eagles from winter 2007-2008.

3.4.1 Nest Site Selection

The top three models accounted for 99.9% of the Akaike model weight with distance to historical nest centroid, land cover within 3 km, and first order interactions between distance to historical nest centroid and three land cover types (forest, agricultural, and emergent herbaceous wetland) present in all three of the top models (Table 3.2). The top model correctly classified 84.4% of nest of sites. The probability that a site was selected for nesting decreased further from the historical nest centroid, and in areas with more forested and agricultural land cover types, but increased in areas with more open water within 3 km of a site. However, interactions indicated that importance of some features were not consistent, e.g., the importance of agricultural and forested land cover types increased with increased distance to the historical nest centroid (Table 3.3).

Table 3.2. Logistic regression models predicting Louisiana Bald Eagle nest sites (n = 387) versus random sites (n = 387), including number of parameters (K), Akaike's Information Criterion adjusted for small sample size (AIC_c), difference between the AIC_c of the given model and the model with the lowest AIC_c (ΔAIC_c), and Akaike's model weight (w_i).

Model	K	AIC _c	ΔAIC _c	w _i
Road ^a , Centroid ^b , Land Cover ^c , Centroid x Forest ^d , Centroid x Agricultural ^e , Centroid x Herbaceous Wetland ^f , Centroid x Road ^g	11	800.7316	0.000	0.635
Centroid, Land Cover, Centroid x Forest, Centroid x Agricultural, Centroid x Herbaceous Wetland	9	802.4554	1.724	0.268
Houses ^h , Centroid, Land Cover, Centroid x Forest, Centroid x Agricultural, Centroid x Herbaceous Wetland	10	804.4975	3.766	0.097
Road, Centroid, Land Cover, Centroid x Road	8	845.7304	44.999	0.000
Road, Centroid, Land Cover	7	856.044	55.312	0.000
Centroid, Land Cover	6	858.504	57.773	0.000
Houses, Centroid, Land Cover	7	860.540	59.808	0.000
Road, Centroid, Centroid x Road		914.829	114.097	0.000
Road, Centroid, Houses, Centroid x Road		916.6933	115.962	0.000
Centroid	1	926.288	125.556	0.000
Houses, Centroid	2	927.821	127.089	0.000
Road, Houses, Centroid	3	928.049	127.317	0.000
Road, Land Cover	6	935.299	134.567	0.000
Land Cover	5	942.008	141.276	0.000
Houses, Land Cover	6	942.272	141.540	0.000
Road	1	1074.935	274.203	0.000
Intercept Only	0	1074.997	274.265	0.000
Houses	1	1075.536	274.804	0.000

^a Distance to nearest road (km).

^b Distance to historical nest centroid (km).

^c Proportion of land cover type within 3 km at 5 levels: open water, developed, forest, agricultural, emergent herbaceous wetland, and reference level set as woody wetland.

^d First order interaction between distance to historical nest centroid (km) and proportion of forest land cover type within 3 km.

^e First order interaction between distance to historical nest centroid (km) and proportion of agricultural land cover type within 3 km.

^f First order interaction between distance to historical nest centroid (km) and proportion of emergent herbaceous wetland land cover type within 3 km.

^g First order interaction between distance to historical nest centroid (km) and distance to nearest road (km).

^h Houses per km².

Table 3.3. Parameter estimates, standard error (SE), lower 85% confidence limits (LCL), and upper 85% confidence limits (UCL) for the top model from 18 *a priori* candidate models used to examine nest site selection of Louisiana Bald Eagles. Variables with 85% confidence limits that do not overlap zero are considered significant and are depicted in bold.

Variable	Estimate	SE	LCL	UCL
Intercept	2.095	0.331	1.618	2.572
Road ^a	0.028	0.082	-0.091	0.146
Centroid^b	-0.022	0.003	-0.027	-0.017
Land Cover ^c				
Open Water	3.139	0.772	2.027	4.250
Developed	0.658	1.342	-1.274	2.590
Forest	-8.029	2.564	-11.720	-4.337
Agricultural	-6.266	1.206	-8.002	-4.529
Emergent Herbaceous Wetland	-0.483	0.791	-1.622	0.656
Centroid x Forest^d	0.051	0.009	0.038	0.064
Centroid x Agricultural^e	0.030	0.006	0.021	0.039
Centroid x Herbaceous Wetland ^f	-0.007	0.011	-0.023	0.010
Centroid x Road ^g	-0.001	0.001	-0.003	0.000

^a Distance to nearest road (km).

^b Distance to historical nest centroid (km).

^c Proportion of land cover type within 3 km at 5 levels: open water, developed, forest, agricultural, emergent herbaceous wetland, and reference level set as woody wetland.

^d First order interaction between distance to historical nest centroid (km) and proportion of forest land cover type within 3 km.

^e First order interaction between distance to historical nest centroid (km) and proportion of agricultural land cover type within 3 km.

^f First order interaction between distance to historical nest centroid (km) and proportion of emergent herbaceous wetland land cover type within 3 km.

^g First order interaction between distance to historical nest centroid (km) and distance to nearest road (km).

Nest sites were, on average, farther from the closest road (2.2, 1.9 km), in areas with almost twice the amount of open water (17.3, 9.8%), in areas with less forest (2.8, 4.9%), and in areas with less than a third of the agricultural land (5.4, 19.5%) of random sites (Figure 3.7).

Nest sites were closer, on average, to the historical nest centroid than were random sites (72, 156 km), with the majority (91%) of nests being within 150 km of the historical nest centroid. Many of those nests near the historical nest centroid were in suitable habitat within the Mississippi

Alluvial Plain. Suitable habitat, to which random sites were restricted, comprised 28% of the area within the Mississippi Alluvial Plain and the Southern Coastal Plain ecoregions, whereas the other ecoregions supported between 12–14% suitable habitat by area (Figure 3.8).

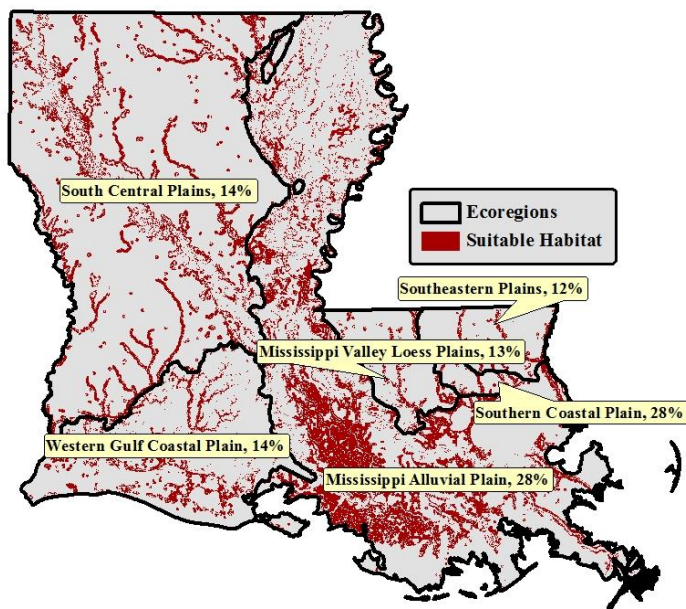


Figure 3.8. Percent of area within each ecoregion that was comprised of suitable habitat (<1 km from open water and in forest, woody wetland, or emergent herbaceous wetland within 1 km from another forest or woody wetland land cover type).

3.4.2 Nest Success

Considerable model uncertainty was exhibited in the set of 16 *a priori* candidate models that I considered in the analysis of nest success. All models varied by less than 10 AIC_C and the intercept only model was within 3.513 ΔAIC_C of the top model. The top model, distance to nearest nest, accounted for 23.5% of the Akaike model weight and only correctly classified 54.5% of nests as either successful or unsuccessful. Despite model uncertainty, distance to nearest nest, which had a negative relationship with the probability of success (parameter estimate = -0.054 ± 0.023), was found in the top three models and these models accounted for 52.3% of the Akaike model weight (Table 3.4). Successful nests were closer, on average, to the next nearest nest (3.1 ± 0.3 km) than were unsuccessful nests (5.4 ± 1.4 km).

Table 3.4. Logistic regression models predicting successful Louisiana Bald Eagle nest sites (n = 266) versus unsuccessful sites (n = 49), including number of parameters (K), Akaike's Information Criterion adjusted for small sample size (AIC_c), difference between the AIC_c of the given model and the model with the lowest AIC_c (Δ AIC_c), and Akaike's model weight (w_i).

Model	K	AIC _c	Δ AIC _c	w_i
Nearest Nest ^a	1	270.802	0.000	0.235
Nearest Nest, Water ^b	2	271.0849	0.283	0.204
Nearest Nest, Centroid ^c	2	272.840	2.039	0.085
Water, Land Cover ^d	6	272.861	2.059	0.084
Nearest Nest, Road ^e , Centroid, Water, Land Cover	9	273.1186	2.317	0.074
Road, Land Cover	6	273.2026	2.401	0.071
Centroid	1	273.584	2.782	0.058
Water	1	273.8819	3.080	0.050
Land Cover	5	274.260	3.458	0.042
Intercept Only	0	274.315	3.513	0.040
Houses ^f	1	275.5542	4.753	0.022
Nearest Nest, Land Cover	6	276.273	5.471	0.015
Road, Centroid, Centroid x Road ^g	3	276.9489	6.147	0.011
Nearest Nest, Road, Centroid, Water, Land Cover, Centroid x Forest ^h , Centroid x Agricultural ⁱ , Centroid x Herbaceous Wetland ^j	12	278.2529	7.451	0.006
Centroid, Land Cover, Centroid x Forest, Centroid x Agricultural, Centroid x Herbaceous Wetland	9	279.4738	8.672	0.003
Nearest Nest, Road, Centroid, Water, Land Cover, Centroid x Forest, Centroid x Agricultural, Centroid x Herbaceous Wetland, Centroid x Road	13	280.4052	9.604	0.002

^a Distance to nearest nest (km).

^b Distance to nearest water body (km).

^c Distance to historical nest centroid (km).

^d Proportion of land cover type within 3 km at 5 levels: open water, developed, forest, agricultural, emergent herbaceous wetland, and reference level set as woody wetland.

^e Distance to nearest road (km).

^f Houses per km².

^g First order interaction between distance to historical nest centroid (km) and distance to nearest road (km).

^h First order interaction between distance to historical nest centroid (km) and proportion of forest land cover type within 3 km.

ⁱ First order interaction between distance to historical nest centroid (km) and proportion of agricultural land cover type within 3 km.

^j First order interaction between distance to historical nest centroid (km) and proportion of emergent herbaceous wetland land cover type within 3 km.

3.5 DISCUSSION

3.5.1 Nest Site Selection

In my analysis, landscape level nest site selection was most influenced by distance to the historical nest centroid and land cover within 3 km of a site, since these variables were present in the top three models which accounted for almost all (99.9%) of the Akaike model weight. The probability of a site being selected for nesting decreased further from the historical nest centroid. This trend is consistent with the hypothesis that Bald Eagles are a philopatric species (Mabie et al. 1994, Saalfeld et al. 2009, Wood 2009), wherein as the nesting population grew, it expanded geographically from the few historical nests that were still present in the state during the winter of 1974-1975 (Louisiana Department of Wildlife and Fisheries 2007). Texas experienced geographical expansion into new areas when reservoirs were constructed inland from the coastal areas where only a few remnant nests were known to exist in 1971, but outside of that ecoregion the highest increases in nesting similarly occurred in the ecoregions that contained the most historical nests (Saalfeld et al. 2009).

The area where the seven historical nests from Louisiana were located has a larger proportion of suitable habitat compared to other regions of the state. This may be another reason why there is such a concentration of nests found near the historical nest centroid (see Figure 3.2, 3.8). However, this region may be reaching a local carrying capacity and future nest site selections may be forced into suitable habitats further from the centroid. I predict that future nests will generally exhibit a ripple effect expanding outward into the next closely available suitable habitat.

Land cover type around a site was an influential variable in my top models. Land cover type within 500 m provided less predictive power than did land cover within 3 km for both the

nest site selection models and the nest success models. This may be explained by the fact that Bald Eagle nest site selection at a local level is relatively homogenous with most nests being found in large trees with the area immediately surrounding the nest also being largely comprised of a wooded land cover type (Andrew and Mosher 1982, Harris et al. 1987, Anthony and Isaacs 1989, Wood et al. 1989, Buehler 1995, 2000, Saalfeld and Conway 2010).

Open water, agricultural and forested land cover types within 3 km of a site were influential in nest site selection. Nest sites had almost twice the amount of open water than did random sites, which probably provided more foraging habitat. Large bodies of open water are considered to be the primary foraging habitats for Bald Eagles (Buehler 2000) and they have been influential in many studies of nest site selection (McEwan and Hirth 1979, Andrew and Mosher 1982, Anthony and Isaacs 1989, Buehler 2000). However, a congregation of smaller water bodies may also provide suitable foraging opportunities (Peterson 1986), which may be the case for the single nest located about 5 km from a substantial body of water (Figure 3.6) but adjacent to several smaller water bodies. My analysis accounted for Bald Eagles that selected for areas with multiple smaller foraging areas within reasonably close proximity because I used proportion of open water around a site. Thus, my results should better account for differing foraging strategies in relation to water than did previous studies which used only a linear distance to nearest large water body.

In my top model, proportions of agricultural and forested land cover types were not consistent across varying distances to the historical nest centroid. Forested land scarcely occurs within 3 km of a nest for about the first 200 km from the historical nest centroid and beyond that point it varies considerably. Likewise, agricultural land rarely comprises more than a third of the land cover within 3 km of a nest for about the first 100 km from the historical nest centroid and

beyond that point it varies considerably. Thus, a shift in the importance of different land cover types may be occurring around 100-200 km from the historical nest centroid. For instance, Bald Eagles may be first selecting nest sites near the historical centroid wherein they select for more woody and emergent herbaceous wetland land cover, but as these areas become occupied and nesting expands further from the historical centroid, the habitats shifts to more forested and agricultural land cover. Future research examining the resource utilization of nesting individuals may provide better insight into the relationship that various habitat types play in Bald Eagle selection.

The number of houses around a site was included in one of the top three models for nest site selection but this variable likely added little important information to the models. In the top three models, when the variable houses was added to a model it increased the ΔAIC_C by about two, which is the standard penalty for the addition of a variable (Anderson 2008, Arnold 2010). Also, houses when modeled alone provided the least explanatory ability. Therefore, I conclude that the variable houses was an uninformative parameter that was included in the top models only because it did not negatively affect the predictive power of the other variables.

Distance to nearest road occurred in the top model but was not considered influential in nest site selection. The distribution of roads in Louisiana may not allow for sites to be more than a few kilometers from the nearest road except for the south and eastern part of the state where there are large woody and emergent herbaceous wetlands making road construction difficult. Thus, Bald Eagles may select for areas away from roads when there is suitable habitat available but areas more than a few kilometers from roads may be limited within Louisiana. So, although distance to road may play some role, it is not highly influential in the selection of a nest site in Louisiana. Overall, human disturbance may not affect nest site selection of Bald Eagles from

Louisiana as strongly as in other studies (Andrew and Mosher 1982, Saalfeld and Conway 2010); however, my results are consistent with the idea that Bald Eagles generally tend to avoid human disturbance, but the influence of human disturbance on nest site selection is minimal compared to other factors (McEwan and Hirth 1979, Millsap et al. 2004).

3.5.2 Nest Success

The models I considered generally provided only weak evidence that the landscape level variables influence nest success. This high model uncertainty and low predictive power may have been caused by several things inherent to Bald Eagle nesting and the data used for my analysis. For instance, Bald Eagles generally have high rates of nests success (see chapter 2; Buehler 2000) which resulted in many more successful than unsuccessful nests. Accordingly, I had a limited sample size of unsuccessful nests. Also, I only considered landscape level variables that could be characterized using remote sensing, whereas nest success may be affected by other things such as weather, prey availability, disease, disturbance, and the age and skill level of the nesting pair. However, of the variables I considered, distance to the nearest nest appears to be the most influential in predicting the success of a nest. Overall, few conclusive management implications may be drawn from my models of nest success, but future research on factors affecting Bald Eagle nest success should give consideration to the distance between nests.

Success of a nest may not be greatly influenced by the physical characteristics around a site, but the initial selection of a site appears to be influenced by at least some landscape level factors as shown by my models. Factors of habitat degradation and the ability of the Bald Eagle to adapt to a changing environment may be the driving force behind a healthy and expanding nesting population in Louisiana. With these results, managers may be able to focus efforts on the protection of current and future suitable habitat, emphasizing on areas with the highest

probability of nesting, such as areas with a large amounts of open water that provide foraging opportunities, and areas with substantial tree cover to support nests and offer perching and roosting sites.

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CHAPTER 4. MIGRATORY ROUTES, STOPOVER SITES AND MIGRATION CHRONOLOGY OF LOUISIANA BALD EAGLES

4.1 INTRODUCTION

Migration, defined as the shift between breeding and non-breeding ranges (Newton 1979), is common among birds (Newton 2007). Mechanisms triggering migration vary depending on species and distance of migrations, but are thought to be influenced by changes in day length, temperature, food availability, or genetic disposition (Berthold 2003, Newton 2007). Meteorological factors, in particular, often influence migration routes and the use of stopover sites (Newton 2007, McIntyre et al. 2008, Lanzone et al. 2012).

Many raptor species use slightly differing routes between spring and fall migrations, sometimes being referred to as loop migration (Meyburg et al. 2003, Klaassen et al. 2010, Mellone et al. 2013), but these species generally exhibit strong route fidelity among years (McClelland et al. 1994, Mojica et al. 2008, Mandernack et al. 2012). Prevailing winds may be a major selective factor in loop migrations, since a following wind would require less expenditure of energy (Kemp et al. 2010). Other deviations from a typical migration can exist such as long-distance movements in a direction other than that normally observed, often referred to as reverse migration (Mann 1950, Alerstam 1978, Richardson 1978, Kerlinger 1989, Thorup 2004). Identifying known migration corridors can help detect risks and threats that may exist along these migration routes and assist managers in ensuring population stability of Bald Eagles.

Banding data and very high frequency (VHF) radio transmitters have been used to document migration but are limited in their ability to track long-distance movements of highly mobile species. Satellite telemetry can provide regular, less biased location data over large landscapes, which can be used to document migration routes, stopover sites, and summering

areas (Bloom et al. 2007, Mojica et al. 2008, Bridge et al. 2011). With the added technology of solar power and the Global Positioning System (GPS), satellite transmitters can provide timely and accurate location data, which is advantageous in determining timing of movements and identifying important use areas (Soutullo et al. 2007).

Bald Eagles (*Haliaeetus leucocephalus*) from southern states such as Florida, Texas, Arizona, and California, migrate north in spring and south in autumn, based on band recoveries, VHF-transmitters, and satellite telemetry (Broley 1947, Hunt et al. 1992, Wood 1992, Mabie et al. 1994, Linthicum et al. 2007, Mojica et al. 2008, Hunt et al. 2009). In Louisiana, Bald Eagles are considered a resident species (Beyer et al. 1908); however, they rarely are observed in the state during June, July and August (Lowery 1974). Louisiana Bald Eagles may have similar migratory behavior as those in other southern states; however, the cause of the seasonal decline in observations from Louisiana has not been documented. For highly migratory species, knowledge of where they go and what areas they use outside of their resident state is important for management.

Accordingly, I deployed satellite GPS transmitters on Louisiana Bald Eagles and subsequently tracked their movements. My objectives were to: (1) document migration parameters, including: departure/arrival dates, migration routes, and stopover sites; (2) compare and examine seasonal and annual repeatability of these parameters for sub-adults and adults; and (3) document possible risks or threats that Louisiana Bald Eagles may encounter both within and outside of the state.

4.2 STUDY AREA

My capture efforts were based out of Mandalay National Wildlife Refuge (NWR) headquarters in Terrebonne parish, where nest density is higher than in any other parish in the state. In winter 2007-2008, 82% of all active nests were located within an 80 km radius of the Mandalay NWR headquarters (Figure 4.1). Thus, focusing capturing efforts in this area allowed me to efficiently and simultaneously maintain multiple bait/trapping sites within multiple nesting territories and maximize capture probability.

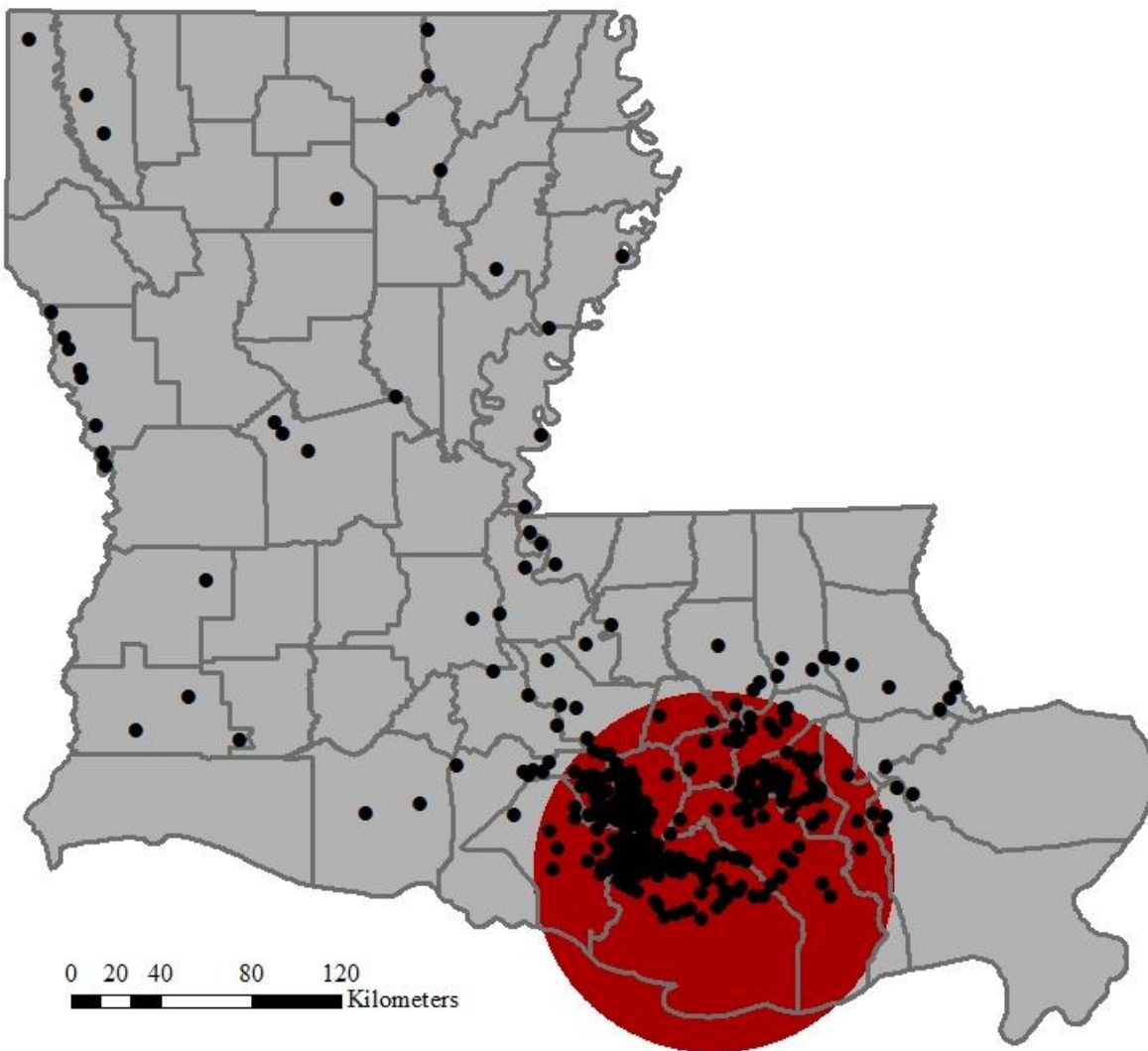


Figure 4.1. Eighty km radius trapping area (red polygon) centered on Mandalay NWR headquarters and winter 2007-2008 Bald Eagle nest locations (black dots).

4.3 METHODS

4.3.1 Trapping and Marking

I captured Bald Eagles using rocket nets baited with carrion during springs 2012 and 2013. The rocket-net system used was a modification of Grubb's portable rocket-net capture system (Grubb 1988, 1991). Rather than the net being deployed from a portable box, the 3-rocket net (9.1 x 15.2 m) was folded like an accordion to approximately 0.3 x 9.1 m extending along the trailing edge, and each rocket was elevated above the ground approximately 1 m using metal posts (see Appendix B). Trap sites were selected based on: (1) areas near previously known active nest sites as determined from 2007-2008 statewide aerial nest survey data collected by the Louisiana Department of Wildlife and Fisheries, (2) proximity to areas of known eagle activity as reported from local landowners and through visual observation, (3) accessibility for personnel and equipment, and (4) the safety of the birds and personnel. These sites often were located in large open areas with low vegetation and within 1 km of known eagle activity areas or nest sites. However, I never trapped directly adjacent to or within the line of sight of any Bald Eagles attending nests, in order to minimize disturbance.

After capture, birds were hooded and restrained from flapping to minimize stress (Louisiana State University (LSU) Agricultural Center Institutional Animal Care and Use Protocol #A2011-22 and Louisiana Department of Wildlife and Fisheries (LDWF) Federal Banding Permit #06669). Plumage, beak, and iris characteristics were used to categorize each bird as either adult (definitive plumage: white head, tail, and upper and lower tail coverts) or sub-adult (>1 years of age but lacking definitive plumage; McCollough 1989). A sample of blood (1–2 ml) was collected for sex determination (Zoogen DNA Services 2013).

I initially deployed transmitters on ten Bald Eagles, and one transmitter was redeployed following a mortality; thus, eleven total birds were fitted with ten 70-gram ARGOS/GPS solar-powered satellite telemetry platform terminal transmitters (PTTs; Microwave Telemetry Inc., Columbia, Maryland) and all birds received a U.S. Fish and Wildlife Service (USFWS) pop-rivet leg band. Each PTT was attached with a backpack style harness using Teflon ribbon (Bally Ribbon Mills, Bally, Pennsylvania; Buehler et al. 1995). Transmitters were programmed to acquire a GPS location every hour and transmit data every other day with an expected battery life of 3–6 years. Capture data were recorded on field forms and each Bald Eagle was subsequently released at the capture site within 2 hours of capture.

4.3.2 Migration

Bald Eagle satellite-tracking data were used to document migration departure/arrival dates, minimum distance and duration of migration, migration routes, and stopover areas. I estimated migration departure date as the initial date an eagle began unidirectional movement away from the wintering or summering area (Mojica et al. 2008). A wintering or summering area was defined as the northernmost (summering) or southernmost (wintering) area where an eagle made omnidirectional movements (<100 km radius) for the greatest consecutive period of time (generally >31 days). Estimated arrival date was defined as the initial date an eagle began omnidirectional movements on the wintering or summering area.

A minimum migration distance was calculated as the Euclidean distance (km) between initial departure location and final arrival location. Duration of migration likewise was calculated as the amount of time between initial departure and arrival. Migration routes were described through visual examination of plotted locations in ArcGIS 10.0 (ESRI 2011) with an

Albers Equal Area Conic projection. Route fidelity was examined for each individual, looking at variations in north and southbound routes, as well as annual variations.

I identified stopover areas as areas used during migration, located between the summering and wintering area, where localized movements (<15 km radius; McIntyre et al. 2008) occurred for >24 hours (Laing et al. 2005). I investigated variations in number of sites used and duration of use between years for both north and southbound migrations. Stopover site fidelity was visually examined for each individual, looking at overlap in stopover locations on north and southbound migrations, as well as annual overlap of sites.

4.3.3 Statistical Analysis

I used repeated measures two-way analysis of variance (ANOVA, PROC GLIMMIX; SAS Institute Inc. 2011) to test for differences ($P < 0.05$) between age groups (sub-adult and adult), years, and their interaction for the following response variables: departure/arrival dates, minimum migration distance, duration of migration, number of stopover sites used, and duration of stopover use. Individual birds were used as repeated measures and age group and year were treated as fixed effects. Due to the lack of radio-marked sub-adult females, I used repeated measures two-way ANOVA (PROC GLIMMIX; SAS Institute Inc. 2011) to test for differences ($P < 0.05$) between sexes (adults only), years, and their interaction for the same response variables. Individual birds were used as repeated measures and sex and year were treated as fixed effects. All data are presented as means \pm SE unless otherwise stated.

4.4 RESULTS

4.4.1 Trapping and Marking

Trapping was initiated on January 18, 2012 and all ten transmitters were successfully deployed by May 3, 2012. However, one of the ten radio-marked eagles died of unknown causes

prior to starting the 2012 migration, wherein the transmitter was recovered and then redeployed on another eagle on February 16, 2013 (Table 4.1). I trapped a total of 38 days, wherein I was successful in trapping at least one Bald Eagle during 29% of the days. The rocket net was shot 11 times catching a total of 16 Louisiana Bald Eagles. Five out of the eleven net shots resulted in two birds being captured per shot.

Table 4.1. Deployment dates, age, sex, and PTT number for 11 Bald Eagles marked in 2012 and 2013.

Eagle ID	PTT #	Age	Sex	Deployment Date
200	105200	Adult	Female	18 January 2012
201 ^a	105201	Adult	Male	18 January 2012
202	105202	Sub-adult	Female	4 February 2012
203	105203	Sub-adult	Female	15 February 2012
204	105204	Sub-adult	Female	10 March 2012
205	105205	Adult	Male	19 March 2012
206 ^b	105206	Sub-adult	Female	10 March 2012
207x ^c	105207	Sub-adult	Male	28 March 2012
207	105207	Adult	Female	16 February 2013
208 ^d	105208	Adult	Male	10 April 2012
209	105209	Adult	Male	3 May 2012

^a Found dead 15 February 2014 in Louisiana, USA and PTT recovered.

^b Found dead 8 February 2014 in Louisiana, USA and PTT recovered.

^c Found dead 12 June 2012 in Louisiana, USA and PTT redeployed on eagle 207 on 16 February 2013.

^d Found dead 22 August 2012 in Northwest Territories, Canada but PTT not recovered after local search.

4.4.2 Migration

Sub-adults departed north from wintering areas earlier than did adults ($F_{1,6} = 9.03$, $P = 0.02$). Departure dates did not differ between years ($F_{1,6} = 2.06$, $P = 0.20$) and the age group x year interaction also was not significant ($F_{1,6} = 2.57$, $P = 0.13$). On average, sub-adults left Louisiana on April 11 ± 6 days, whereas adults left on May 23 ± 8 days (Figure 4.2), with the earliest departure on March 14 and the latest being June 30. Sub-adults arrived on summering

areas earlier than adults ($F_{1,6} = 6.77$, $P = 0.04$). Arrival dates did not differ between years ($F_{1,6} = 0.11$, $P = 0.76$) and the age group x year interaction also was not significant ($F_{1,6} = 0.01$, $P = 0.93$). On average, sub-adults arrived on June 9 \pm 5 days, whereas adults arrived on July 20 \pm 8 days (Figure 4.2).

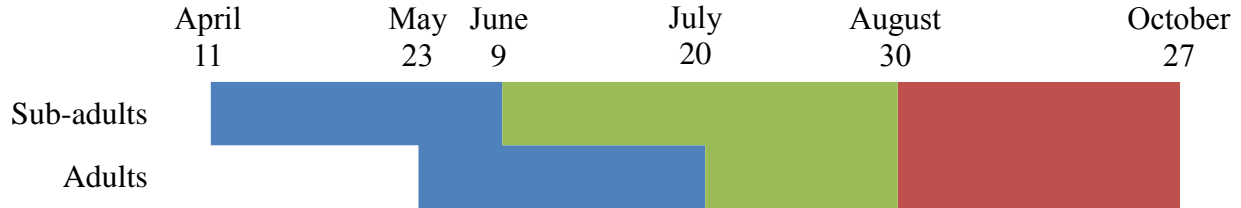


Figure 4.2. Timeline of mean departure/arrival dates for north and southbound migrations, depicting average duration of north (blue) and southbound migrations (red) as well as time spent on summering areas (green) for adult and sub-adult Bald Eagles tracked with satellite telemetry from Louisiana in 2012–2013.

Southbound departures from summering areas started August 30 \pm 5 days (Figure 4.2), on average, with no differences between age groups ($F_{1,6} = 2.26$, $P = 0.18$), years ($F_{1,6} = 0.18$, $P = 0.68$), and the age group x year interaction was not significant ($F_{1,6} = 2.49$, $P = 0.17$). Radio-marked individuals arrived at their winter home ranges in Louisiana from September 27 to November 12 (see Appendix C) with an average arrival of October 27 \pm 3 days (Figure 4.2). Arrival dates did not differ between age groups ($F_{1,6} = 0.23$, $P = 0.65$), years ($F_{1,6} = 1.95$, $P = 0.21$), and the age group x year interaction was not significant ($F_{1,6} = 1.16$, $P = 0.32$).

Migration distance, duration, number of stopover sites used, and duration of stopover use did not differ between north and southbound migrations, years, age groups, sexes for adults, and none of the interactions were significant (all P 's > 0.09). Distance between wintering and summering areas averaged 2,628 km (range 986–3,556 km) and marked birds spent on average 59 days (range 23–110 days) on migration. All migrants used from 3–19 stopover sites ($\bar{x} = 9.3 \pm 0.9$) and stayed an average of 4.3 \pm 0.3 days (range = 1.0–38.8 days) at each stopover site.

A total of 325 stopover sites were identified during both migrations, of those, 13 sites (4%) were revisited by individuals during multiple migrations.

As radio-marked individuals moved away from Louisiana, they flew relatively direct routes toward their summering areas, spreading out west to British Columbia, east to Ontario, and as far north as the Northwest Territories of Canada (Figure 4.3, 4.4). All 8 radio-marked individuals that were tracked over two migrations used at least some part of the previous years migration routes (see Appendix D). The most noteworthy variation in interannual fidelity was adult male Bald Eagle 209, which followed relatively the same northbound migration route as the previous year but traveled approximately half as far north as the previous year. On his return southbound migration he then again followed relatively the same route as the northbound migrations and never traveled along the previous years southbound route.

Within years, north and southbound migration routes varied for 13 of the 17 migrations in which a north and southbound migration were completed in the same year (see Appendix D). Of those that varied, most (69.2%) had northbound migration routes that were generally east of subsequent southbound migrations. This was often more apparent near the middle of their migrations compared to the beginning and end of the migration. Exceptions to this observation were 2013 migrations for Bald Eagles 204, 205, and 206 as well as 2012 migration for Bald Eagle 209. All four of these migrations had northbound migration routes that were generally west of subsequent southbound migrations (see Appendix D).

Five marked individuals made reverse migrations (Bald Eagles 200, 202, 204, 205, and 209; see Appendix D). Six of eleven documented reverse migrations occurred while on southbound migration and near their winter home ranges. Typically the individual would return to the previous winter home range but before establishing localized movements for >31 days, the

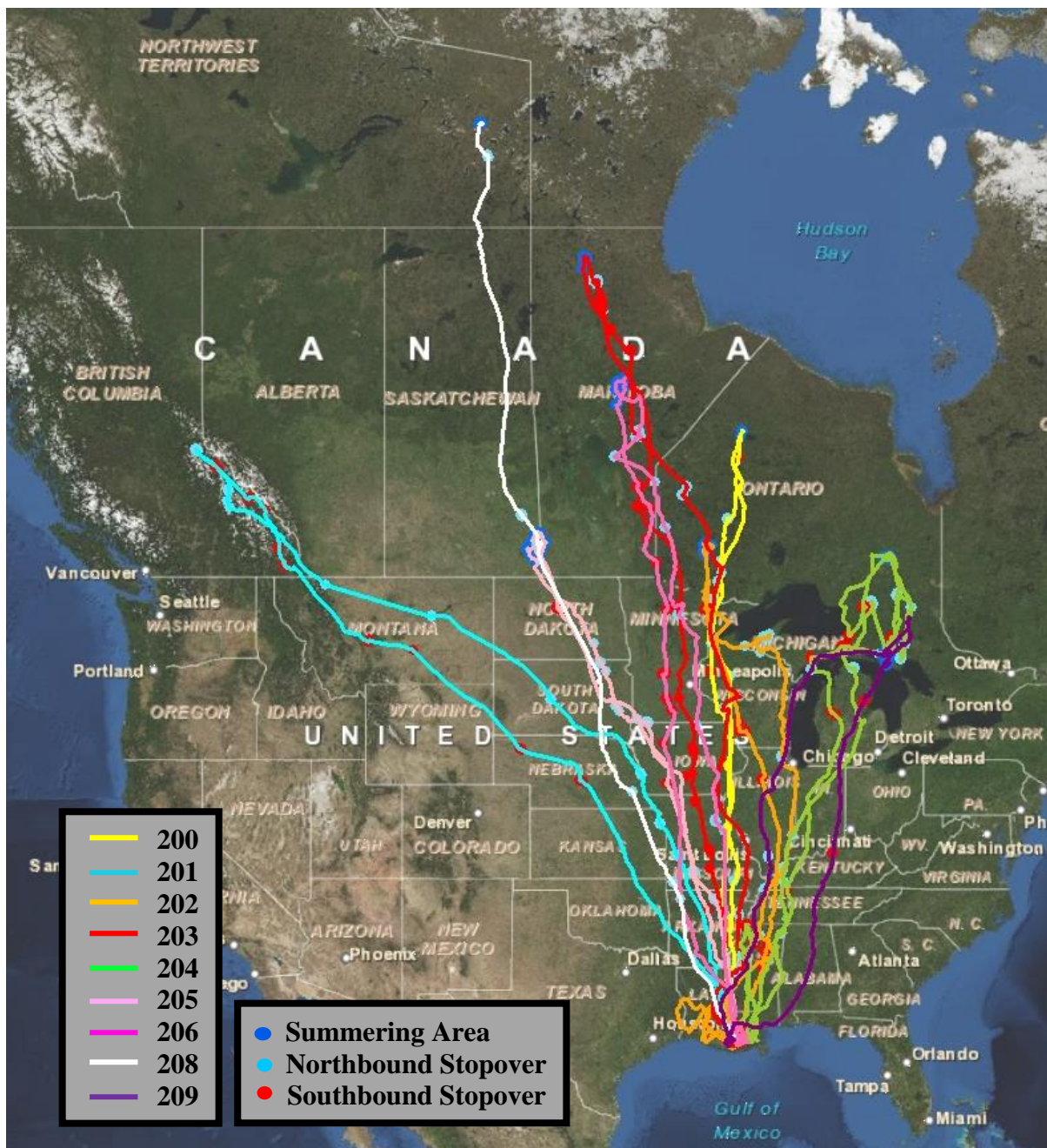


Figure 4.3. Migration routes, stopover sites, and summering areas of 9 Bald Eagles tracked by satellite telemetry from Louisiana in 2012. Note Bald Eagle 208 died on its summering area in the Northwest Territories of Canada.

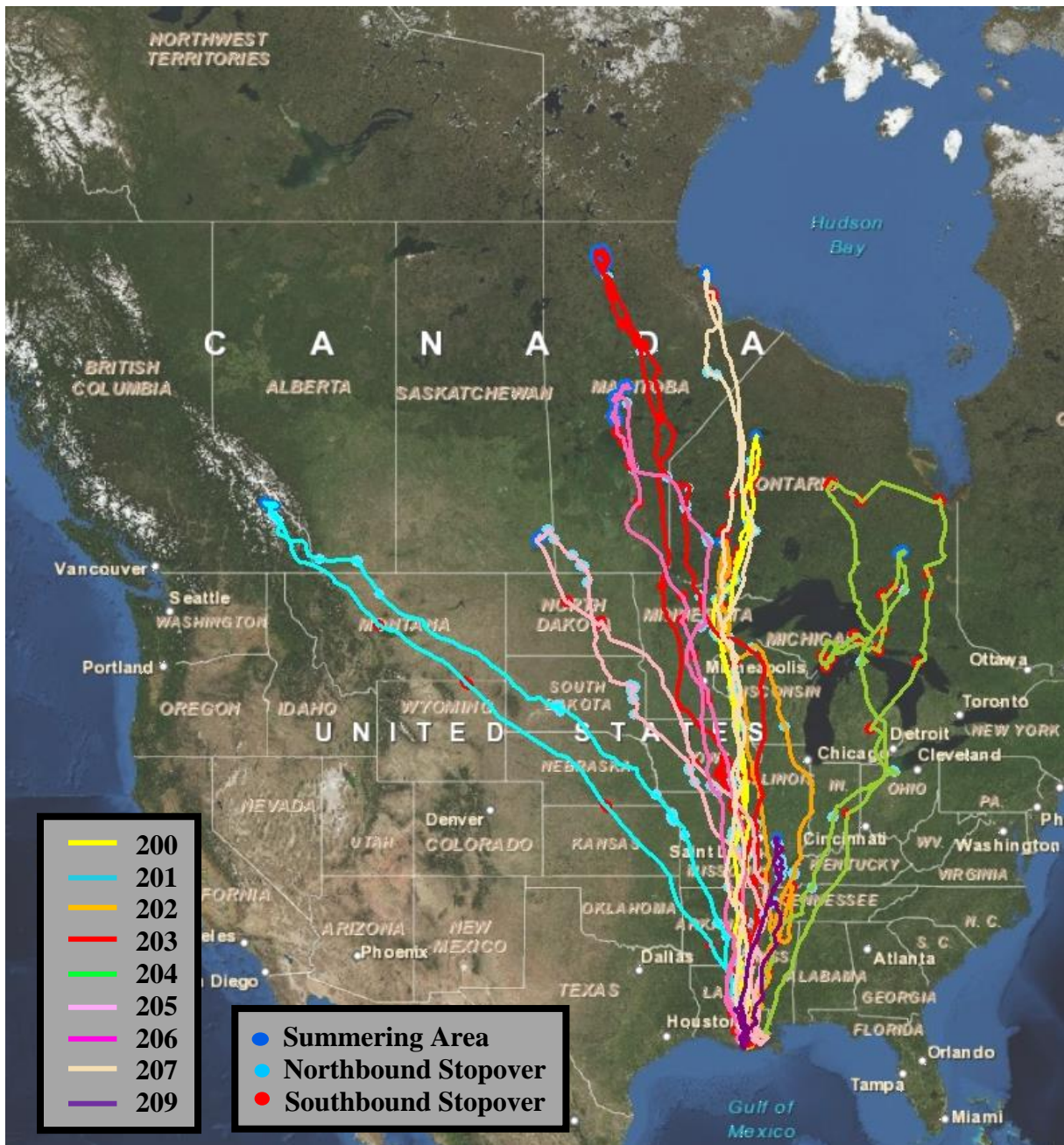


Figure 4.4. Migration routes, stopover sites, and summering areas of 9 Bald Eagles tracked by satellite telemetry from Louisiana in 2013. Note this is the first depicted movements for Bald Eagle 207.

individual would loop north to northwest approximately 150–475 km before returning to the winter home range again. Bald Eagle 202 also made a reverse migration while on its 2013 southbound migration wherein it curved back north about 275 km to an area about 50 km south of a stopover site it used while on its northbound migration, then again headed south to its final wintering area.

The only reverse migrations that were observed near summering areas ($n = 4$) were for Bald Eagles 204 and 209, which were the only two birds to travel across the Great Lakes rather than going around the western tip of Lake Superior as did other individuals (Figure 4.3, 4.4). Adult male Bald Eagle 209 traveled north to its summering area along the northern shore of the Great Lakes but only stayed there a few days before continuing north, flying approximately 200 km then turning around and returning to its 2012 summer home range. Sub-adult female Bald Eagle 204 crossed the Great Lakes and went about 200 km north before turning around and returning to the Great Lakes. She did this one more time before heading north to her final 2012 summer home range. On both her 2012 and 2013 departures south from her summer home range, Bald Eagle 204 again made reverse migrations before crossing the Great Lakes and continuing south to her winter home ranges.

4.5 DISCUSSION

4.5.1 Trapping and Marking

Sub-adult male 207x, which died prior to migration and was excluded from analysis, was the only sub-adult male caught despite attempts to radio-mark an equal number of males and females as well as sub-adults and adults. This may be due to a bias inherent to using a rocket net or other carrion-based trapping method for species that are sexually dimorphic in size. Male Bald Eagles are typically smaller than females (see Chapter 5; Bortolotti 1984) and dominance is

based on size rather than age (Garcelon 1990). Therefore, when multiple eagles were present at a bait/trapping site, larger females were more successful at displacing males from the bait, resulting in fewer males caught. When I did catch males, they were either alone, with an adult female (presumed mate), or at a communal feeding area such as a landfill. Future research that involves marking Bald Eagles may require added consideration and effort to catch males, if an equal sex ratio of marked individuals is desired.

4.5.2 Migration

Summer migration to northern latitudes by southern Bald Eagles is thought to be related to temperature (Wood et al. 1998). However, temperature may be affecting other factors that influence departure such as a shift in available food resources. In particular, fish exhibit a vertical migration to lower, cooler, and more oxygenated water when water temperatures increase (Diana 1995). Fish and waterfowl are a primary food sources for Bald Eagles in Louisiana (Dugoni et al. 1986); thus, fish may be less accessible to eagles during the heat of summer because they move to lower depths. Likewise, large numbers of waterfowl winter in Louisiana (Reynolds et al. 2014), whereas numbers are substantially lower in the summer. Thus, Louisiana Bald Eagles may migrate to habitats that provide greater food availability in summer. If availability of fish and waterfowl were a major factor in summer migration of Bald Eagles from southern latitudes, I hypothesize that non-migrating individuals will use a relatively greater proportion of other prey sources during the summer.

Although all radio-marked individuals from my study migrated north for the summer, not all Louisiana Bald Eagles may migrate. A study in Florida showed 8 out of 69 radio-marked Bald Eagles did not migrate outside of the state (Mojica 2006). Reported observations from a citizen-based online bird reporting database eBird (eBird 2014) shows that some of Bald Eagles

are present within Louisiana throughout the year, but the frequency of observations markedly declines during the summer months. Therefore, a large proportion of the population probably has similar migratory patterns as my radio-marked birds, whereas only a small proportion of Louisiana Bald Eagles may forgo migration.

The only age variation in migration parameters detected was for northbound departure date and arrival date, wherein sub-adults left their wintering areas and arrived at their summering areas earlier than did adults. Mojica et al. (2008) found that older sub-adults left earlier than fledglings in Florida. Thus, adults and fledglings apparently depart later than sub-adults. This may be due to nesting adults and fledglings being restricted by nests, brood rearing, and attaining first flight, whereas non-breeding adults and sub-adults are not be restricted by these activities. Accordingly, nesting eagles with nest failures prior to hatching might be expected to leave earlier, on average, than do eagles that are successful in hatching and raising young.

Migrant Bald Eagles from Louisiana generally used a similar migration corridor as did birds from eastern Texas, based on sightings of banded and color-marked nestlings (Mabie et al. 1994). However, Mabie et al. (1994) documented sightings in Arizona, Mexico, New York and South Carolina, whereas none of the Louisiana birds traveled to or through those areas. Bald Eagles from Arizona (Hunt et al. 2009) and California (Linthicum et al. 2007) generally used migration corridors that were farther west than those used by Louisiana Bald Eagles, typically staying along or west of the Rocky Mountains. Marked birds from Florida (Broley 1947, Mojica et al. 2008) tended to use corridors farther east, generally moving along or east of the Appalachian Mountains. Based on these data, migration corridors of southern Bald Eagles can be split into three basic groups: west of the Rocky Mountains, east of the Appalachian

Mountains, and a central group between the two Mountain ranges with some interchange between the groups.

Examination of individual migration routes shows that Louisiana Bald Eagles have a relatively high degree of route fidelity, especially among years, consistent with results of Mandernack et al. (2012) and Mojica et al. (2008). However, Mojica et al. (2008) also suggested route fidelity increases with age, whereas no age differences were documented in my study. Continued tracking of my radio-marked birds should provide a greater understanding of potential changes in route fidelity by individuals over time.

Migration routes of Louisiana Bald Eagles varied between their north and southbound migrations with northbound routes generally east of southbound routes. A similar loop-type pattern was observed in Bald Eagles traveling between California and Canada (Linthicum et al. 2007), but their northbound routes were west rather than east of southbound routes. Environmental and meteorological conditions may play a large role in loop migration observed for other raptor species (Meyburg et al. 2003, Kemp et al. 2010, Mellone et al. 2013). Weather and wind, in particular, have been suggested as having a large role in bird migration (Newton 2007, McIntyre et al. 2008, Lanzone et al. 2012). Further research into wind conditions, such as prevailing winds at a typical migrating altitude, may provide insight into the shifts in seasonal migration routes.

I observed several reverse migrations, e.g., long-distance movements in a direction other than a typical north or southbound migration. Reverse migrations occasionally occur when unsuitable nesting conditions are encountered upon arrival to a breeding area, wherein the bird retreats and then returns later when conditions are more favorable (Newton 2007). This may have occurred for adult female Bald Eagle 200 as she had successfully nested in 2012 but prior

to returning in 2013 the nest had been destroyed by Hurricane Isaac, as reported by the landowner (L. Ostheimer, personal communication). However, unfavorable breeding conditions were not likely a factor in other reverse migrations near winter home ranges as some of those birds were not of breeding age or never documented as nesting.

Reverse migrations that occurred near summering areas were only observed for those birds that crossed the Great Lakes rather than going around the western shore of Lake Superior. Thus, they may be related to either greater food availability near the shores of the Great Lakes or an aversion to crossing large bodies of water. Large water crossings pose great risk for raptors (Kerlinger 1989); thus, it may be advantageous to wait for favorable crossing conditions.

Other possible threats to migrating Bald Eagles include collisions at wind energy facilities as birds collide with the fast moving turbine blades (Barrios and Rodríguez 2004, Madders and Whitfield 2006, De Lucas et al. 2008, Pagel et al. 2013). The Midwest has one of the highest concentrations of wind energy facilities, with Iowa and Illinois being in the top five states with the most wind capacity installed (American Wind Energy Association 2014). Wind energy production is projected to increase substantially throughout the United States (U.S. Department of Energy 2008), which will also increase threats to migrating Bald Eagles traveling through these areas. Further monitoring of injuries and mortalities caused by wind turbines may provide better insight into the possible threat posed to Bald Eagles and potential management opportunities to reduce those threats.

Stopover sites are important areas for rest and re-fueling of depleted energy reserves on the long migrations made by Bald Eagles (Restani 2000, Mojica et al. 2008). These areas may be critical in the management of Louisiana Bald Eagles and migrating Bald Eagles in general, especially when considering the amount of time and energy expended outside of their breeding

habitats. However, stopover site use by Louisiana Bald Eagles differed from other populations that use concentrated prey sources, such as salmon runs. Louisiana birds did not have many stopover sites that overlapped between years or individuals, whereas eagles using salmon runs use the same sites repeatedly. Therefore, Louisiana eagles may be using more general prey sources or opportunistic feeding areas, and thus targeting specific areas for conservation of stopover use may not be as applicable as compared to other populations using repetitive concentrated sites. Thus, management priority may be more advantageous when focused on areas with good foraging habitat such as large bodies of water.

In summary, I documented departure and arrival dates, migration routes, distances traveled, stopover sites, seasonal and annual repeatability of these parameters, and locations where Louisiana Bald Eagles travel during summer months. My results elucidate challenges for managing a species that may spend almost half of the year outside of the state, traveling up to 3,500 km while using a variety of habitats across much of the United States and Canada. Accordingly, management of this species can not be focused solely at a local level. Although, there is still need for research, protection, and conservation of nest sites and home ranges within Louisiana, managers may also want to work in cooperation with other states, agencies, and Canada. Given the long-distance migration over a vast geographical area by this species, clearly there is a need for a landscape level approach to the management of migratory Bald Eagles from Louisiana and other regions.

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CHAPTER 5. WINTER AND SUMMER HOME RANGES OF LOUISIANA BALD EAGLES

5.1 INTRODUCTION

Understanding distributions of animals in space and time provides insight into relationships between animals and their environments. The concept of “home range” was first introduced by Burt (1943) as the “area traversed by an individual during normal activities of food gathering, mating, and caring for young.” Although this definition is conceptually sound, it is hard to quantitatively define. The size of an animal’s home range may be more tangibly redefined as the “extent of area with a defined probability of occurrence of an animal during a specified time period” (Kernohan et al. 2001). Areas of high use within home ranges can be expressed as “core areas” (Hodder et al. 1998). After establishing a quantifiable definition of home range and core area, there are still a variety of techniques that can be used to estimate their size (Worton 1987, Kie et al. 2010, Fischer et al. 2013).

Tracking technology has greatly improved over the years wherein Global Positioning System (GPS) satellite-tracking devices now provide large numbers of accurate locations over extended periods of time (Walter et al. 2011), which can create issues with spatial autocorrelation (Kie et al. 2010). Home range estimation techniques using minimum convex polygons, harmonic mean contours, and kernel density estimators were commonly used with locations acquired through visual observation, or by very high frequency (VHF) or satellite telemetry, but these methods generally provided few locations and therefore were assumed not to be autocorrelated (Kernohan et al. 2001, Kie et al. 2010, Cumming and Corn  lis 2012). Introduction of the Brownian bridge movement model (BBMM) improves on previous methods by incorporating temporal information to depict the probability of occurrence between locations

(Horne et al. 2007, Walter et al. 2011, Fischer et al. 2013). This depiction of an animal's home range, using its movement path rather than individual locations, should provide a better estimate of home range and core area size than methods previously used for Bald Eagles (*Haliaeetus leucocephalus*).

Estimates of home range size vary markedly for Bald Eagles depending upon season, age, and sampling technique. Studies of adults on their breeding areas have reported home ranges ranging from 2–47 km² using harmonic mean contours (Garrett et al. 1993, Watson 2002). Sub-adult home ranges typically are larger than those of adults, ranging from 102–593 km² using VHF telemetry (Grubb et al. 1989, McClelland et al. 1994) and even larger using satellite telemetry with a kernel density estimator (Mojica 2006). Tracking the same individuals over multiple years, allows for direct comparisons of home ranges, which should provide a clearer understanding into the relationship that age, year, and season may have on home range and core area size. Size of these areas may represent the amount of resources needed for that individual during these seasonal time periods, wherein variations may denote a change in resources needed or available based on seasons, age, or nesting status. Identifying the spatial needs of these individuals can assist managers in understanding the broader needs for the general population as a whole, specifically relating to resource and size requirements.

Accordingly, I deployed satellite GPS transmitters on Louisiana Bald Eagles and estimated their winter (breeding) and summer (non-breeding) home ranges using BBMM. My objectives were to estimate and compare wintering and summering home range size as well as document the seasonal and annual repeatability of home range use for sub-adults and adults.

5.2 STUDY AREA

I based capture efforts out of Mandalay National Wildlife Refuge (NWR) headquarters in Terrebonne parish, where nest density is higher than any other parish in the state. In winter 2007-2008, 82% of all active nests were located within an 80 km radius of the Mandalay NWR headquarters (Figure 5.1). Focusing capturing efforts in this area allowed me to efficiently and simultaneously maintain multiple bait/trapping sites within multiple nesting territories and maximize capture probability.

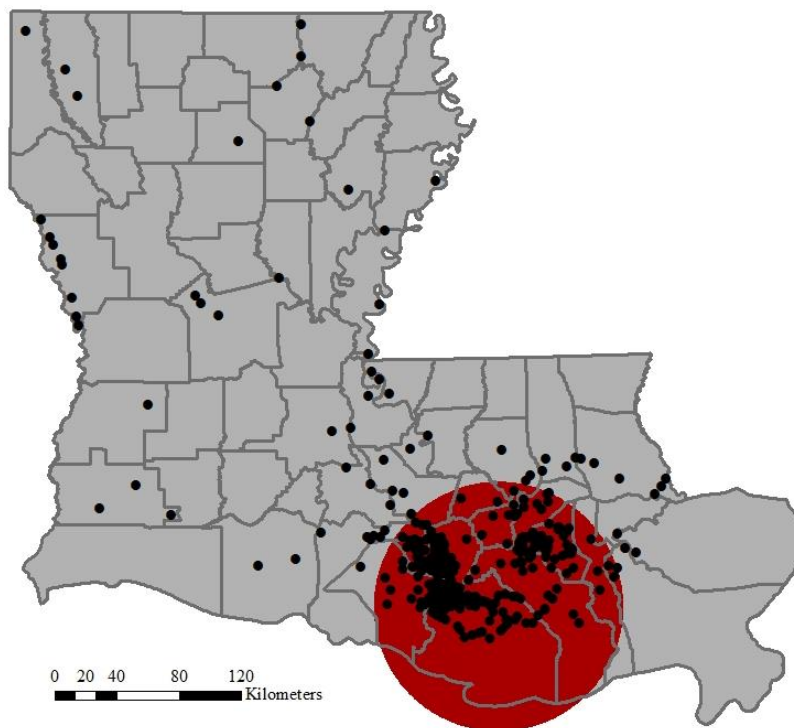


Figure 5.1. Eighty km radius trapping area (red polygon) centered on Mandalay NWR headquarters and winter 2007-2008 Bald Eagle nest locations (black dots).

5.3 METHODS

5.3.1 Trapping and Marking

I captured Bald Eagles using rocket nets baited with carrion during springs 2012 and 2013. The rocket-net system used was a modification of Grubb's portable rocket-net capture system (Grubb 1988, 1991). Rather than the net being deployed from a portable box, the 3-

rocket net (9.1 x 15.2 m) was folded like an accordion to approximately 0.3 x 9.1 m extending along the trailing edge and each rocket was elevated above the ground approximately 1 m using metal posts (see Appendix B). Trap sites were selected based on: (1) areas near previously known active nest sites as determined from 2007-2008 statewide aerial nest survey data collected by the Louisiana Department of Wildlife and Fisheries, (2) proximity to areas of known eagle activity as reported from local landowners and through visual observation, (3) accessibility for personnel and equipment, and (4) the safety of the birds and personnel. These sites were often located in large open areas with low vegetation and within 1 km of known eagle activity areas or nest sites. However, I never trapped directly adjacent to or within the line of sight of any Bald Eagles attending nests, in order to minimize disturbance.

After capture, birds were hooded and restrained from flapping to minimize stress (Louisiana State University (LSU) Agricultural Center Institutional Animal Care and Use Protocol #A2011-22 and Louisiana Department of Wildlife and Fisheries (LDWF) Federal Banding Permit #06669). Plumage, beak, and iris characteristics were used to categorize each bird as either adult (definitive plumage: white head, tail, and upper and lower tail coverts) or sub-adult (>1 years of age but lacking definitive plumage; McCollough 1989). A sample of blood (1–2 ml) was collected for sex determination (Zoogen DNA Services 2013).

I initially deployed transmitters on ten Bald Eagles, and one transmitter was redeployed following a mortality; thus, eleven total birds were fitted with ten 70-gram ARGOS/GPS solar-powered satellite telemetry platform terminal transmitters (PTTs; Microwave Telemetry Inc., Columbia, Maryland) and all birds received a U.S. Fish and Wildlife Service (USFWS) pop-rivet leg band. Each PTT was attached with a backpack style harness using Teflon ribbon (Bally Ribbon Mills, Bally, Pennsylvania; Buehler et al. 1995). Transmitters were programmed to

acquire a GPS location every hour and transmit data every other day with an expected battery life of 3–6 years. Capture data were recorded on field forms and each Bald Eagle was subsequently released at the capture site within 2 hours of capture.

5.3.2 Home Range

I estimated home ranges of Louisiana Bald Eagles on their wintering and summering areas using similar techniques. Home ranges were calculated using GPS location data acquired for eagles that stayed on their wintering or summering area, as previously defined, for >31 days. I used the software package BBMM in Program R (version 3.0.1) to calculate overall home range size using a 95% BBMM and a 50% BBMM to represent the core area of use (Horne et al. 2007). Locations were stratified into diurnal and nocturnal movements in order to account for differing movement patterns and provide a better estimate of BBMM variance. Sunrise and sunset times were calculated for each point given its geographical location and date. Horizontal spatial accuracy of GPS locations was assumed to be 18 m based on the manufacturer's technical specifications. Cell size was set to 90 m and was later resampled to 30 m in ArcGIS 10.0 (ESRI 2011) using a bilinear interpolation. Extents for each home range were the same size (300 x 300 km) and were centered over the locations by calculating the midpoint between the maximum and minimum northing and easting. This was done in order to allow comparison between BBMMs since the probability of an individual being within a given cell is calculated as a fraction of the probability of that individual being within the extent, which is set at one (Horne et al. 2007). Therefore, the size of the extent would affect home range size if it was not standardized across all individuals. A total of ten individuals were used in my analysis of home ranges.

Nesting status was classified as nesting or non-nesting. A Bald Eagle was presumed to be nesting if it used the same location (presumed nest) every day for at least 35 days as

determined by GPS locations. Presumed nest sites were later visually confirmed from the ground. This criteria was chosen to reflect the incubation period, since both sexes participate in incubation (Buehler 2000), but distinguish non-nesting birds that may use the same roost or perch site as these were not used consistently for multiple consecutive days.

I compared home range sizes of wintering and summering areas by sex, age group, and nesting status. Home range fidelity was examined for both winter and summering home ranges. Fidelity was quantified as the proportional overlap of an individual's 95% home range from year to year.

5.3.3 Statistical Analysis

I used repeated measures three-way analysis of variance (ANOVA, PROC GLIMMIX; SAS Institute Inc. 2011) to test whether home range size differed ($P < 0.05$) between age groups (sub-adult and adult), years, seasons (winter and summer), and their two and three-way interactions. Due to the lack of radio-marked sub-adult females, I used repeated measures three-way ANOVA (PROC GLIMMIX; SAS Institute Inc. 2011) to test whether home range size differed ($P < 0.05$) between sexes (adults only), years, seasons, and their two and three-way interactions. Individual birds were used as repeated measures and all explanatory variables were treated as fixed effects. I visually compared average winter and summer home range sizes of nesting and non-nesting individuals, but low sample size prevented further analysis by nesting status.

5.4 RESULTS

In 2012, all but one Bald Eagle established a summer home range in Canada. Adult male Bald Eagle 201 was the exception and flew to British Columbia, Canada but stayed only 5 days at its northernmost stopover site before starting its southbound migration. In 2013, adult female

Bald Eagle 200 stayed at a stopover site for 34 days but then she traveled approximately another 500 km north to the area where she established a home range the previous year. That area was again her northernmost stopover site but she only stayed there for 17 days. Therefore, both Bald Eagle 201 and 200's northernmost stopover site were not considered in the home range analysis for those years (Table 5.1). However, when marked birds did establish summer home ranges, they stayed for about two months ($\bar{x} = 63.4 \pm 6.2$, range = 32.8–120.8 days).

Winter and summer home range sizes varied from 19.7–1,997.7 and 8.8–909.8 km², respectively, and core area sizes varied from 0.6–142.6 and 1.0–55.8 km², respectively (Table 5.1). Home range size did not differ between male and female adults ($F_{1,6} = 1.46$, $P = 0.27$) when controlling for season (winter or summer home range), year, and their interactions. Home range size did not differ between adults and sub-adults ($F_{1,18} = 1.18$, $P = 0.29$) when controlling for season, year, and their interactions; however, there was a marginally significant difference between season ($F_{1,18} = 4.30$, $P = 0.05$) and the season x year interaction also was marginally significant ($F_{1,18} = 4.31$, $P = 0.05$).

Summer home ranges were smaller for adults and larger for sub-adults in 2013 compared to 2012 but overall summer home ranges were smaller than winter home ranges (Table 5.2). Home ranges were larger in the winter of 2012–2013 than the winter of 2011–2012 for all radio-marked individuals (Table 5.1), and nesting Bald Eagles had smaller winter home ranges, on average, than non-nesting birds (Table 5.2). Nesting adults spent most of their time at or near the nest site, whereas non-nesting birds moved between several different high-use areas (Figure 5.2).

Table 5.1. Individual winter and summer home ranges, core areas, and percent overlap of first year home ranges for radio-marked Louisiana Bald Eagles. A 95% and 50% Brownian bridge movement model were used to estimate home range and core area size in square kilometers.

Eagle ID, Sex ^a	Winter							Summer						
	2011-2012			2012-2013			Overlap	2012			2013			Overlap
	Nesting Status, Age ^b	Home Range	Core Area	Nesting Status, Age	Home Range	Core Area		Age ^b	Home Range	Core Area	Age	Home Range	Core Area	
200, F ^c	Nest, A	27.8	0.6	No, A	996.2	51.5	93%	A	97.3	12.5	A	-	-	-
201, M ^c	Nest, A	43.9	3.0	Nest, A	65.8	3.1	96%	A	-	-	A	160.5	11.2	-
202, F	No, S	911.1	52.8	No, S	929.4	72.3	55%	S	277.2	19.9	S	64.3	4.8	20%
203, F	No, S	1148.2	81.6	No, S	1997.7	142.6	29%	S	164.1	16.0	S	554.6	31.7	80%
204, F	No, S	777.6	53.2	No, S	869.9	60.9	36%	S	120.5	10.7	S	170.4	12.7	69%
205, M	No, A	62.7	8.8	No, A	76.5	8.9	82%	A	909.8	55.8	A	158.7	14.4	0%
206, F	No, S	256.3	16.4	No, S	938.2	68.9	44%	S	178.0	15.4	S	650.0	47.1	2%
207, F ^d	-	-	-	No, A	445.0	26.2	-	-	-	-	A	131.9	18.5	-
208, M ^e	No, A	19.7	2.5	-	-	-	-	A	60.8	5.0	-	-	-	-
209, M	No, A	294.6	42.7	No, A	859.2	92.8	57%	A	602.1	58.7	A	8.75	1.0	0%

^a F = female, M = male.

^b Nest = nesting, No = non-nesting, A = adult, S = sub-adult.

^c No summer home range established.

^d Transmitter not deployed until winter 2012-2013.

^e Died prior to establishing 2012-2013 winter home range.

Table 5.2. Mean size of winter and summer home ranges ($\bar{x} \pm \text{SE}$ in km^2) of radio-marked Louisiana Bald Eagles as calculated using 95% Brownian bridge movement models and displayed as $\bar{x} \pm \text{SE}$ in square kilometers.

Winter		<i>n</i>	2011-2012	<i>n</i>	2012-2013
Adults, Nesting		2	35.9 \pm 8.0	1	65.8 \pm 0.0
Adults, Non-Nesting		3	125.7 \pm 85.4	4	594.2 \pm 208.6
Adults		5	89.7 \pm 51.7	5	488.5 \pm 193.1
Sub-adults		4	773.3 \pm 188.6	4	1183.8 \pm 271.7
All		9	393.5 \pm 145.2	9	797.5 \pm 193.9
Summer			2012		2013
Adults, Nesting		1	97.3 \pm 0.0	1	160.5 \pm 0.0
Adults, Non-Nesting		3	524.2 \pm 248.1	3	99.8 \pm 46.2
Adults		4	417.5 \pm 205.4	4	115.0 \pm 36.0
Sub-adults		4	185.0 \pm 33.1	4	359.8 \pm 143.0
All		8	301.2 \pm 105.9	8	237.4 \pm 82.5

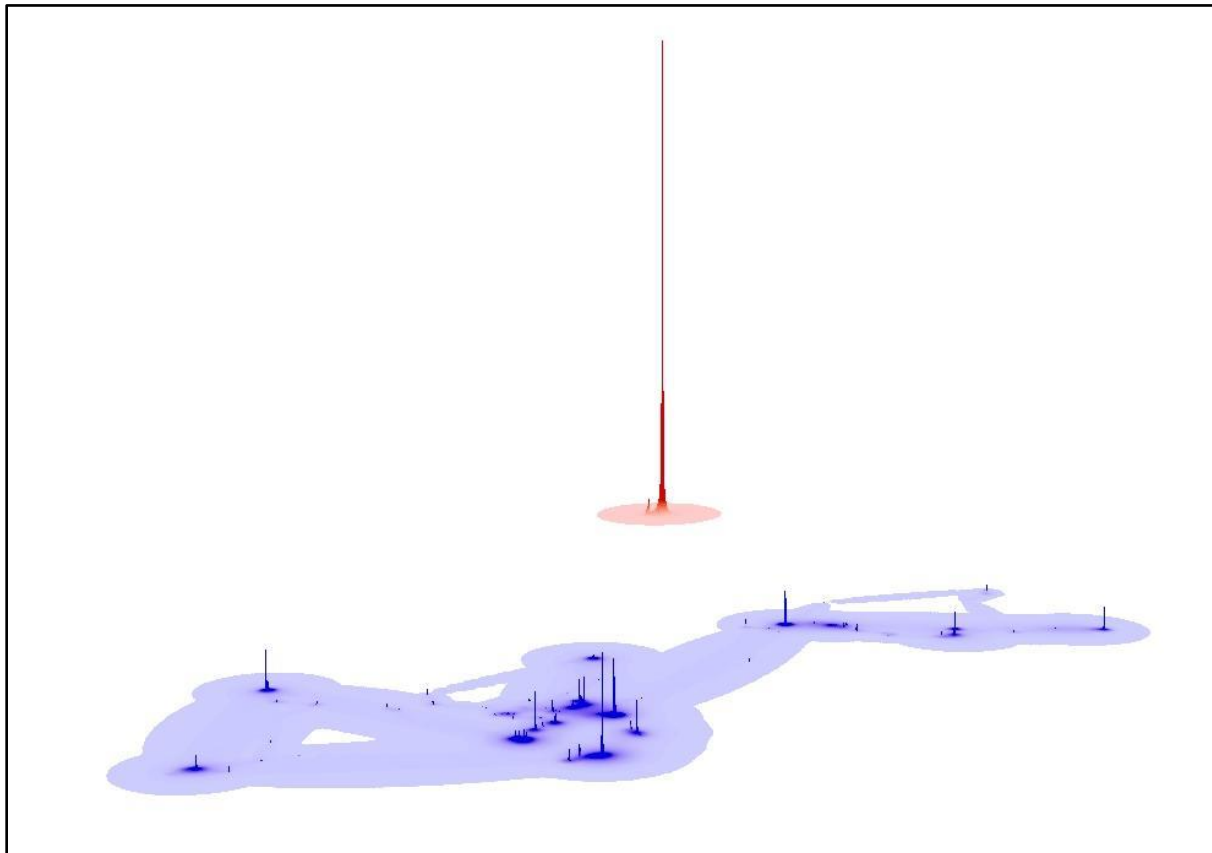


Figure 5.2. Utilization distribution of 2012 winter home ranges for a nesting adult Bald Eagle 200 (red) and a non-nesting sub-adult Bald Eagle 204 (blue) created using Brownian bridge movement models and depicted in 3D.

All radio-marked birds returned to Louisiana from their summering areas and revisited at least part of their first winter home range in the second year, using, on average, $61 \pm 9\%$ of their first years winter home range (see Appendix E; Table 5.1). Of the birds that established a summer home range, only sub-adults revisited at least part of their first summer home range, on average overlapping $43 \pm 13\%$ of the first years home range (Table 5.1). Adult Bald Eagle 205 established a home range in both years and returned to relatively the same area but had no overlap in summer home ranges, whereas adult Bald Eagle 209 established its summer home range about half as far north as the previous year (see Appendix D).

5.5 DISCUSSION

My estimated home range sizes were considerably smaller than those observed for sub-adults in Florida using satellite transmitters and a fixed kernel density estimator (Mojica 2006). Part of this difference may be due to the fact that the BBMM does not assume independence between points and rather uses time data to predict the area utilized between locations (Fischer et al. 2013). Therefore, the BBMM may provide a better representation of areas where a bird only traveled between high use areas, which was prevalent in non-breeding birds as depicted in their utilization distributions (Figure 5.2). Non-breeding birds generally moved between multiple high use areas that were distributed over a large area of their home range, whereas breeding adults generally had a singular central high use area. Conversely, my estimate of home range size for breeding adults was similar to those in Oregon and Washington (Garrett et al. 1993, Watson 2002) using harmonic mean contours. These results may be more similar due to a lack of long-distance travels between high use areas. Thus, various home range techniques may provide comparable results for nesting birds, whereas the BBMM should provide a better representation of home range size for non-nesting birds that make long-distance movements over

a short period of time (Walter et al. 2011, Fischer et al. 2013). Furthermore biological differences may also be occurring between studies, but the lack of comparability between techniques makes it difficult to decipher these differences.

Differences in home range size between sex or age groups may have been masked by my small sample of nesting adults because some non-nesting adults had home ranges that appeared to be more similar to sub-adults. For example, in winter 2011-2012 adult female 200 was confirmed nesting and had a home range size of 27.8 km, but in 2012-2013 she did not nest and had a home range size of 996.2 km. Thus, non-nesting birds probably are less restricted by nests and therefore explore and exploit food resources over a larger area.

Variation in times of capture within winter may have affected my estimates; potential biases that may have been incurred include: distinction of nesting status, number of locations acquired on the first years winter home range, or capture effect which has the potential to cause change in normal behavior in movement (Proulx 1999). The number of radio-marked birds that were nesting could have been underestimated in my analysis of home range because some nesting birds may have had failed nests prior to being marked and thus were not detected. Although visual confirmation was only conducted for those individuals that were presumed nesting, as determined from location data, no other individuals used the same location for multiple consecutive days; thus, I had to assume that the designated nesting status for each individual was accurate during the period they were tracked. However, future studies, where nesting status is presumed from location data, may want to consider visual confirmation for any bird that uses the same location for multiple consecutive days. If visual confirmation cannot logistically be obtained, the restriction of 35 consecutive days provides a conservative estimate

for designating nesting status for Bald Eagles through interpretation of satellite tracking locations.

Home ranges were smaller for all marked individuals during the first winter they were marked. Thus, capture date may have biased low the first winters home range size because locations were not recorded from the time birds first arrived on their 2011–2012 winter home range. Although these differences may reflect biological difference between years, the greater amount of time in which locations were collected in the second winter provided more locations, perhaps at the boundaries of an individual's home range, resulting in estimates of larger size (Boulanger and White 1990, Kernohan et al. 2001). Future research into variations in home range size within a season may also show that as a bird first establishes a winter or summer home range the size is larger and subsequently decreases as birds become more familiar with an area and food sources that are available.

Only one of the radio-marked Bald Eagles in my study did not return to the same general winter or summering area the following year. Other studies also reported that Bald Eagles have a high degree of fidelity to breeding areas and relatively high fidelity to non-breeding areas (Harmata and Stahlecker 1993, McClelland et al. 1994, Linthicum et al. 2007, Mandernack et al. 2012). Bald Eagles exhibit high nest site fidelity and nesting territories often are used year after year (Jenkins and Jackman 1993). I found that home range fidelity occurs for both summer and winter home ranges, as eagles travel to relatively the same locations each year (see Chapter 4). Fidelity of home ranges may be attributed to the familiarity of the bird to the area, mate acquisition, as well as predictable suitable habitat that can provide good foraging areas, nesting and roosting trees, and protection.

Bald Eagles 201 and 200 returned to their same northernmost summering areas but they did not stay there for >31 days and thus were excluded from my home range analysis for the second summer. Those birds may have been exhibiting nomadic behavior wherein they moved between foraging sites >100 km apart, as reported in other studies of Bald Eagles (Gerrard et al. 1978, McClelland et al. 1994, Laing et al. 2005, Mojica 2006); however, nomadic movements are difficult to distinguish objectively from stopovers and migrations. For that reason, I did not attempt to define nomadic movements, but continued monitoring of Louisiana Bald Eagle movements may warrant the re-evaluation of movements for birds that did not establish defined home ranges.

In summary, continued monitoring of my marked birds should provide more insight into the spatial requirements of Louisiana Bald Eagles and especially for nesting individuals. However, my baseline estimates of home range size reported here for adults and sub-adults on their winter and summering areas provide basic information on the size requirements of these areas. Although non-nesting individuals had large home ranges, they may not extensively use the entirety of these areas but only small core areas, which may indicate essential foraging areas. Future research into the habitats used within core areas may be useful in ensuring the needs and future spatial requirements of Bald Eagles in Louisiana.

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CHAPTER 6. MORPHOMETRIC SEX DETERMINATION OF BALD EAGLES FROM LOUISIANA

6.1 INTRODUCTION

Many raptors are monomorphic in plumage but sexually dimorphic in size with females being relatively larger than males (Andersson and Norberg 1981, Krüger 2005). Female Bald Eagles (*Haliaeetus leucocephalus*) can be about 25% larger than males (Buehler 2000). Accurate identification of sex is an important factor in the conservation, management, and understanding of a species ecology. For example, ignoring gender may bias estimates when examining variables such as home range size, migration, food preferences, and behavior (Andersson and Norberg 1981). The ability to distinguish sex on initial handling would greatly facilitate study designs which require sampling of equal ratios of males and females.

Several techniques are available to determine sex of birds. Molecular techniques use DNA to accurately determine the gender of a species (Au et al. 1975). However, these results often are obtained post-release and can be costly when a large number of birds must be sexed. Laparoscopy is invasive, time consuming, and requires skill and training (Garcelon et al. 1985). Bortolotti (1984b) developed a field method which used morphometrics to correctly classify 98.1% of the birds sampled from the northern United States and Canada; however, this method has not been tested on smaller southern Bald Eagles.

Bald Eagles indeed follow Bergmann's Rule (Bergmann 1847) with birds from colder northern climates being larger than those from warmer southern climates (Driscoll et al. 1999, Buehler 2000). Misclassified birds may require an updated morphometric formula to accurately sex southern Bald Eagles. Accordingly, I evaluated Bortolotti's (1984b) field method for sex

determination, and upon documenting numerous misclassifications, I used discriminant analysis to develop a new formula applicable to Louisiana and other southern Bald Eagles.

6.2 METHODS

I captured Bald Eagles using rocket nets baited with carrion during springs 2012 and 2013 (Chapter 4). All individuals were caught within an 80 km radius of Mandalay National Wildlife Refuge headquarters in Houma, Louisiana. This area is the centroid of Bald Eagle nesting in Louisiana, comprising 82% of known active nests in the winter of 2007-2008.

In addition to wild captured Bald Eagles, I sampled individuals admitted for rehabilitation to Louisiana State University (LSU) Wildlife Hospital. I also sampled birds that were found dead or had been euthanized and were subsequently frozen until data collection. I excluded birds that were found outside of Louisiana, hatch year birds, or if a blood sample could not be collected due to decomposition.

Beak depth (± 0.1 mm) and hallux claw length (± 0.1 mm) were recorded for all Bald Eagles. Beak depth was measured from the leading edge of the cere to the adjacent ventral portion of the mandible; hallux length was the chord length from the dorsal leading edge of the digital pad to the tip of the hallux talon (Bortolotti 1984b). Plumage, beak, and iris characteristics were used to categorize each bird as either adult (definitive plumage: white head, tail, and upper and lower tail coverts) or sub-adult (>1 years of age but lacking definitive plumage; McCollough 1989). Blood samples were used for DNA sexing in order to verify sex with a reported accuracy of 99.9% (Zoogen DNA Services 2013) and to determine whether or not birds were correctly classified using Bortolotti's (1984b) field method.

6.2.1 Statistical Analysis

I used a multivariate analysis of variance (MANOVA, PROC GLM; SAS Institute Inc. 2011) to determine whether beak depth and hallux length measurements differed by sex (male or female) and therefore would be suitable for use in a discriminant analysis. I also tested whether my morphometric data could be pooled across age groups (adults and sub-adults), and data collection types (wild caught, rehabilitated, and frozen birds). For example, freezing possibly could cause shrinkage in various measurements. Beak depth and hallux length were multivariate response variables and sex, age group, collection method, and their two and three-way interactions were explanatory variables in the analysis. Significance ($P < 0.05$) was determined using Wilks' lambda (Manly 2004). Finally, I used a linear discriminant analysis (PROC DISCRIM; SAS Institute Inc. 2011) to develop a model to determine sex of Louisiana Bald Eagles similar to that reported by Bortolotti (1984b). Beak depth and hallux length were input variables and sex was the response variable. Cross-validation (i.e., leave-one-out) was used to determine the classification error rate of the linear discriminant analysis (Arlot and Celisse 2010).

6.3 RESULTS

I collected blood samples and morphometric measurements from 28 Bald Eagles from Louisiana (16 wild caught, 6 rehabilitated, and 6 frozen; see Appendix F). Evaluation of Bortolotti's (1984b) formula for field sexing Bald Eagles revealed that 6 females, including 2 adults, were misclassified as males for an overall correct classification rate of 78.6% (Figure 6.1). As expected, Bald Eagles from Bortolotti's (1984b) study were larger, on average, than birds from Louisiana (Table 6.1).

MANOVA indicated that average beak depth and hallux length of Louisiana Bald Eagles were smaller for males than females (Wilks' Lambda = 0.21, $F_{2,17} = 31.35$, $P < 0.001$; Table 6.1). Age, collection method, and all interactions were not significant (P 's > 0.10); therefore, I pooled age groups and collection methods in the subsequent discriminant analysis.

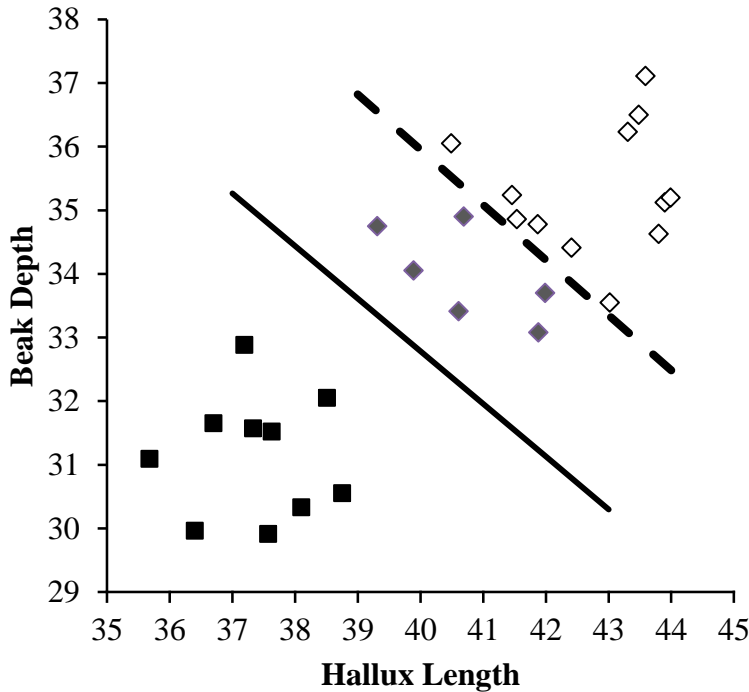


Figure 6.1. Sexual size variation between males (black squares) and females (diamonds) in relation to beak depth (mm) and hallux length (mm). Shaded diamonds represent females that were misclassified as males using the Bortolotti (1984b) method. The lines illustrate the discrimination boundaries which separate males from females using the Bortolotti (1984b) formula (dashed) and my formula based on Louisiana Bald Eagles (solid).

Table 6.1. Comparison of sex and age class variation in beak depth and hallux claw length. All measurements are in mm.

		Males				Females			
		<i>N</i>	\bar{x}	SD	Range	<i>N</i>	\bar{x}	SD	Range
Beak Depth	Louisiana ^a	10	31.15	0.964	29.91 – 32.88	18	34.87	1.102	33.08 – 37.11
	Bortolotti ^b	63	32.2	-	29.6 – 34.6	45	36.0	-	32.6 – 42.1
Hallux Length	Louisiana	10	37.38	0.950	35.68 – 38.75	18	42.07	1.466	39.31 – 43.99
	Bortolotti	77	39.6	-	23.7 – 43.0	55	44.6	-	41.2 – 48.9

^a Measurements of Bald Eagles from Louisiana.

^b Bortolotti's (1984b) measurements of Bald Eagles from the northern United States and Canada.

Discriminant analysis using beak depth and hallux length from Louisiana Bald Eagles accounted for 83% of the variability between the sexes. The generated decision boundary of the final model can be described by the formula $D_{\text{sex}} = (2.18 * X_{\text{hallux length}}) + (2.63 * Y_{\text{beak depth}}) - 173.54$, where $D < 0$ indicated male and $D > 0$ indicated female (Figure 6.1). Validation of the model using the leave-one-out cross-validation procedure returned an overall 100% correct classification rate.

6.4 DISCUSSION

Bortolotti's (1984b) formula for sex determination was inaccurate for the relatively smaller Louisiana Bald Eagles. Hallux length and beak depth of Louisiana Bald Eagles were, on average, smaller than those recorded in Bortolotti's (1984b) study, given northern birds are larger (Garcelon et al. 1985, Palmer et al. 1988, Driscoll et al. 1999), but were similar respectively, to those recorded in Arizona (Driscoll et al. 1999). These results are consistent with clinal variation in Bald Eagles, i.e., birds from northern regions being larger than those from southern regions (Bergmann 1847, Driscoll et al. 1999, Buehler 2000). Given this clinal variation, Bortolotti's (1984b) method misclassifies many females from Louisiana, but correctly classifies males. However, the general premise of hallux length and beak depth as useful criteria for sex determination of Bald Eagles, as first presented by Bortolotti (1984b), is still applicable to Louisiana Bald Eagles after recalibration of his formula.

Using my formula, beak depth and hallux length provided 100% correct classification of male and female Bald Eagles in Louisiana, and given similar mean size as Arizona Bald Eagles, should be applicable to other southern Bald Eagles. Louisiana sub-adults and adults were similar when controlling for sex but a p-value of 0.10 was suggestive of some age variation. Sample size limited my ability to evaluate variations for individual year classes but future evaluation

with larger sample size may reveal that males and females are more similar at early ages.

However, measurements of bony structures change less with age than other measurements such as wing chord, tail length, and weight (Bortolotti 1984a, Buehler 2000).

Potential bias from birds of unknown origins is a concern because Bald Eagles are highly migratory. Bald Eagles from Louisiana have been documented migrating north to Canada during the summer (see Chapter 4), and birds from Saskatchewan have migrated south during the winter to areas of Texas and Missouri (Gerrard et al. 1978, Griffin et al. 1980). The overlap of populations during migration and while on wintering or summering areas may exacerbate misclassifications if origin is not known.

Origins of birds in my sample were not known; however, of the 16 wild caught Bald Eagles, 11 were fitted with radio transmitters during my study (see Chapter 4) and remained in Louisiana during the winter breeding season, migrated north during the summer non-breeding season, and then returned to Louisiana the following winter. Thus, I believe it is a reasonable assumption that birds in my analysis were part of the southern population. Overall, my formula should be more accurate for determining the sex of southern Bald Eagles; however, further research is needed to verify whether the formula is generalizable over all southern populations.

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CHAPTER 7. CONCLUSIONS

I analyzed data collected from statewide aerial nest surveys, conducted from 1975–2008, to quantify the recovery of the nesting population of Bald Eagles in Louisiana (Chapter 2). Active nests increased exponentially from 7 to 387 during this period, exhibiting a mean annual rate of increase of $11.1 \pm 0.3\%$ per year with no indications of slowing. Productivity and nest success increased only slightly and there was no significant time trend in brood size. By 1990, the nesting population in Louisiana had exceeded all the goals of the Southeastern States Bald Eagle Recovery Plan, and in 2007 the species was removed from the federal list of endangered and threatened wildlife.

I analyzed nest location and status data collected from the most recent year of the statewide aerial nest survey program (2007–2008) to describe nesting habitats used by Louisiana Bald Eagles and to examine landscape level nest site selection and success (Chapter 3). I found that nests were located in areas mainly comprised of woody and emergent herbaceous wetland cover types, 2.2 km, on average, from the nearest road, and within 500 m of a substantial body of open water. Nest success was not greatly influenced by the physical characteristics around a site, but nest site selection was most influenced by distance to the historical nest centroid and the proportion of open water, forest, agricultural, and emergent herbaceous wetland land cover within 3 km around a site. Based on my results, managers should be able to focus efforts on the protection of current and future suitable nesting habitat, prioritizing areas with the highest probability of nesting.

Using satellite GPS transmitters, I provided evidence of previously undocumented migration of Louisiana Bald Eagles and quantitatively estimated migration parameters, including, timing of departure and arrival, migration routes, stopover sites, and seasonal and

annual repeatability of these parameters (Chapter 4). Sub-adults departed Louisiana and arrived at their summering areas significantly earlier than did adults. All radio-marked individuals from my study migrated north for the summer, returning to wintering areas in Louisiana; however, a small proportion of Bald Eagles may not migrate. Individuals that migrated spent about two months on their migration, flying relatively direct routes between Louisiana and their summering areas, displaying strong route fidelity and spreading out from British Columbia to Ontario, and north as far as the Northwest Territories of Canada. Accordingly, my results elucidate challenges presented for managing a species that may spend approximately a third of the year outside of the state and travels up to 3,500 km while using a variety of habitats across much of the United States and Canada. Given the observed long-distance migration over a vast geographical area, clearly there is a need for a landscape level approach to the management of migratory Bald Eagles from Louisiana and other regions.

I estimated home range and core area sizes for Louisiana Bald Eagles during winter and summer, using Brownian bridge movement models (Chapter 5). Home ranges varied from 19.7–1,997.7 km² but were larger, on average, in the winter of 2012–2013 than in the winter of 2011–2012 for all radio-marked individuals, and nesting Bald Eagles had smaller winter home ranges than did non-nesting birds. All radio-marked birds captured in Louisiana returned to Louisiana and revisited at least part of their first winter home range in the second year, showing high site fidelity. Continued monitoring of radio-marked birds should provide more insight into the spatial requirements of Louisiana Bald Eagles, especially for nesting individuals. However, my baseline estimates of home range size for adults and sub-adults on their winter and summering areas provide new information on the size requirements of these areas and may help to identify areas an individual requires to fulfill its needs.

Evaluating the standard morphometric technique for determining the sex of Bald Eagles length revealed misclassifications for Louisiana Bald Eagles (Chapter 6). Bald Eagles from Louisiana were relatively smaller than the northern Bald Eagles, upon which the technique was developed. My formula should be more applicable for determining the sex of southern Bald Eagles; however, further research is needed to determine if the formula is generalizable over all southern populations.

The continued stability and growth of the nesting population may depend on the ability of Bald Eagle's to cope with human activity, as well as the protection and availability of current and future nesting habitats. Human disturbance, habitat degradation and the ability of the Bald Eagle to adapt to a changing environment may be the driving force behind a healthy and expanding population in Louisiana. Local management efforts may want to focus on maintaining the nest list frame for Louisiana and conservation of known home ranges and nest sites, especially near the historical nest centroid. Factors to consider outside Louisiana, such as the conservation of specific areas for stopover use may not be as applicable for Louisiana Bald Eagles as compared to other migrant populations that use specific sites year after year. Thus, priority may be more advantageous when focused on areas with good foraging habitat such as large bodies of water like reservoirs, lakes, rivers, and ponds. My results also suggest that, due to long-distance migration over a vast geographical area by this species, there is a need for a landscape level approach to the management of migratory Bald Eagles from Louisiana and other regions. Therefore continentally, efforts concentrated on preservation of important migration use areas and future research into the habitats used at stopover sites and summering areas would be beneficial. My results ultimately should help wildlife managers identify potential risks and

threats to Bald Eagles, both within and outside of Louisiana, and provide perspective into the future management and research needs of the species.

APPENDIX A. NATIONAL LAND COVER DATABASE CLASSIFICATION DESCRIPTIONS

Open Water

Areas of open water, generally with less than 25% cover of vegetation or soil.

Woody Wetlands

Areas where forest or shrub land vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Emergent Herbaceous Wetlands

Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Developed

Barren Land (Rock/Sand/Clay) - Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Developed, Open Space - Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

Developed, Low Intensity - Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49% of total cover. These areas most commonly include single-family housing units.

Developed, Medium Intensity - Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79% of the total cover. These areas most commonly include single-family housing units.

Developed, High Intensity - Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100% of the total cover.

Agricultural

Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle.

Pasture/hay vegetation accounts for greater than 20% of total vegetation.

Grassland/Herbaceous - Areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Forest

Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.

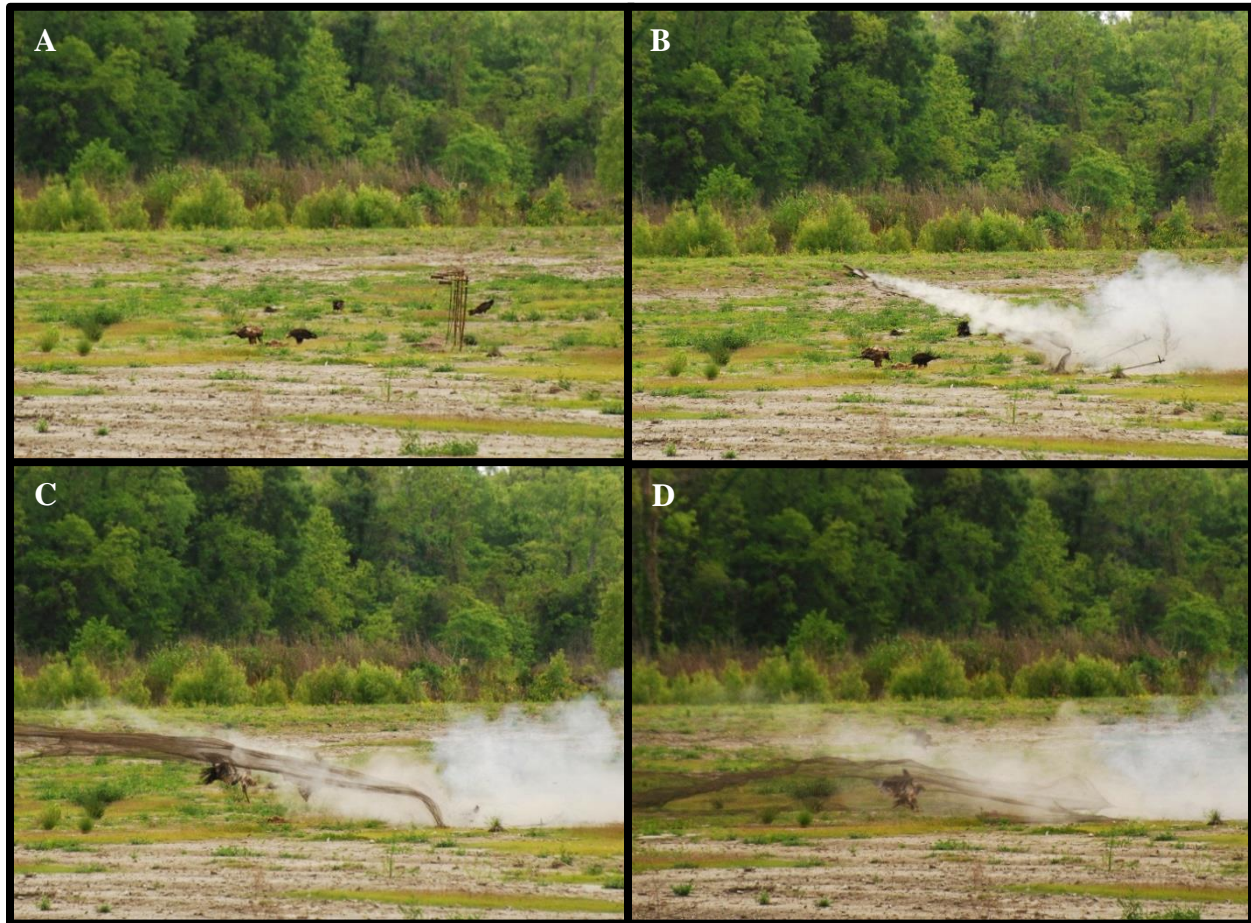
Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.

Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

APPENDIX B. PHOTOS OF ROCKET-NET SYSTEM



Example rocket net setup.



Time-series photos of rocket net being deployed and successfully capturing two Bald Eagles.

APPENDIX C. MIGRATION PARAMETERS

Summary of individual departure and arrival dates, duration, distance traveled, and number of stopover sites used for north and southbound migrations of Louisiana Bald Eagles tracked by satellite in 2012 and 2013.

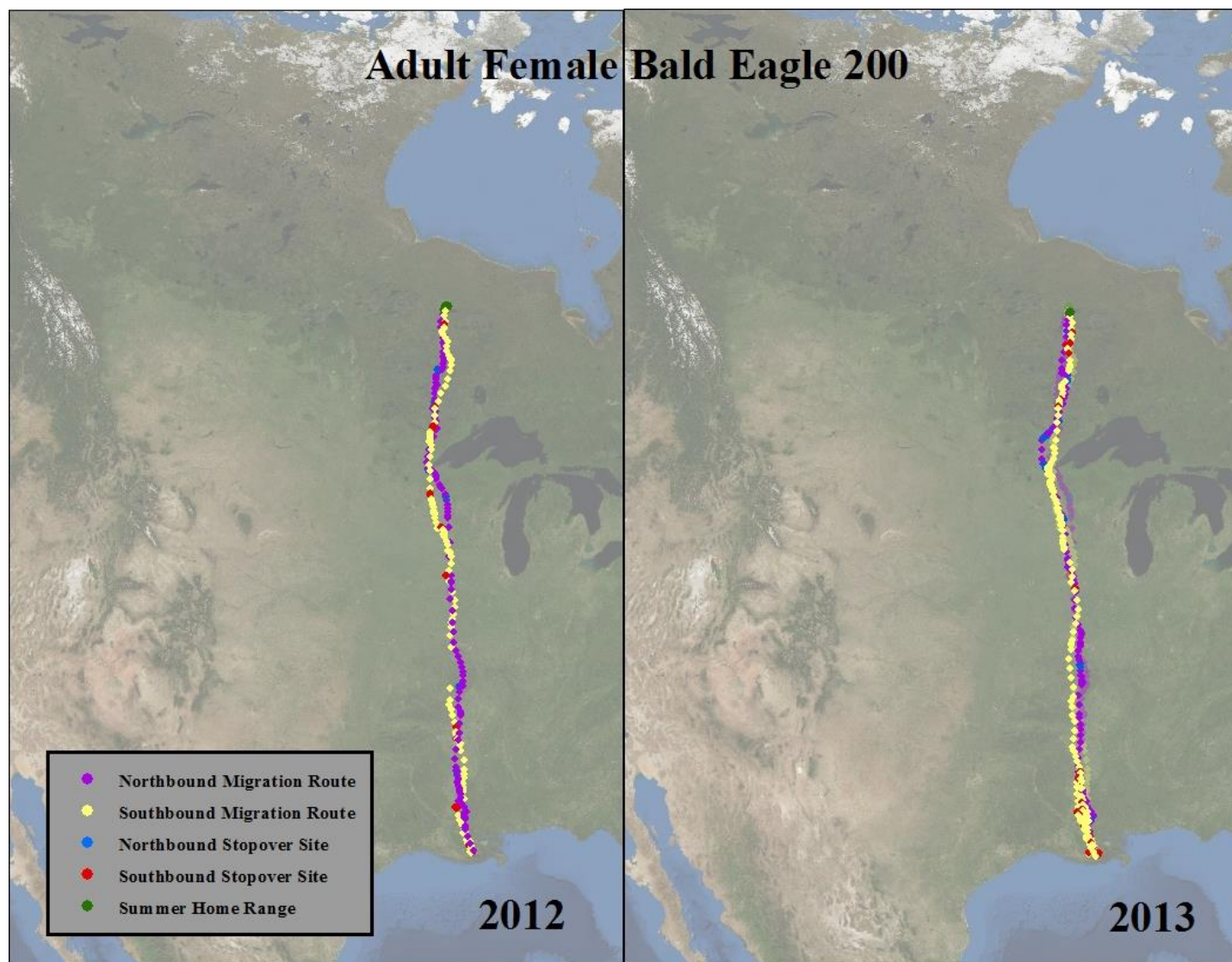
Eagle ID, Age-Sex ^a	Year	Route ^b	Departure Date	Arrival Date	Duration	Distance ^c	Stopover Sites
200, A-F	2012	N	5/10	7/9	60	2702	8
200, A-F	2012	S	8/14	10/28	75	2648	11
200, A-F	2013	N	4/27	7/17	81	2670	10
200, A-F	2013	S	8/3	11/7	96	2663	18
201, A-M	2012	N	6/30	8/29	59	3573	11
201, A-M	2012	S	9/2	10/29	56	3556	9
201, A-M	2013	N	6/11	8/27	76	3230	12
201, A-M	2013	S	9/28	10/22	24	3225	5
202, S-F	2012	N	3/14	7/3	110	2245	9
202, S-F	2012	S	8/28	11/1	65	2224	9
202, S-F	2013	N	5/5	6/8	34	2262	5
202, S-F	2013	S	8/12	10/20	69	2263	11
203, S-F	2012	N	3/26	6/18	84	3206	13
203, S-F	2012	S	8/2	10/10	69	3257	12
203, S-F	2013	N	4/15	6/11	57	3294	10
203, S-F	2013	S	8/2	10/19	78	3196	13
204, S-F	2012	N	3/29	5/20	52	2275	10
204, S-F	2012	S	8/9	10/28	80	2250	13
204, S-F	2013	N	4/23	6/05	43	2167	5
204, S-F	2013	S	8/4	11/12	100	2294	19
205, A-M	2012	N	5/3	7/10	68	2368	8
205, A-M	2012	S	9/4	9/28	24	2410	3
205, A-M	2013	N	4/20	7/22	93	2468	13
205, A-M	2013	S	9/20	11/8	48	2450	4
206, S-F	2012	N	4/13	5/27	44	2879	9
206, S-F	2012	S	9/25	11/3	39	2799	9
206, S-F	2013	N	4/22	6/5	44	2763	7
206, S-F	2013	S	9/11	11/2	52	2764	12
207, A-F	2013	N	5/18	7/3	45	3152	10
207, A-F	2013	S	9/26	11/05	39	3144	9
208, A-M	2012	N	5/1	6/2	31	3769	6
209, A-M	2012	N	6/20	8/8	49	1955	6
209, A-M	2012	S	9/18	10/15	27	1925	3
209, A-M	2013	N	6/16	7/9	23	998	7
209, A-M	2013	S	9/10	10/25	44	986	6

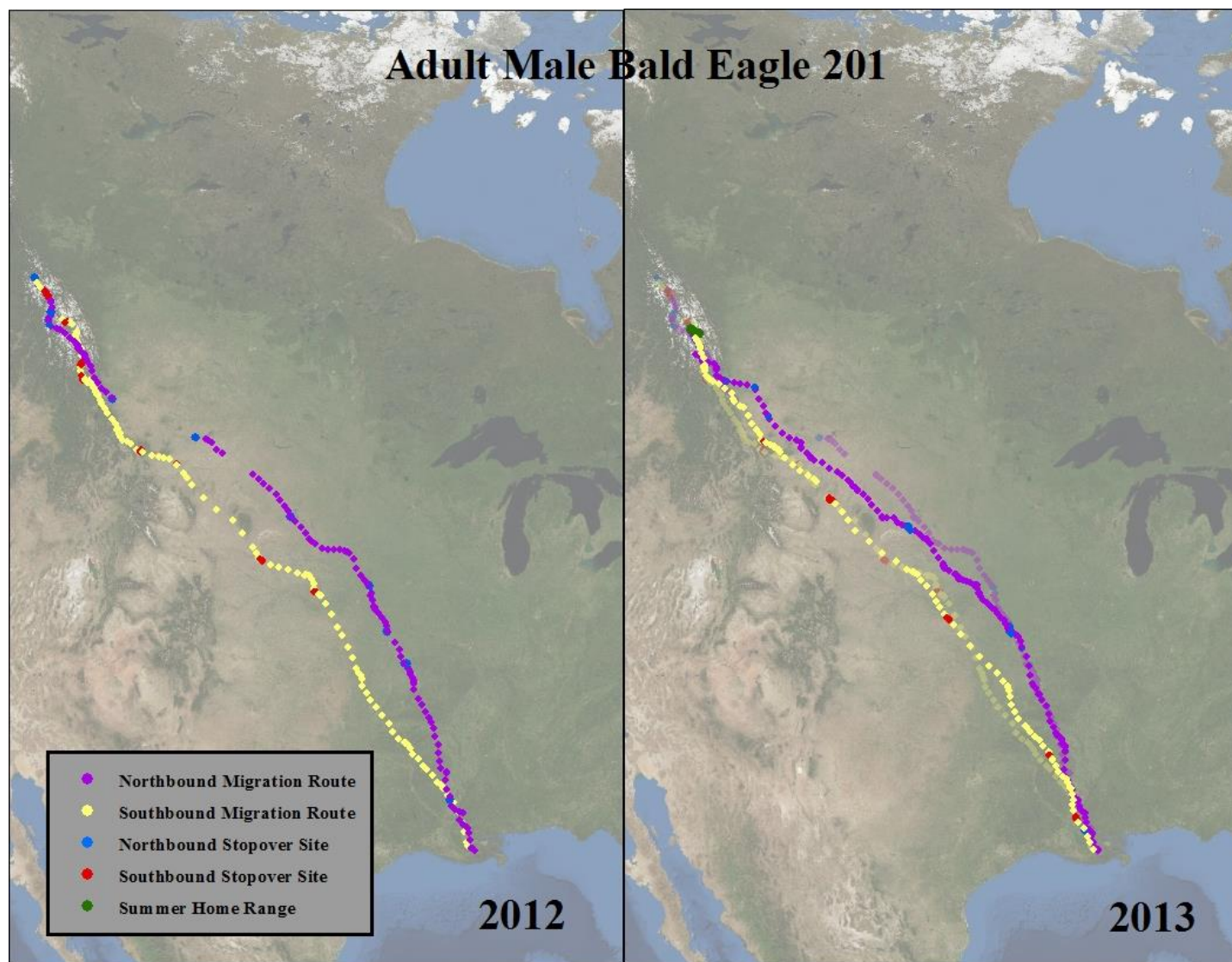
^a A = adult, S = sub-adult, F = female, M = male.

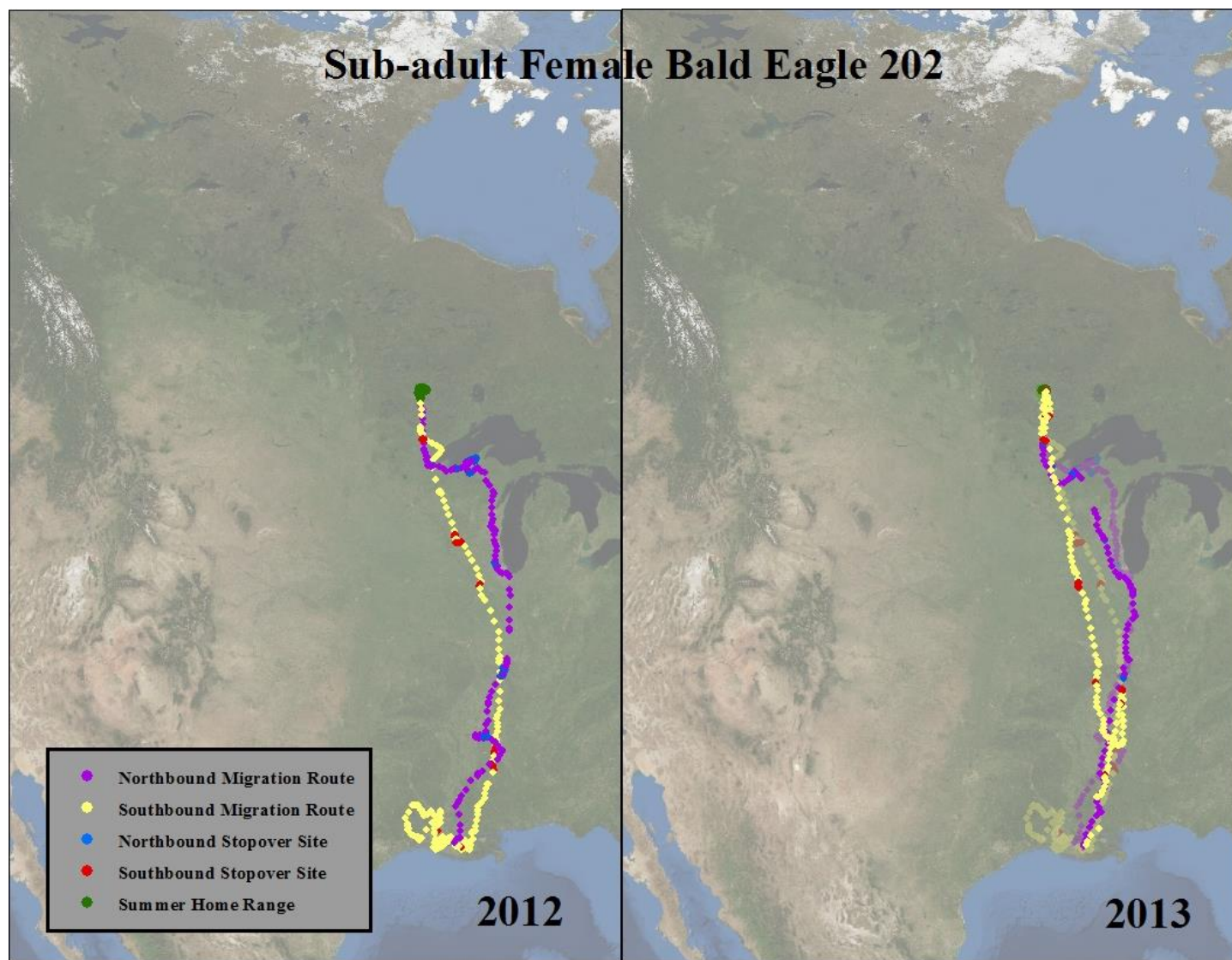
^b N = northbound, S = southbound.

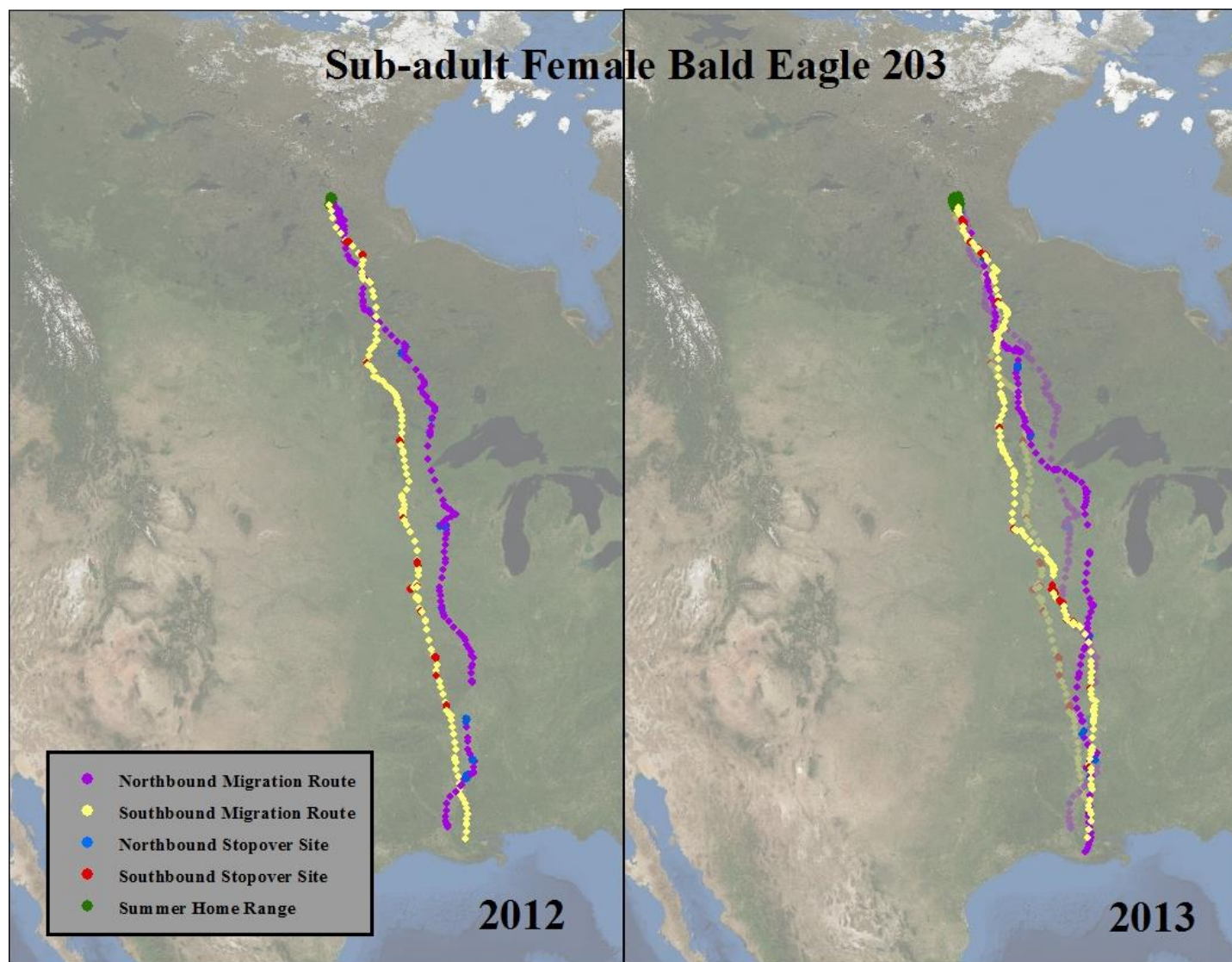
^c Euclidean distance (km) between initial departure location and final arrival location.

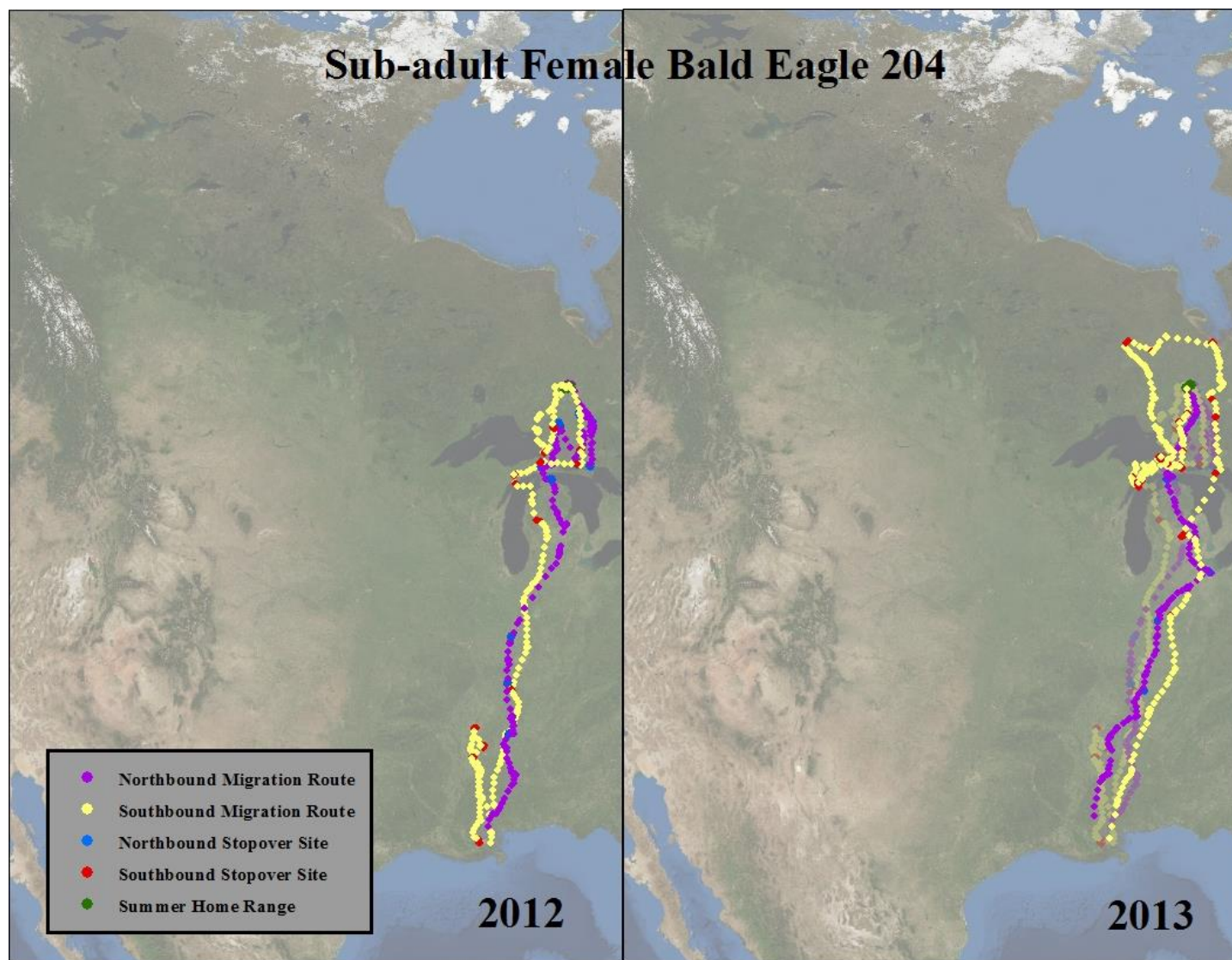
APPENDIX D. MIGRATION MAPS

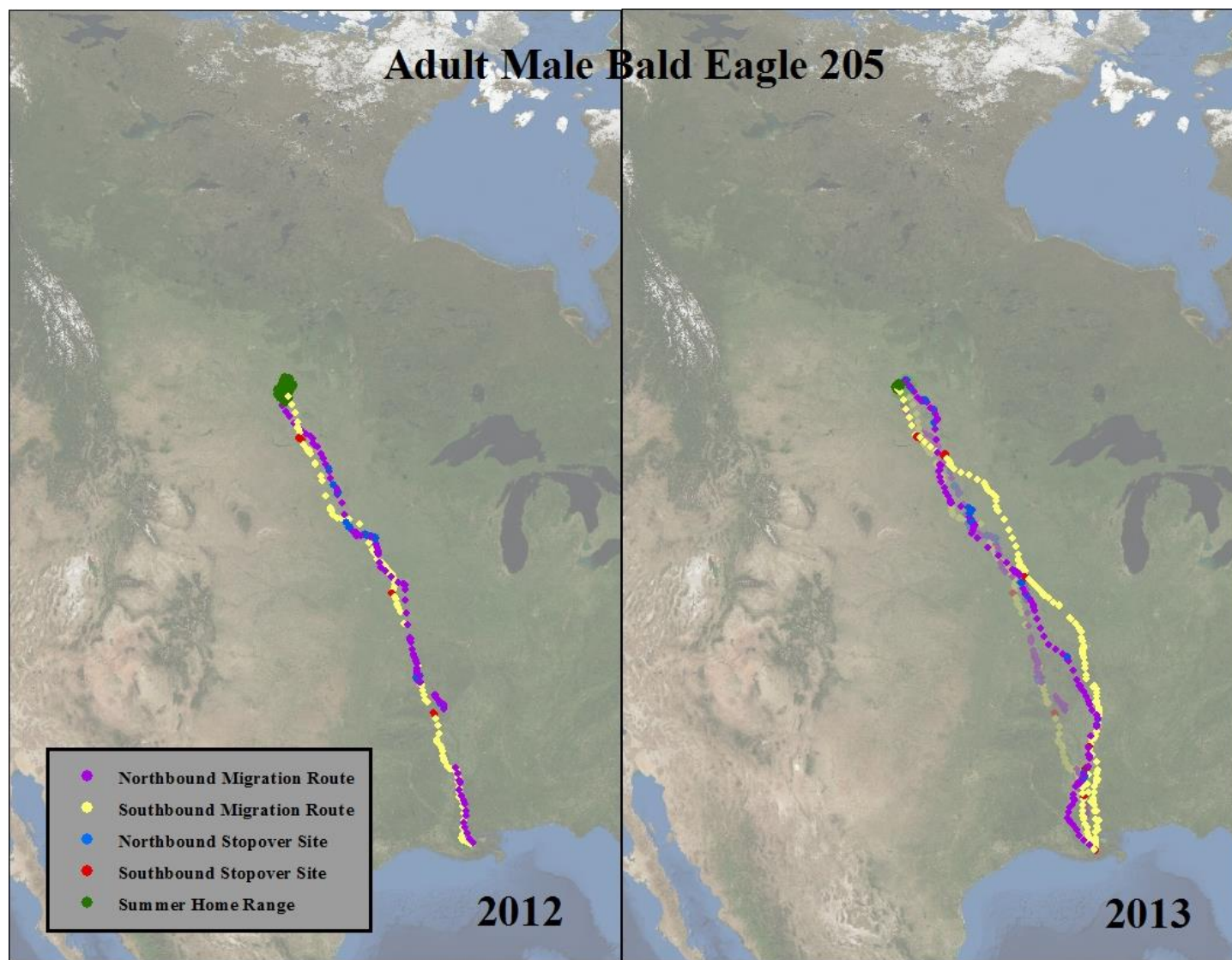


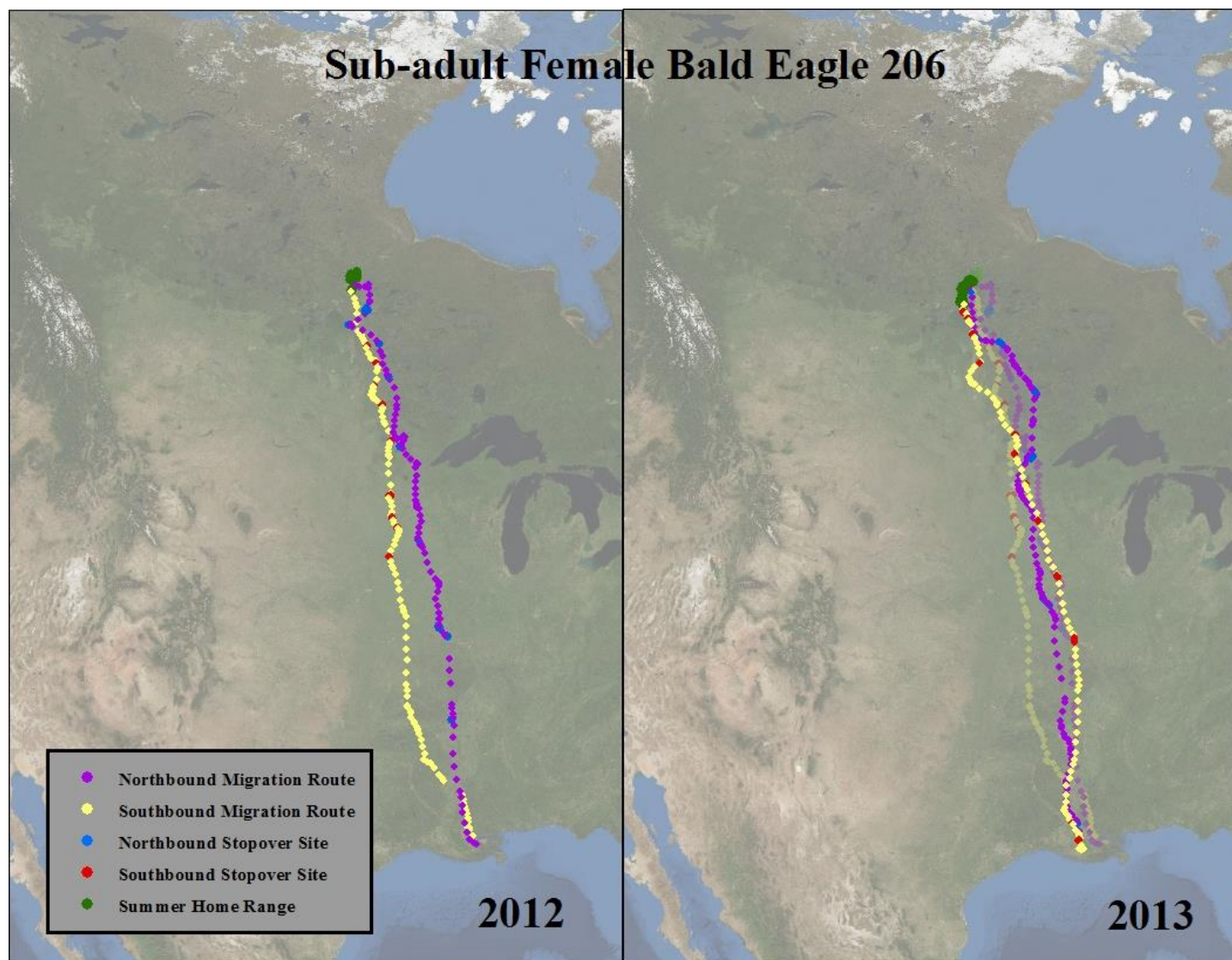


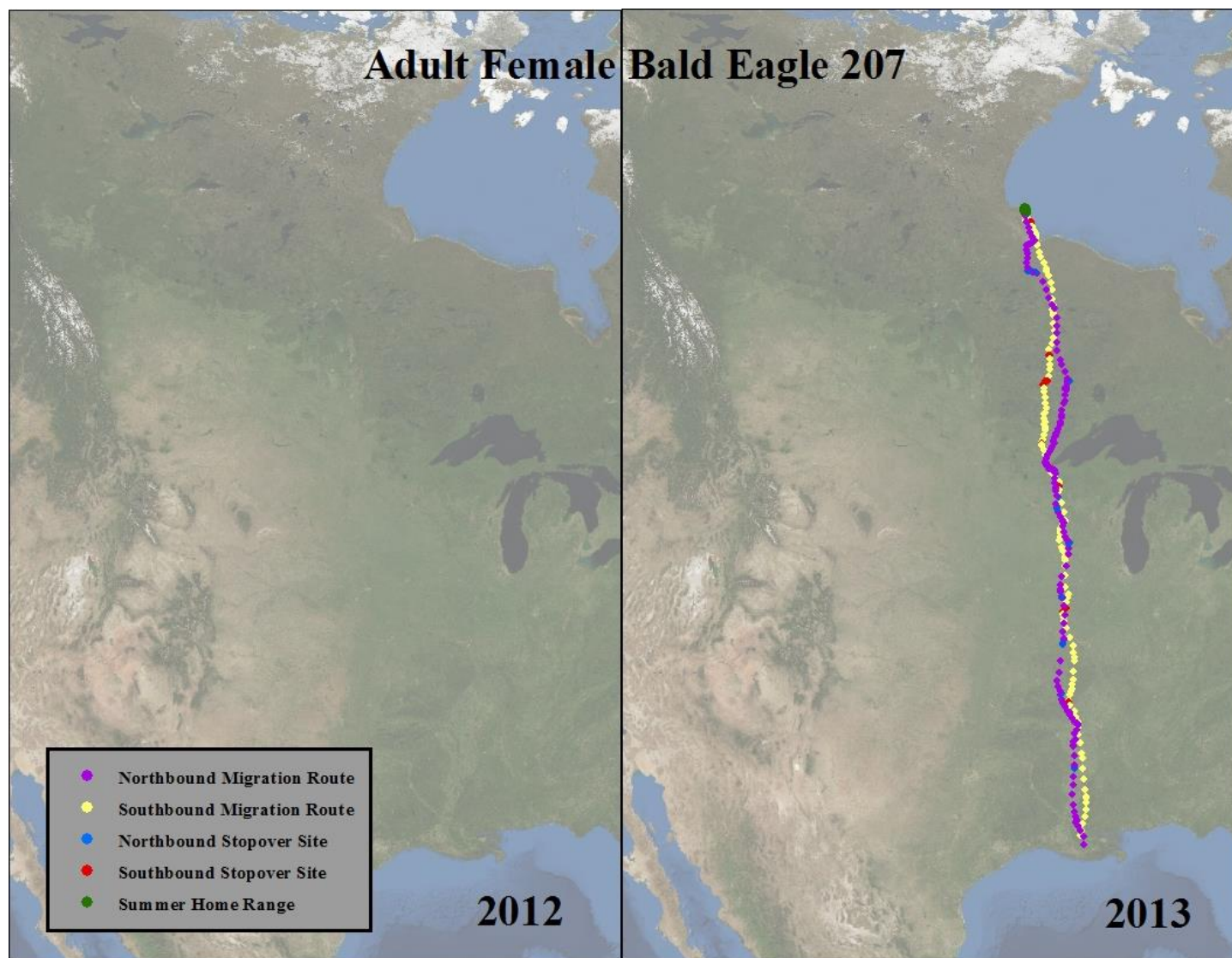


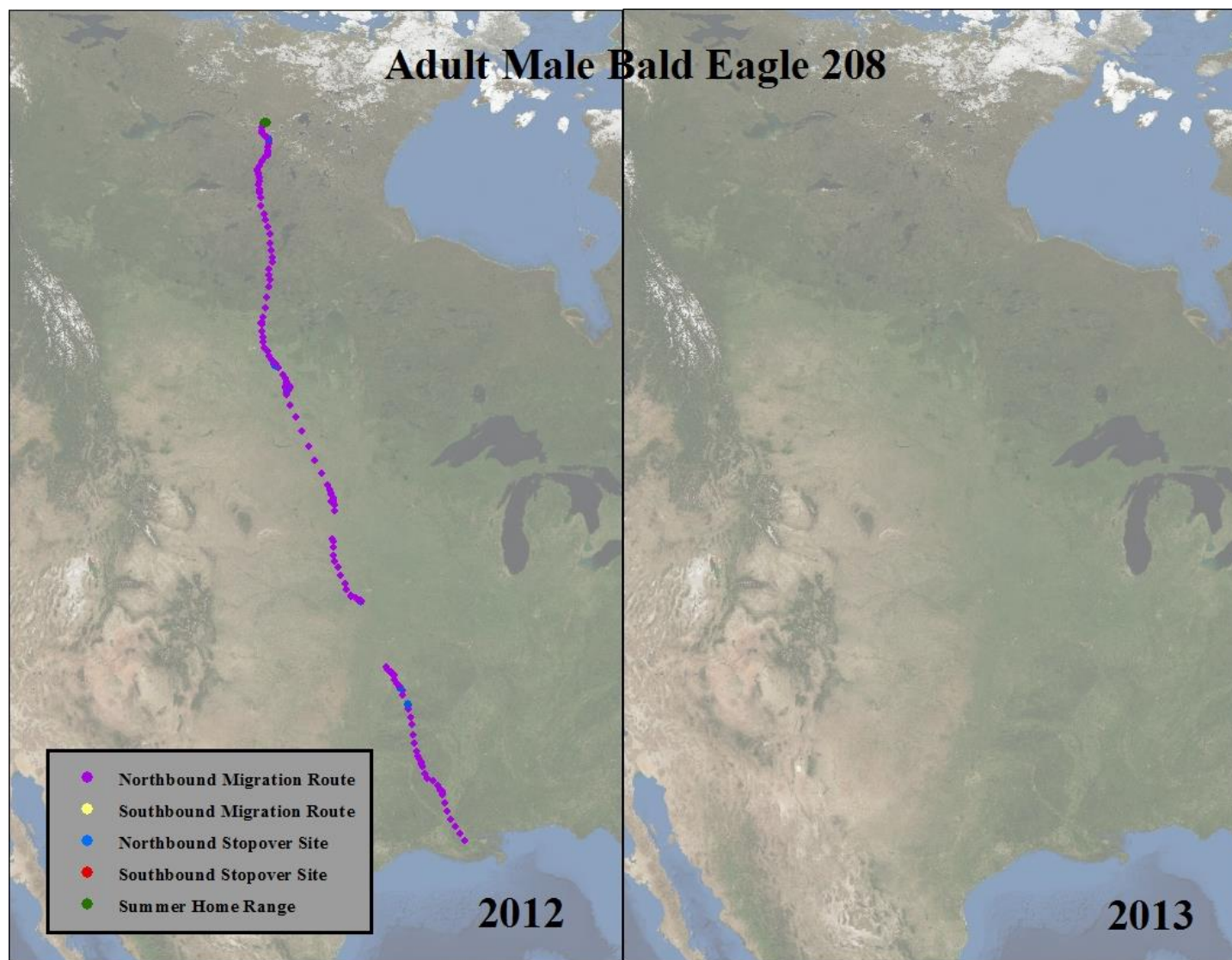


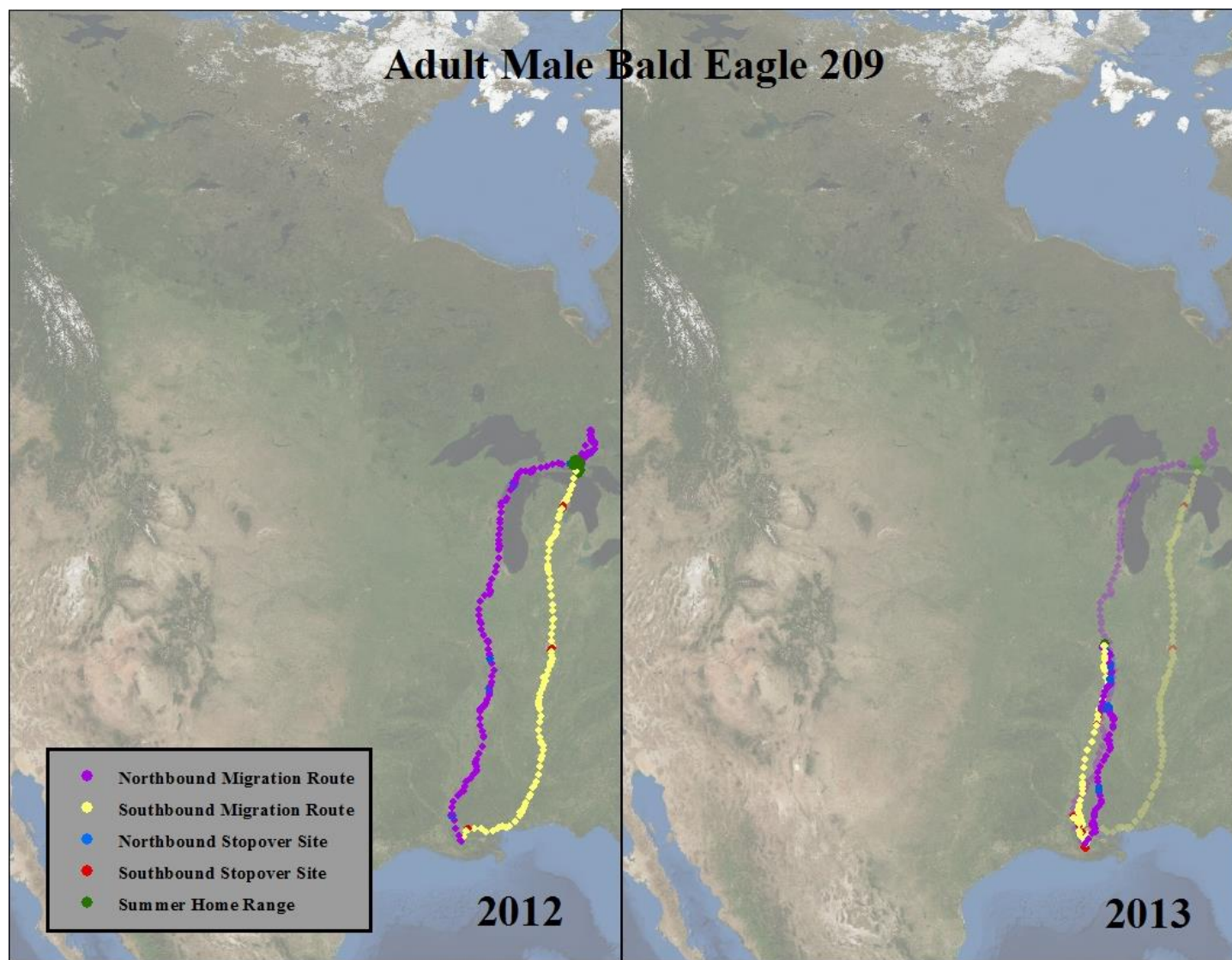




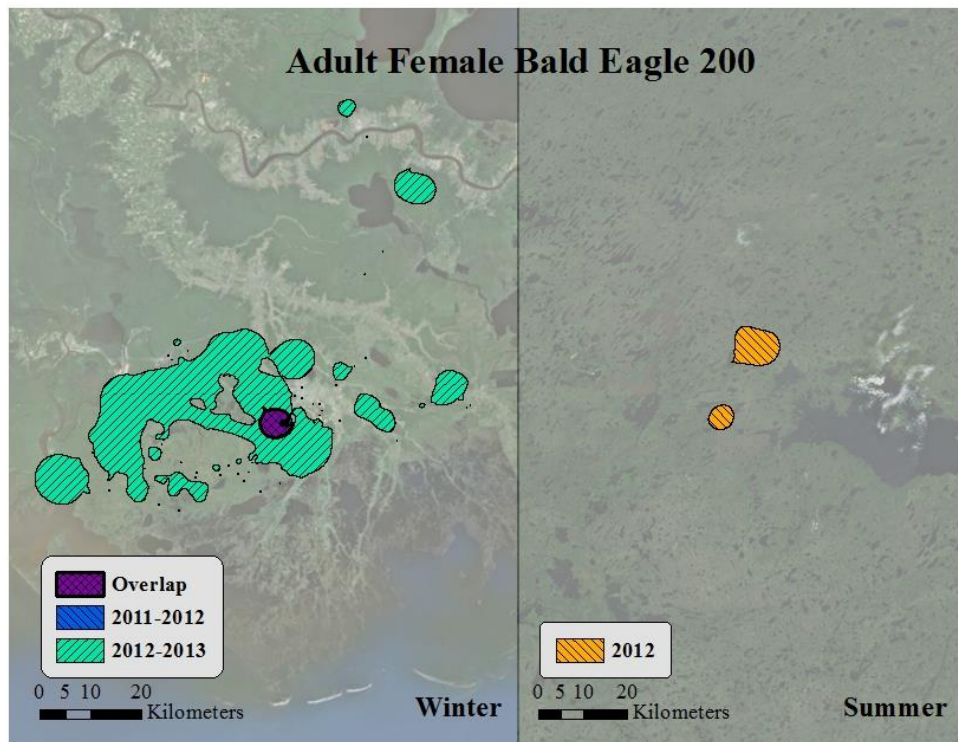




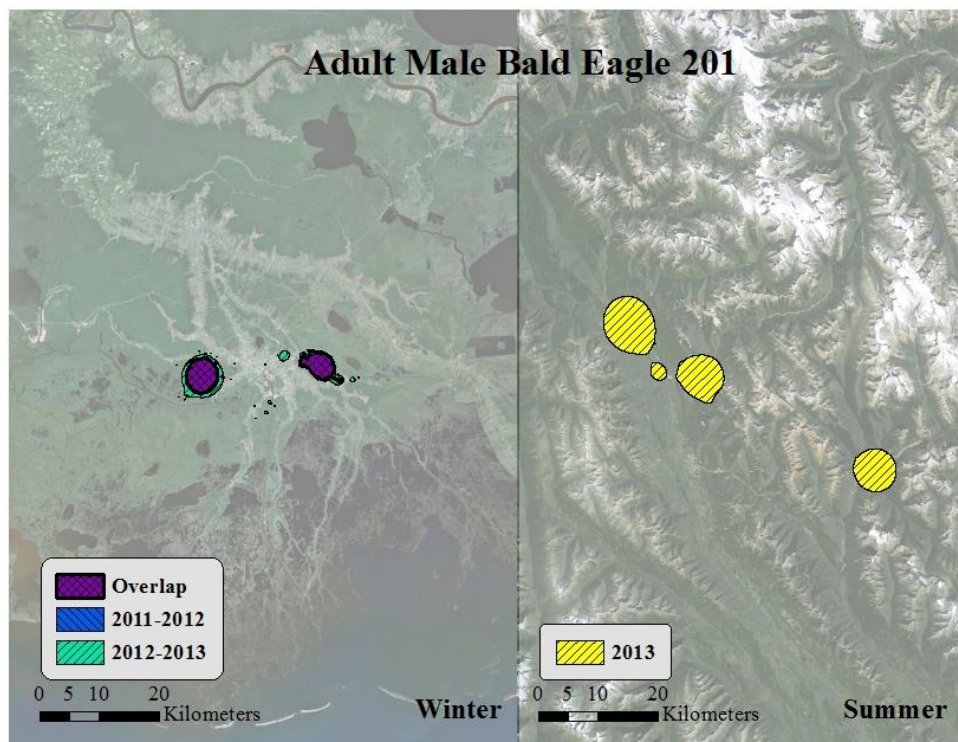




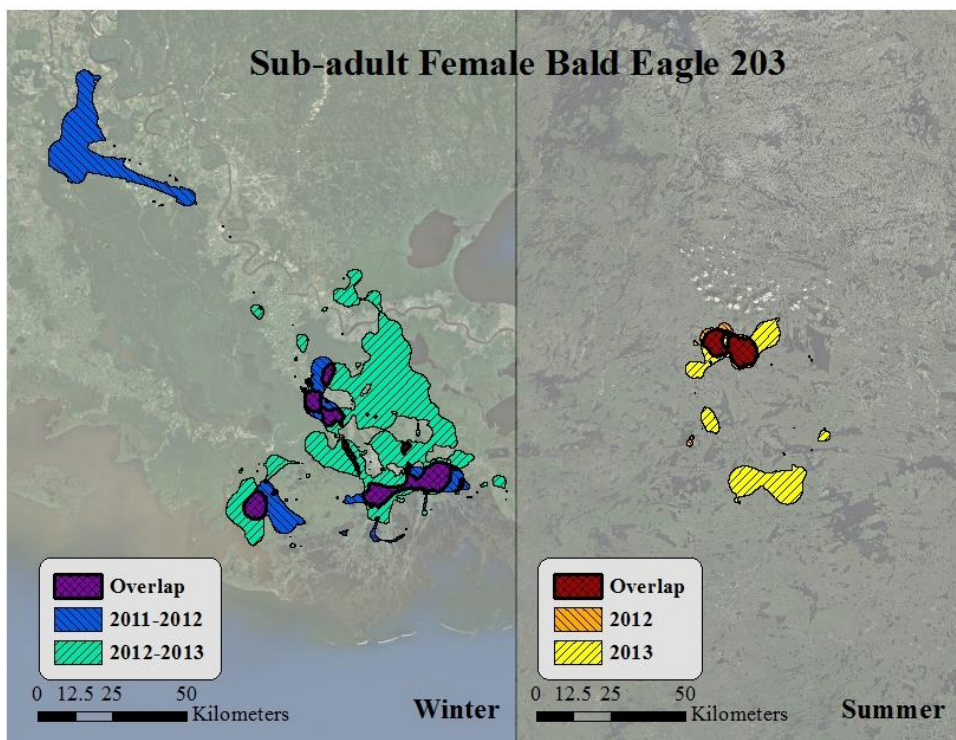
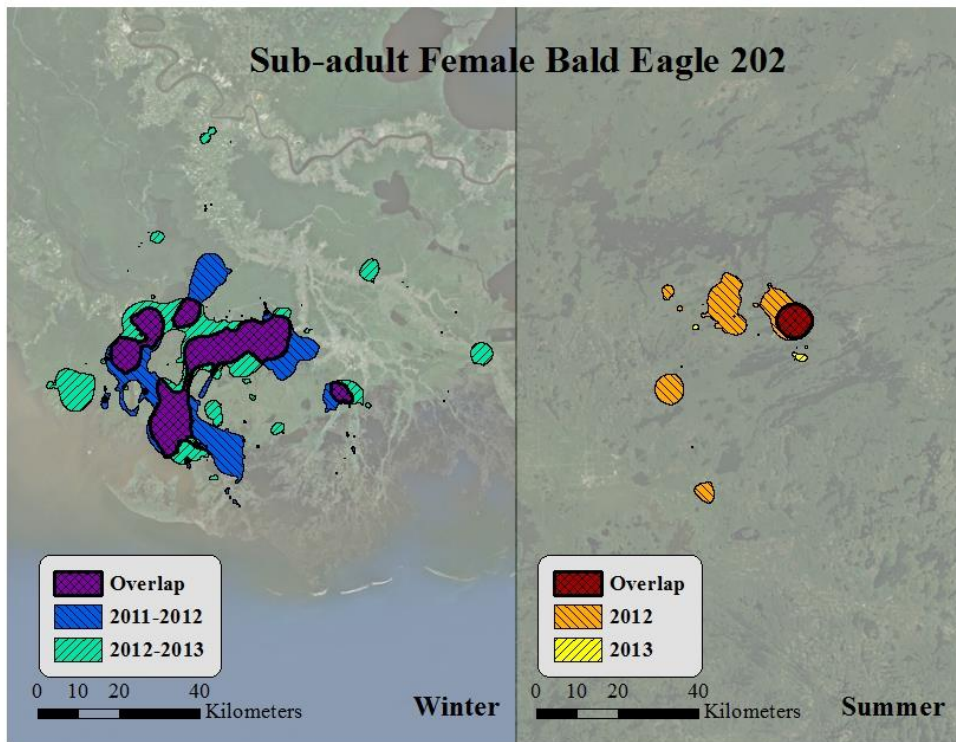
APPENDIX E. WINTER AND SUMMER HOME RANGE MAPS

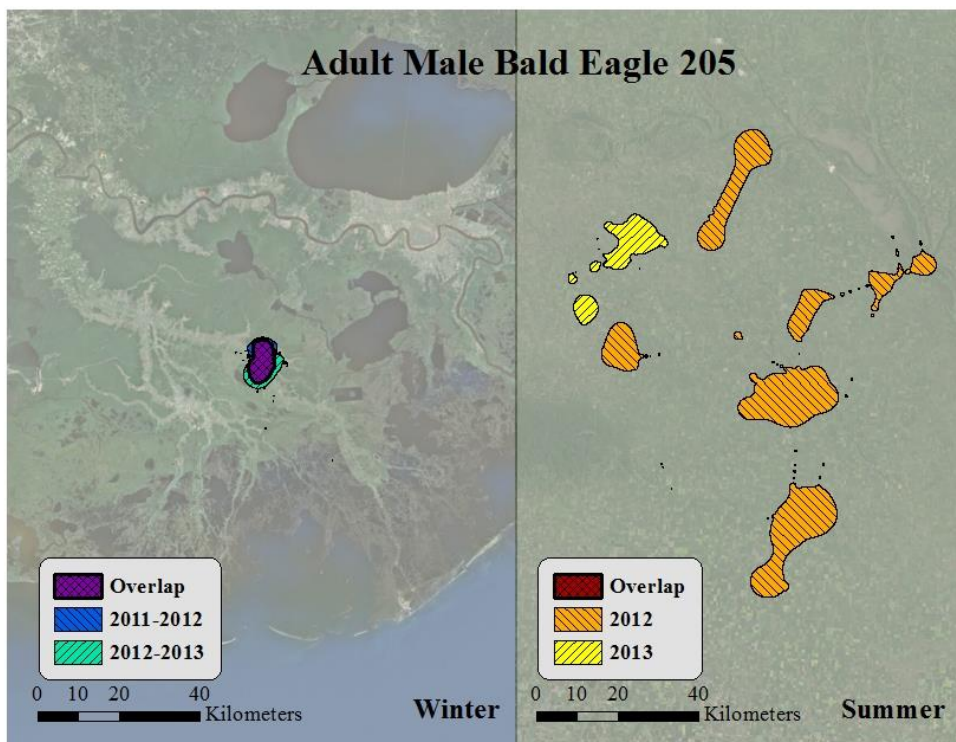
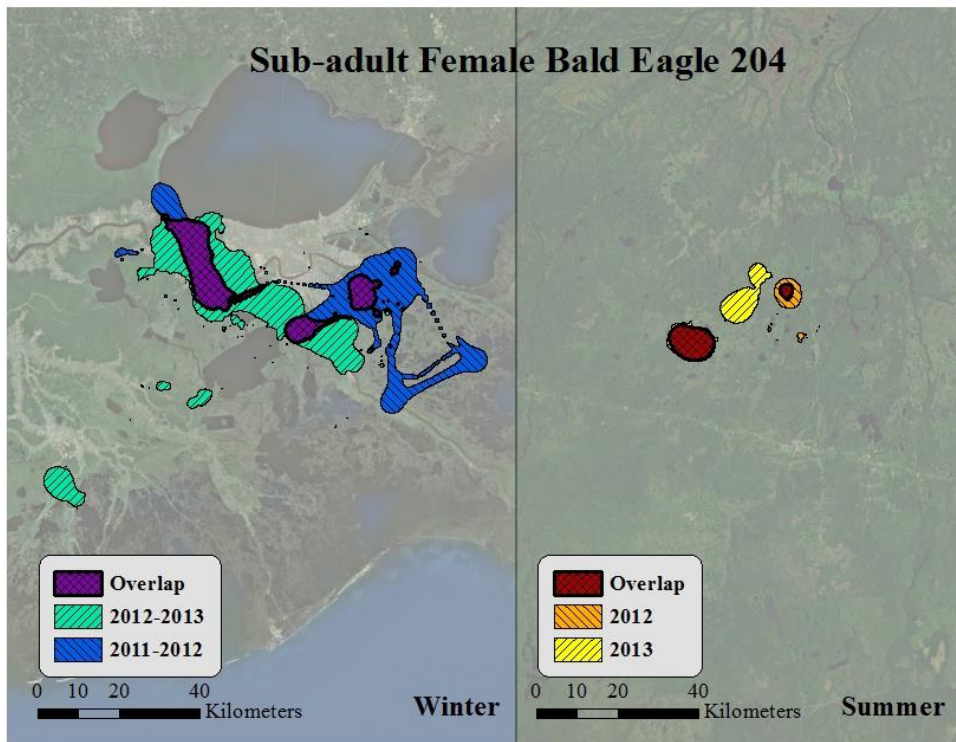


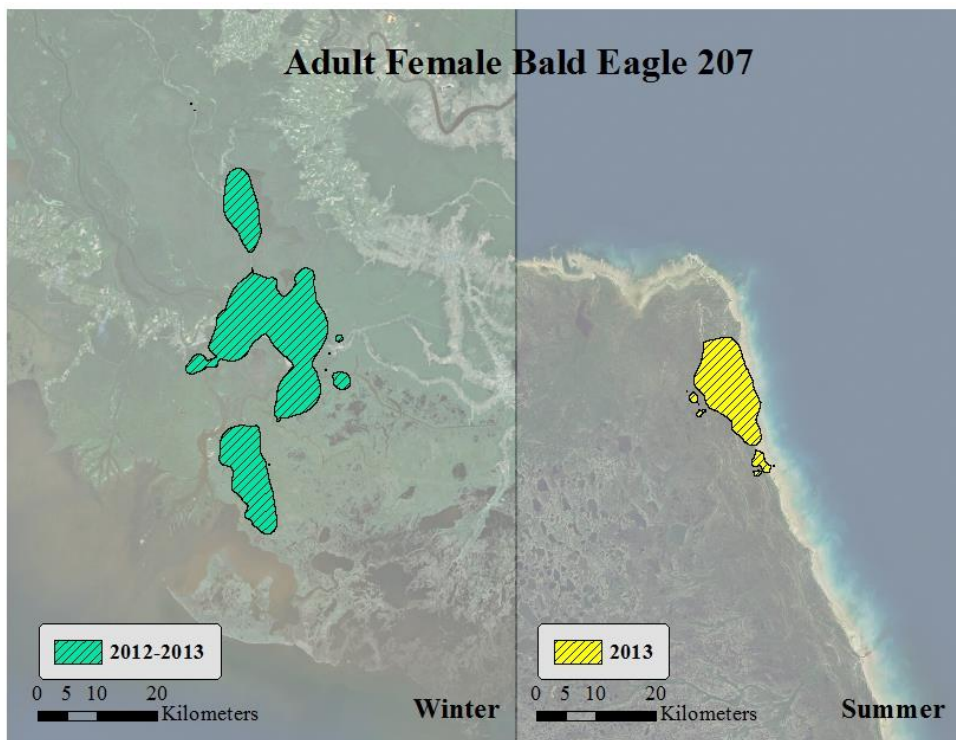
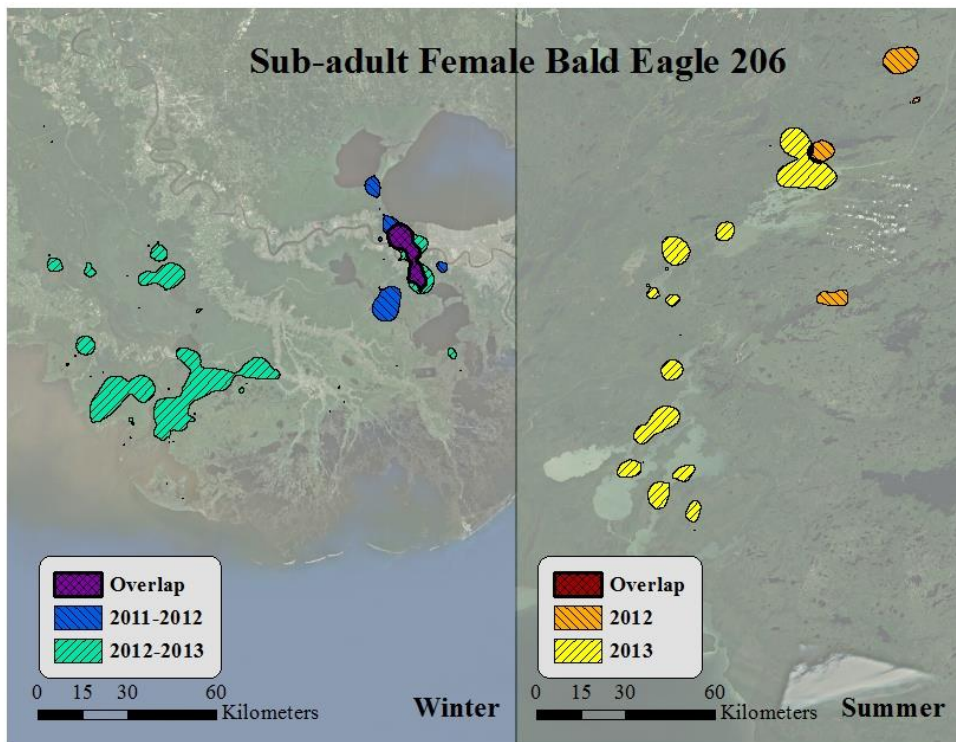
No 2013 summer home range established.



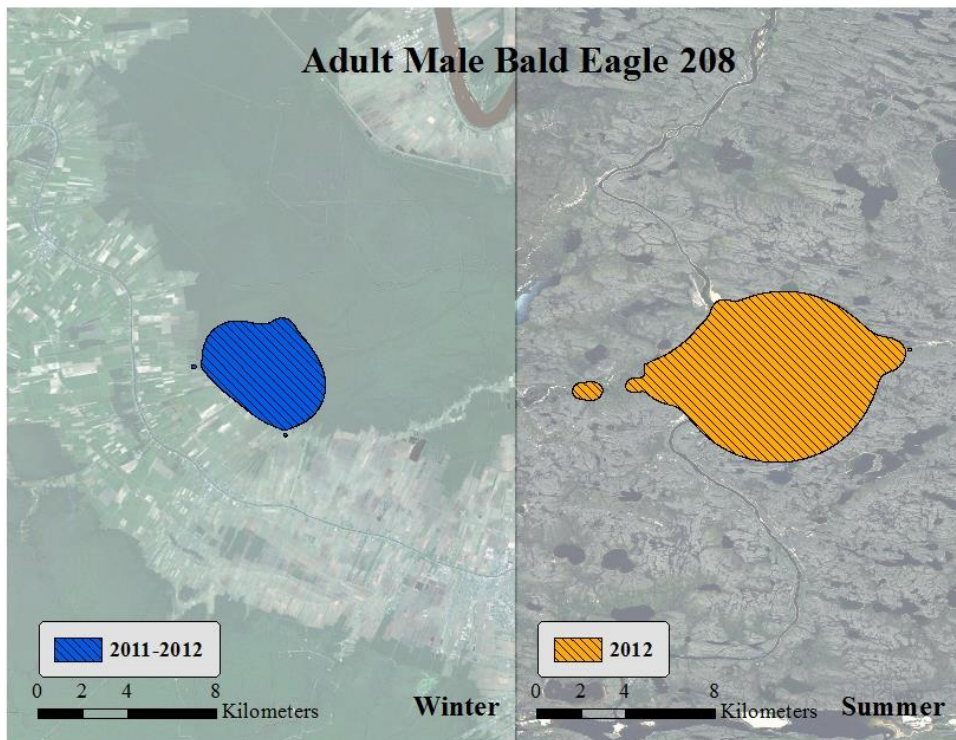
No 2012 summer home range established.



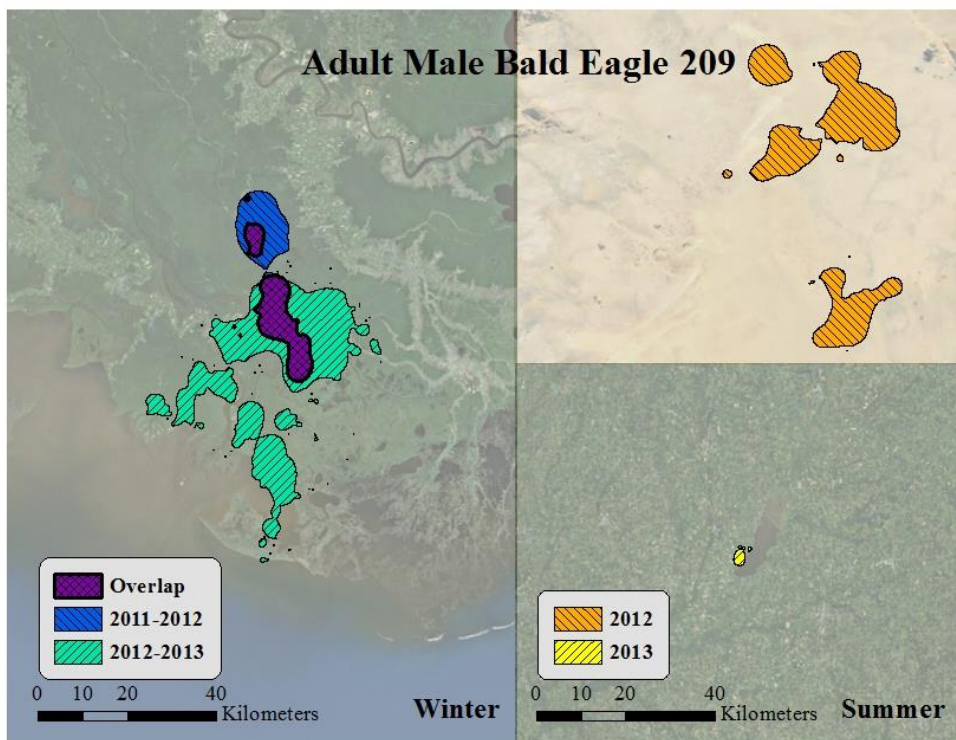




Transmitter not deployed until winter 2012-2013.



Died prior to establishing 2012-2013 winter home range.



2012 summer home range in Ontario, Canada.

2013 summer home range in Illinois, USA.

APPENDIX F. MORPHOMETRIC MEASUREMENTS

Summary of individual morphometric measurements in mm from Louisiana Bald Eagles that were either caught using a rocket net (wild caught, n=16), admitted for rehabilitation to Louisiana State University Wildlife Hospital (rehabilitated, n=6), or were found dead or had been euthanized and were subsequently frozen until data collection (frozen, n=6).

Sex	Age	Hallux Length	Beak Depth	Sample Type
Female	Adult	43.31	36.23	Wild Caught
Female	Adult	43.48	36.50	Wild Caught
Female	Adult	40.69	34.90	Wild Caught
Female	Adult	43.90	35.12	Rehabilitated
Female	Adult	41.54	34.86	Rehabilitated
Female	Adult	41.87	34.78	Rehabilitated
Female	Adult	42.41	34.41	Rehabilitated
Female	Adult	39.31	34.75	Rehabilitated
Female	Adult	43.99	35.20	Frozen
Female	Adult	40.49	36.05	Frozen
Female	Sub-adult	43.80	34.63	Wild Caught
Female	Sub-adult	41.46	35.24	Wild Caught
Female	Sub-adult	43.59	37.11	Wild Caught
Female	Sub-adult	40.61	33.41	Wild Caught
Female	Sub-adult	41.99	33.70	Wild Caught
Female	Sub-adult	39.89	34.05	Wild Caught
Female	Sub-adult	43.02	33.55	Wild Caught
Female	Sub-adult	41.88	33.08	Frozen
		42.07 ±0.346	34.87 ±0.260	
Male	Adult	36.70	31.65	Wild Caught
Male	Adult	38.51	32.05	Wild Caught
Male	Adult	37.63	31.52	Wild Caught
Male	Adult	38.10	30.33	Wild Caught
Male	Adult	38.75	30.55	Wild Caught
Male	Adult	35.68	31.09	Frozen
Male	Adult	37.19	32.88	Frozen
Male	Sub-adult	37.57	29.91	Wild Caught
Male	Sub-adult	36.40	29.96	Rehabilitated
Male	Sub-adult	37.33	31.57	Frozen
		37.38 ±0.300	31.15 ±0.305	

VITA

Nickolas Ryan Smith was born and raised in Norwood Young America, Minnesota where he graduated from Central High School in 2004. He attended South Dakota State University and graduated with a Bachelor of Science degree in Wildlife and Fisheries Sciences in 2008. Prior to enrolling in the graduate program at Louisiana State University in 2011, he spent several years working in the wildlife field for Northern Prairie Wildlife Research Center, Ducks Unlimited, and the Iowa Department of Natural Resources. He will receive his master's degree in August 2014.