Evaluating Potential Effects of Widening US 64 on the Black Bear Population of Alligator River National Wildlife Refuge, Dare County, North Carolina

Final Report

Principal Investigator: Michael R. Vaughan, PhD

Co-Principal Investigator: Marcella Kelly, PhD

Project Coordinator: J. Andrew Trent, MS

Virginia Tech
Department of Fish and Wildlife Conservation
100 Cheatham Hall
Blacksburg Va. 24061

December 2011

Technical Report Documentation Page

1. Report No. **FHWA/NC/2009-24**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluating potential effects of widening US 64 on the black bear population of Alligator River National Wildlife Refuge, Dare County, North Carolina		5. Report Date Dec 21, 2011 6. Performing Organization Code
7. Author(s) Michael Vaughan PhD, Marcella Kelly PhD, J. Andrew Trent MS		8. Performing Organization Report No.
9. Performing Organization Name and Address Virginia Tech, Department of Fish and Wildlife Conservation 100 Cheatham Hall, Blacksburg Va. 24061		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address North Carolina Department of Transportation Research and Analysis Group 1 South Wilmington Street Raleigh, North Carolina 27601		13. Type of Report and Period Covered Final Report March 15, 2009 – March 31, 2012 14. Sponsoring Agency Code HWY2009-24
Supplementary Notes:		

16. Abstract

This report summarizes research conducted along US Highway 64 (US 64) and US Highway 264 (US 264) in Alligator River National Wildlife Refuge (ARNWR), Dare County, NC regarding the proposed expansion of US 64. The study site included the areas adjacent to US 64 from the Alligator River Bridge to the US 64/US 264 intersection and from Cub Road to Borrow Pit Road on US 264. This report evaluates potential effects of the road improvement project on the black bear population, delineates significant wildlife crossing areas, and provides data on movement patterns and population dynamics of black bears on ARNWR. The primary focus of the research was to identify sites along US 64, frequently used by black bears and white-tailed deer as potential sites for wildlife crossing structures.

It is the legal obligation of the US Fish and Wildlife Service to conduct a Compatibility Determination to decide whether the proposed project is compatible with the purpose of the refuge. Thus we evaluated the current wildlife use patterns surrounding the highway and the potential short- and long-term effects of the expansion project on the entire suite of wildlife occupying the areas directly adjacent to US 64. We employed a variety of research methods including; roadside barbed wire hair collection, GPS collar deployments, remote camera trapping, road kill surveys, and driving surveys.

The road side barbed wire surveys documented 890 black bear road crossings from March 2009 – March 2011. 83 individual bears (65M:18F) were genetically identified from hair samples collected. GPS collars were deployed on 49 individual bears (26M:23F) and detailed 15 bears (11M:4F) crossing US 64, 99 times. The GPS collars also detailed intense use of the areas directly adjacent to US 64. We photo-captured 170 white-tailed deer, > 200 bobcats and raccoons and an additional 260 black bears at 12 guard rail openings along US 64 from June 2009 – March 2011. Driving surveys provided additional 3 and 19 sightings of black bears and white-tailed deer respectively from March 2009 – March 2010. We identified 184 individual bears (132M:52F) within the study area.

Road kill surveys documented 8 white-tailed deer (2M:3F:3U) road mortalities from November 2008 – July 2011. Including historical data collected by the USFWS, the cumulative total of road killed black bears on US 64 from January 1993 – July 2011 was 63 (35M:20F:8U: =3.32/year). Road kill data also included; 75 bats (7 species, 1 species a NC Threatened Species), 82 small mammals (9 species), 134 mid-sized mammals (10 species), 1,153 birds (66 species), 4,014 reptiles (44 species), and 7,498 amphibians (18 species). Four species recovered in our surveys were NC Species of Concern.

This study identified 6 high priority areas for black bear and white-tailed deer crossing and an extensive network of crossing areas for small mammals, reptiles, and amphibians.

17. Key Words Environmental Impacts,	18. Distribution Statement		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 82	22. Price

DISCLAIMER

The contents of this report reflect the views of the author(s) and not necessarily the views of the University. The author(s) are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of either the North Carolina Department of Transportation or the Federal Highway Administration at the time of publication. This report does not constitute a standard, specification, or regulation.

Acknowledgements

This project involved several agencies, organizations, and personnel who contributed to its success. Anne Burroughs and John Kirby with the NCDOT, PDEA-NEU-Biological Surveys Group, assisted with funding and oversight, and provided support at all levels. Mike Bryant and Scott Lanier, USFWS - ARNWR management, graciously permitted full access to Alligator River NWR, its personnel, and facilities. Dennis Stewart, USFWS, provided biological insight and knowledge and legal guidance throughout the project. Colleen Olfenbuttel, Bear and Furbearer Biologist, NCWRC, and James Turner, District Biologist, NCWRC, shared their knowledge of black bears, and provided support and field assistance with road killed bears and harvest data. We also acknowledge Kris Fair, USFWS, for her support and help in all aspects of this project including collecting road kills and stringing miles of barbed wire. Field technicians too numerous to name and a small army of volunteers provided by the USFWS and Virginia Tech, were the backbone of this project and we appreciate their hard work under tough environmental conditions.

Sponsors

We gratefully acknowledge all who provided funding or support for this project:

NC Department of Transportation
Office of Research and Development
Raleigh, NC

US Fish and Wildlife Service
Alligator River National Wildlife Refuge
Manteo, NC

NC Wildlife Resources Commission
Raleigh, NC

Virginia Tech
Department of Fish and Wildlife Conservation
Blacksburg, VA

Cite this report as: Vaughan, M.R., Kelly, M.J., Trent, J.A. 2011. Evaluating potential effects of widening US 64 on the Black Bear Population of Alligator River National Wildlife Refuge, Dare County, North Carolina. Final Report. VT-NCDOT Contract No. MA-2009-02. 82pp.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This report summarizes research conducted along US Highway 64 (US 64) and US Highway 264 (US 264) in Alligator River National Wildlife Refuge (ARNWR), Dare County, NC regarding the proposed expansion of US 64. The study site included the areas adjacent to US 64 from the Alligator River Bridge to the US 64/US 264 intersection and from Cub Road to Borrow Pit Road on US 264. This report evaluates potential effects of the road improvement project on the black bear population, delineates significant wildlife crossing areas, and provides data on movement patterns and population dynamics of black bears on ARNWR. The primary focus of the research was to identify sites along US 64, frequently used by black bears and white-tailed deer as potential sites for wildlife crossing structures.

It is the legal obligation of the US Fish and Wildlife Service to conduct a Compatibility Determination to decide whether the proposed project is compatible with the purpose of the refuge. Thus we evaluated the current wildlife use patterns surrounding the highway and the potential short- and long-term effects of the expansion project on the entire suite of wildlife occupying the areas directly adjacent to US 64. We employed a variety of research methods including; roadside barbed wire hair collection, GPS collar deployments, remote camera trapping, road kill surveys, and driving surveys.

The road side barbed wire surveys documented 890 black bear road crossings from March 2009 – March 2011. 83 individual bears (65M:18F) were genetically identified from hair samples collected. GPS collars were deployed on 49 individual bears (26M:23F) and detailed 15 bears (11M:4F) crossing US 64, 99 times. The GPS collars also detailed intense use of the areas directly adjacent to US 64. We photo-captured 170 white-tailed deer, > 200 bobcats and raccoons and an additional 260 black bears at 12 guard rail openings along US 64 from June 2009 – March 2011. Driving surveys provided additional 3 and 19 sightings of black bears and white-tailed deer respectively from March 2009 – March 2010. We identified 184 individual bears (132M:52F) within the study area.

Road kill surveys documented 8 white-tailed deer (2M:3F:3U) road mortalities from November 2008 – July 2011. Including historical data collected by the USFWS, the cumulative total of road killed black bears on US 64 from January 1993 – July 2011 was 63 (35M:20F:8U: $\bar{x}$=3.32/year). Road kill data also included; 75 bats (7 species, 1 species a NC Threatened Species), 82 small mammals (9 species), 134 mid-sized mammals (10 species), 1,153 birds (66 species), 4,014 reptiles (44 species), and 7,498 amphibians (18 species). Four species recovered in our surveys were NC Species of Concern.

This study identified 6 high priority areas for black bear and white-tailed deer crossing and an extensive network of crossing areas for small mammals, reptiles, and amphibians.

Evaluating Potential Effects of Widening US Highway 64 on the Black Bear Population of Alligator River National Wildlife Refuge, Dare County, North Carolina

Final Report

December 2011

INTRODUCTION

The increasing network of over 4 million miles of roads traveled by 255 million automobiles (U.S.D.T., 2006) constitutes a significant and growing threat for many wildlife populations in the United States. According to the US Department of Transportation, the number of wildlife-vehicle collisions (WVC) per year continues to rise, but signifies only one part of the threat to wildlife. Roads also act as barriers to daily movements, migration, dispersal patterns, and they influence habitat connectivity, quality, and quantity (Forman et al. 2003). For small or isolated wildlife populations, roads could diminish gene flow and potentially push populations into extinction (Alexander and Waters 2000)

Human safety is of paramount importance when considering road design and construction, yet hundreds of human fatalities and tens of thousands of injuries (Huijser, 2006) still occur each year across the United States from WVC. Thus, highway departments, and state and federal agencies increasingly are investing more resources into developing and refining wildlife mitigation techniques and crossing structures.

Of particular importance when considering wildlife mitigation techniques and the design and placement of crossing structures, is a baseline understanding of the wildlife-highway interactions (including road mortalities, movement corridors, and successful crossing areas) before road building or improvements are initiated.

The North Carolina Department of Transportation (NCDOT) has proposed a highway improvement project for the 18.9km (11.7 miles) stretch of US Highway 64 (US 64) through Dare County, NC that bisects the northern part of the Alligator River National Wildlife Refuge (ARNWR). This temporary disruption could have short-term and lasting impacts on some wildlife species, and as such, ARNWR staff must conduct a Compatibility Determination to decide whether the proposed project is compatible with the purpose of the refuge. A first step (Phase 1, preconstruction) in that process was to provide the refuge staff with data on where large animal species (black bears, red wolves, and white-tailed deer) are most likely to cross US 64 and to use those data to help determine placement of highway wildlife crossing structures. The refuge has consistently advised that a favorable Compatibility Determination requires sufficient data for the decision making process and the results from Phase 1 are critical to that process. Further stipulations to ensure a compatible project require additional data collection

during construction (Phase 2) and post construction (Phase 3) to determine the short- and long-term impacts on certain species (see Klinger 2001, and Smiley and Lively 2001; abstracts only). This project originally addressed only the preconstruction phase for black bears and white-tailed deer, but was extended to examine impacts on all mammals, birds, reptiles, and amphibians.

BACKGROUND INFORMATION

US 64 in North Carolina has been widened to a four-lane highway from Raleigh to Columbia. Widening was completed to Columbia, North Carolina in 2005, from Columbia to US Highway 264 (US 264) on ARNWR it remains a two-lane highway. In preparation for widening the 20-mile section of US 64 from Plymouth to Columbia, North Carolina, NCDOT contracted for research to determine where highway underpasses should be placed to accommodate wildlife and decrease the likelihood of WVC. That research used track counts, remote cameras near established animal trails, and GIS techniques to determine frequently used black bear and white-tailed deer road crossing locations (Scheick and Jones 1999 and 2000, Kindall 2004, Kindall and van Manen 2007). In the final analysis, habitat features proved most useful in determining placement of wildlife underpasses while trail monitoring and track counts were of little value because of some inherent biases. Now, NCDOT must determine where wildlife crossing structures should be placed for the section from Columbia to US 264 on ARNWR. The remaining sections to be completed are the 25.1 km (15.6 mi) section of highway from Columbia to Alligator River and the 18.9 km (11.7) section that runs through ARNWR. ARNWR is home to a high density black bear (*Ursus americanus*) population (Tredick 2005), and the highway is surrounded by prime black bear habitat. Records indicate that since 1993, 0 - 9 bear mortalities from vehicle collisions are documented annually on highway 64 within the refuge boundaries.

The section of US 64 from Columbia to Alligator River is similar in some respects to the Plymouth to Columbia section, thus the application of GIS techniques to describe habitat features may prove useful in identifying likely animal crossing locations. However, the habitat in the section of highway from Alligator River to US 264 on ARNWR (the focus of this project) is quite different. Habitat adjacent to the highway is mostly a continuous block of homogenous forest and there are no obvious habitat features that would identify animal crossing locations. In addition, deer and bear tracks and trails are ubiquitous throughout the 18.9 km section of US 64 through ARNWR and would not prove useful for identifying animal crossing locations. Thus, an alternative approach to identifying animal crossing locations is required.

PROBLEM NEED/DEFINITION

NCDOT is currently engaged in a project to widen US 64 from 2 to 4 lanes from Raleigh to Manteo, North Carolina. Widening was completed to Columbia, North Carolina in 2005. The remaining sections to be completed are the 25.1 km (15.6 mi) section of highway from Columbia to Alligator River and the 18.9 km (11.7) section that runs through ARNWR. ARNWR is home to a high density black bear (*Ursus americanus*) population (Tredick 2005), and the highway is surrounded by prime black bear habitat. Records indicate that since 1993, up to 9 bear mortalities from vehicle collisions are documented annually on US 64 within refuge boundaries. Widening the highway may be accompanied by increased speed limits, and likely will create a barrier to movement of wildlife from one side of the highway to the other; thus, it is imperative that wildlife underpasses/overpasses be constructed in areas identified as high use bear crossings (Kindall 2004, Kindall and van Manen 2007, Scheick and Jones 1999, van Manen et al. 2001).

Construction of the highway itself most likely will disrupt the bear population, as well as other wild animal populations (e.g., red wolves, white-tailed deer) living adjacent to the existing highway during the 1-2 year construction period. Demographic parameters likely to be affected include reproduction and survival. Movements and home ranges also may be affected (Thompson 2003, Thompson et al 2005, Kindall 2004). Under these assumed responses, bears would have to shift out of their home ranges during the construction phase and move into areas already occupied by other bears likely causing social disruptions. While the disruption due directly to construction will be short-term, the effects on the bear population may be long lasting and even permanent. Habitat loss, as a direct result of highway widening, may result in a reduction of the bear population (Thompson 2003).

A first step in preparing for the proposed highway improvement project is to identify frequently used animal crossing locations on the existing highway. These locations would be potential candidates for road crossing structures.

OBJECTIVES

The objectives of this research project were to:

1. Evaluate potential effects of the US 64 road improvement project on the black bear population on Alligator River National Wildlife Refuge.

2. Identify significant wildlife crossing areas on the section of US 64 that runs through Alligator River National Wildlife Refuge to determine where wildlife crossing structures could be placed.

3. Determine seasonal movement patterns, reproductive success, and survival of bears along the highway improvement corridor on Alligator River National Wildlife Refuge.

STUDY AREA

Dare County, NC is comprised of the Outer Banks coastal area and a large peninsula just inland and west of Manteo, NC (Fig. 1). The 652 km^2 ARNWR was established in 1984 to protect and manage unique forested wetlands communities and associated wildlife. Most (598 km^2) of the refuge is in Dare county, while the remainder (54 km^2) is in Hyde County (Fig. 2). The Dare County bombing range, operated by the US Air Force and US Navy, and within the boundaries of the refuge, adds another 189 km^2. The refuge is bounded to the north by the Albermarle Sound, to the east by the Croatan Sound, to the west by the Alligator River, and to the south by privately owned forest and agricultural lands. US 64 bisects the northern section of the refuge and US 264 traverses the eastern section. The core study area is composed of approximately 5km on either side of US 64 through ARNWR (Fig. 2) with a focused effort either on or directly adjacent to the highway.

The refuge has a diversity of plant and animal life including high and low pocosins, hardwood swamps, more than 200 resident and migrant bird species, white-tailed deer (*Odocoileus virginianus*), and the endangered red wolf (*Canis rufus*). It is also an eastern stronghold for the American black bear (*Ursus americanus*).

Figure 1. Dare County (in red) in eastern North Carolina.

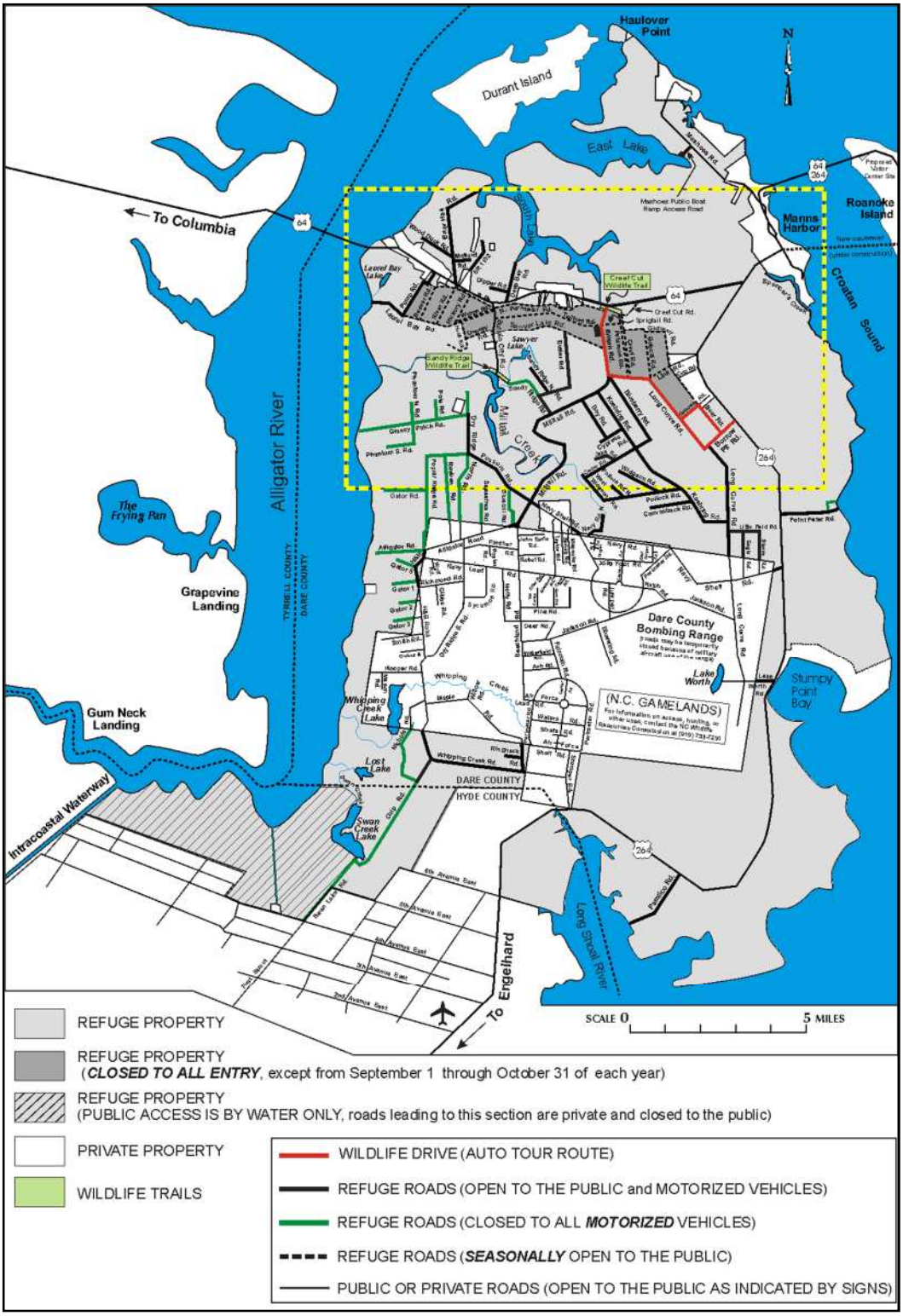

Figure 2. Study area: Alligator River National Wildlife Refuge, Dare County, North Carolina. Yellow border represents the approximate study area for this project.

METHODS

Objective/Task 1: Evaluate potential effects of the road improvement project on the black bear population on Alligator River National Wildlife Refuge.

Literature Review and Historical Data

We performed a thorough literature review of all bear research that had taken place on and around ARNWR to gain an understanding of black bear density, reproductive and survival rates, movement patterns and home range size for the immediate area. We also reviewed the literature of all other wildlife species within the general area. We also searched and reviewed the literature on highway/wildlife interactions and crossing structures. We monitored and reviewed conference literature with related wildlife/highway themes or presentations. We also initiated meetings with local, state, and federal agencies to collect and synthesize historical bear mortality, age, and population data as well as to establish a method for sharing mortality data for the duration of the study.

Objective/Task 2: Identify significant wildlife crossing areas to determine where wildlife underpasses or other design features could be placed.

Highway Barbed Wire Hair Snags

US 64 though ARNWR has a guardrail on one side of the road or the other side for the entire length of the refuge. We divided and marked the entire guard rail system within the study area into 0.01 mile sections using an alpha numeric code. The letters advanced each time the guardrail changed sides of the road and each number represented a 0.01 mile section starting from the eastern end of the study area. Initially we proposed a single strand of barbed wire along the entire length of the existing guard rail adjacent to US 64 within the study area and along a ~2 mile stretch of US 264 deemed a "control" area. The barbed wire snags hair (Fig. 3) from bears crossing over the guard rail and roadway. But during a short pilot study of multiple wire configurations we determined that a double strand (one above the guard rail and one extended behind the guardrail posts ~45-50 cm above the ground) was the most effective design (Fig. 4). Once in place, the entire length of wire was checked for hair samples within a ~7 day cycle during the summer months (April – August) and within a ~14 day cycle during the remaining months (September – March).

Figure 3. Black bear hair “snagged” on a barb as a bear crossed the road and guardrail, ARNWR, 2010.

Figure 4. Configuration of barbed wire for hair collection on a guard rail on ARNWR, 2009 – 2011. The top and back strands were used throughout the study. The bottom strand was tested and later removed.

Each barb on the wire was closely examined for any hair remains; each barb with hair was considered and individual **sample** and collected into individual coin envelopes. If hair samples were found on consecutive barbs on the same wire, they were collected individually, but labeled as one **crossing event** (i.e. 5 consecutive samples were marked as 1/5, 2/5 etc.). If hair samples were found on both the back and top wire, even in direct line with one another, they were collected using forceps and labeled as individual bear crossing events. Data recorded at each hair sample included; date, UTM coordinates, road section, wire ID (i.e. top or back strand), direction of bear travel (determined from the direction the hair was snagged into the barb), number of hairs collected, and number of samples for each crossing event. After collecting the sample, we burned the barb and all tools used to collect the hair with a lighter to remove any remaining genetic material.

All collected samples were stored under dry, room temperature conditions until sent for analysis. All samples with 3+ hairs with follicles attached were sent to Wildlife Genetics International for genetic analysis. Each successful hair sample analysis provides the sex and individual identification of the bear leaving the sample.

Road kill Surveys

We performed road kill surveys by walking both sides of US 64 through the study area in Dare County and a ~2 mile stretch of US 264 every ~7 days during the summer months (April – August) and every ~14 days the remaining months (September – March). During the surveys every vertebrate animal mortality was identified to as precise a taxonomic level as possible along with UTM coordinates, date, sex, age, and location on roadway (i.e. grass on canal side or in highway). All road kills were either removed from the search area or marked with paint to avoid double counts. Difficult to identify specimens were collected and identification confirmed by the project manager.

We recorded the same suite of data on fresh mid-sized wildlife (larger than amphibians and snakes) discovered during the normal course of any field day. We made a special effort to respond immediately to and retrieve any large mammals (river otter, bobcat, coyote, white-tailed deer, black bear, red wolf) reported dead or possibly dead (i.e. hit by car, but ran off roadside) anywhere in Dare, Tyrrell, and Hyde Counties. All large mammals were removed from the roadside and disposed of by burial on the ARNWR.

Red wolves and any large canid were scanned for PIT tag identification, weighed, sex determined, and internal organ samples (liver and kidney) collected and frozen for later analysis. All canids were then turned over to the Red Wolf Recovery Team for storage. Black bears were collected and checked for identifying marks (tattoo, ear tag, ear tag wound), a hair sample collected, both upper pre-molars pulled for age determination, weighed, and extensively measured. Internal organ samples (liver and kidney) also were collected and frozen for later analysis.

Remote Camera Surveys

Potential remote camera sites were determined based on locations where it would be impossible to have barbed wire monitoring animal movement at the roadside. All breaks in the guard rail (roads, driveways, guardrail switching sides of the road, or canal crosses) were targeted for remote camera placement (Fig. 5). We identified 32 "breaks", but only 12 sites were deemed to be viable camera deployment locations. All personal driveways and one paved road were removed from camera site considerations due to concerns for citizen's privacy and theft issues. Not all 12 sites were monitored for the full 2- year duration due to theft, camera destruction, and equipment malfunction. Once a camera was deployed it was checked every 10-14 days at which time new batteries, film, and disk were installed if needed and repairs were made to malfunctioning cameras. All photos were downloaded and analyzed as raw numbers of individual species of animals, with consecutive photos of an individual considered one event.

Figure 5. Remote cameras for monitoring animal movements at breaks in the guardrail system on ARNWR, 2009 – 2011.

Wildlife Driving Surveys

To identify white-tailed deer crossing areas we performed driving surveys along US 64 within the study area and along the 2 mile "control" area on US 264. We performed the driving surveys on three randomly chosen days per week starting at one of four randomly chosen time periods (Sunrise, Sunset, 2200-2400, 2400-0200). We drove the entire length of the 2 sites twice (roundtrip) at no more than 45 miles per hour. We used a large spotlight to illuminate the non-guardrail side of the road in order to record animals very near the wood line. We recorded the time we started and completed the surveys. If wildlife were seen we recorded the time, species, number of individuals, sex if possible, the mile marker location (in order to return to record the exact UTM coordinates), and the location of the animal (i.e. road, grass shoulder, canal shoulder,

private lawns, etc.). These surveys were carried out for one full year of the project (February 2009 – Feb 2010).

Black Bear Trapping and Marking

Bear trapping was conducted during the summer months (May – September) of 2009 and 2010. We used culvert traps baited with pastries and liquid sweeteners (raspberry extract, molasses, and corn syrup) set within ARNWR (Fig. 6). We set traps either along gated roads or within forested blocks along the roadways. We did not set baited traps along US 64 specifically to deter "pulling" bears onto the hwy. On one occasion we trapped a bear along US 64 that had been on the roadway for 2-3 days (occasionally stopping traffic) in an attempt to "haze" the bear off the roadside before it caused an accident or was involved in a WVC. All traps were checked twice daily (morning and evening) except for the roadside trap, which was checked ~ every 4 hours. Non-target captures or bears that had been recently handled were immediately released from the trap. Traps were closed during times of dangerous weather (i.e. flooding, nor'easters, hurricanes, heavy lighting, extremely hot temperatures, etc.).

Captured bears were anesthetized using a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride. All bears were weighed, measured, ear tagged, and lip tattooed. We collected hair samples for genetic analysis, the first upper premolar for aging, blood samples for hormone and disease analysis, and ticks and other parasites for later analysis.

We had 30 GPS radio-collars and attempted to place half on males and half on females. We also attempted to radio collar at least 5 yearling male bears in order to gain a better sense of the variance in home range size and movement patterns. We avoided collaring yearling females due to their small size as well as our interest in adult reproductive data.

We monitored fully processed bears until they recovered and were able to walk away from the capture site.

Figure 6. Baited black bear culvert trap set along a gated road on ARNWR, 2010. *Note cub inside culvert is not strong enough to pull the lever and be captured, and thus separated from the mother (on road). Mother was captured at site and 3 cubs remained safe in tree outside of the trap.

GPS Radio Collar Data

We equipped all collars with either double thick cotton or leather "break-away spacers" (Hellgren et al. 1988). GPS collars used on this project were programmable in terms of when the GPS unit was turned on to get a real time location. One consideration when programming the collars was that the more locations the collar attempted to take, the faster the batteries would drain. Therefore, we decided to balance the number of attempted locations with a battery life of at least 24 months. To capture actual road crossing locations, we programmed the collars to attempt an intense number of locations for a short duration of time while also always attempting a location every 5 hours for larger scale movements and home range data needs (Table 1). All the GPS data collected was stored on-board the collars and downloaded to a handheld computer at a later time. We attempted to download the data from each collar every 3 or 4 months.

Table 1. Sample of black bear GPS radio collar programming schedule used during 2009 – 2011 on ARNWR, Dare County, NC. The times represent when the GPS unit turned itself on and attempted a satellite location. The schedule continued from the day the collar was deployed through a two-year period.

Day 1	5 hr:	00:00 05:00 10:00 15:00 20:00
	Intense:	00:00 00:30, 01:00 01:30 02:00 02:30 03:00 03:30 04:00
Day 2	5 hr:	01:00 06:00 11:00 16:00 21:00
	Intense:	00:00 00:30, 01:00 01:30 02:00 02:30 03:00 03:30 04:00
Day 3	5 hr:	02:00 07:00 12:00 17:00 22:00
	Intense:	00:00 00:30, 01:00 01:30 02:00 02:30 03:00 03:30 04:00
Day 4	5 hr:	03:00 08:00 13:00 18:00 23:00
	Intense:	00:00 00:30, 01:00 01:30 02:00 02:30 03:00 03:30 04:00
Day 5	5 hr:	04:00 09:00 14:00 19:00
	Intense:	04:00 04:30, 05:00 05:30 06:00 06:30 07:00 07:30 08:00
Day 6	5 hr:	00:00 05:00 10:00 15:00 20:00
	Intense:	04:00 04:30, 05:00 05:30 06:00 06:30 07:00 07:30 08:00
Day 7	5 hr:	01:00 06:00 11:00 16:00 21:00
	Intense:	04:00 04:30, 05:00 05:30 06:00 06:30 07:00 07:30 08:00
Day 8	5 hr:	02:00 07:00 12:00 17:00 22:00
	Intense:	04:00 04:30, 05:00 05:30 06:00 06:30 07:00 07:30 08:00
Day 9	5 hr:	03:00 08:00 13:00 18:00 23:00
	Intense:	08:00 08:30, 09:00 09:30 10:00 10:30 11:00 11:30 12:00
ETC….		

Objective/Task 3: Determine seasonal movement patterns, reproductive success, and survival of black bears along the highway improvement corridor on Alligator River National Wildlife Refuge

GPS Radio Collar Data

Seasonal movement patterns for bears within the study area were determined using ARC-GIS software. We defined the seasons as follows; spring: ~March (after den emergence) – May, summer: June – September, fall: October – December (up to den entrance), winter: ~December (after den entrance) – ~March (up to den emergence).

We determined reproductive status of every female black bear captured or recorded as a mortality event. Female bears not seen with cubs or yearlings were determined to be either: solitary - not with young and showing no sign of lactation or estrus (this did not mean they would not become reproductive); lactating – milk was produced from teat when stimulated (the bear could have had young and they were not seen or she had recently separated from suckling yearlings); or in estrus – upon examination the vulva was swollen and red or was exuding a semi-translucent mucus.

On multiple occasions after radio collaring, we visually located as many of the females as possible to refine and monitor reproductive status and to gain some insight into survival of young bears. We attempted to maintain radio collars on the same individual bears for as long as possible so that the data could be combined with historic road kill and harvest data from the area to attain an approximate adult bear survivorship.

Results

Objective/Task 1: Evaluate **potential** effects of the road improvement project on the black bear population on Alligator River National Wildlife Refuge.

Literature Review and Historical Data

The literature suggest that highway widening projects can create barriers to movement of wildlife from one side of the highway to the other (Kindall 2004, Kindall and van Manen 2007, Scheick and Jones 1999, van Manen et al. 2001). Additionally, construction of the highway itself will likely cause disruptions in the bear population and in other wild animal populations (e.g., red wolves, white-tailed deer) living adjacent to the existing highway during the 1-2 year construction period. Reproduction, survival, and movement patterns also are likely to be affected (Thompson 2003, Thompson et al 2005, Kindall 2004). While the literature suggests that disruptions due to construction may be short-term, the effects on the bear population may be long lasting and even permanent. Habitat loss, as a direct result of highway widening, may result in a reduction of the bear population (Thompson 2003).

Research on black bears in the "lowlands" and coastal regions of the eastern USA is somewhat limited compared with the multitude of long term studies conducted in the mountain regions of North Carolina, Tennessee, and Virginia. Five primary studies on the demography of bear populations in the region include 2 at the Great Dismal Swamp National Wildlife Refuge (GDSNWR) (Wills 2008, and Hellgren 1988), and 3 at ARNWR (Folta 1998, Allen 1999, and Tredick 2005). Allen's (1999) study estimated a black bear population of 315 – 429 and a density of 0.86 bears/km^2. Tredick's (2005) study, the first to use a noninvasive collection of hair samples combined with mark-recapture, estimated 55 – 98 bears and 46 – 115 bears in 2003 and 2004, respectively on the ARNWR Farm Unit resulting in an overall average density of 0.65 – 0.94 bears/km^2.

Hellgren (1988) recorded an average litter size of 2.1 cubs and age at primiparity of 4 years old on GDSNWR and felt that the need for dry den sites was not acting as a limiting factor. At the time of the Great Dismal Swamp study the refuge was very similar to ARNWR in terms of management for black bears as both refuges were bear sanctuaries with no hunting allowed within their boundaries. ARNWR, however, experiences greater impacts from coastal weather patterns than GDWNWR due to surrounding waterways and direct proximity to the Atlantic Ocean. Although there have not been many detailed studies on reproductive rates of bears in ARNWR, dry den sites did not appear to have been a limiting factor during either the Folta (1998) or Allen (1999) studies. Data on reproduction indicate a fairly stable to slightly increasing population.

Previous home range estimates for black bears in the GDSNWR ranged from 8.9 – 105.4 km^2 for adult females to 16.8 – 427.6 km^2 for adult males. Tredick (2005) used both DNA hair collection locations and radio collar locations to determine the home ranges of bears on the Pocosin Lakes National Wildlife Refuge (PLNWR) in coastal North Carolina. She documented home ranges of 0.86 km^2 for female and 3.44 km^2 for male bears using hair trap data and 1.16 km^2 for female and 8.79 km^2 for male bears using radio telemetry.

Historical data on highway mortalities have been recorded by US Fish and Wildlife Service (USFWS) personnel since 1993. Between 1993 and 2008 (when our project began) there were 48 (27M:14F:7U: X= 3.0/year) documented bear mortalities on US 64 in Dare County NC (Fig. 7A&B). Nine of the 14 documented female bear highway mortalities (64.3%) were of reproductive age (4+ years old). US 64 through ARNWR (from the Alligator River bridge to the 64/264 intersection) is only 11.3 miles, thus from 1993 – 2008 an average of 4.25 road killed bears per mile were recorded, equating to an average of 0.265 bears per mile per year.

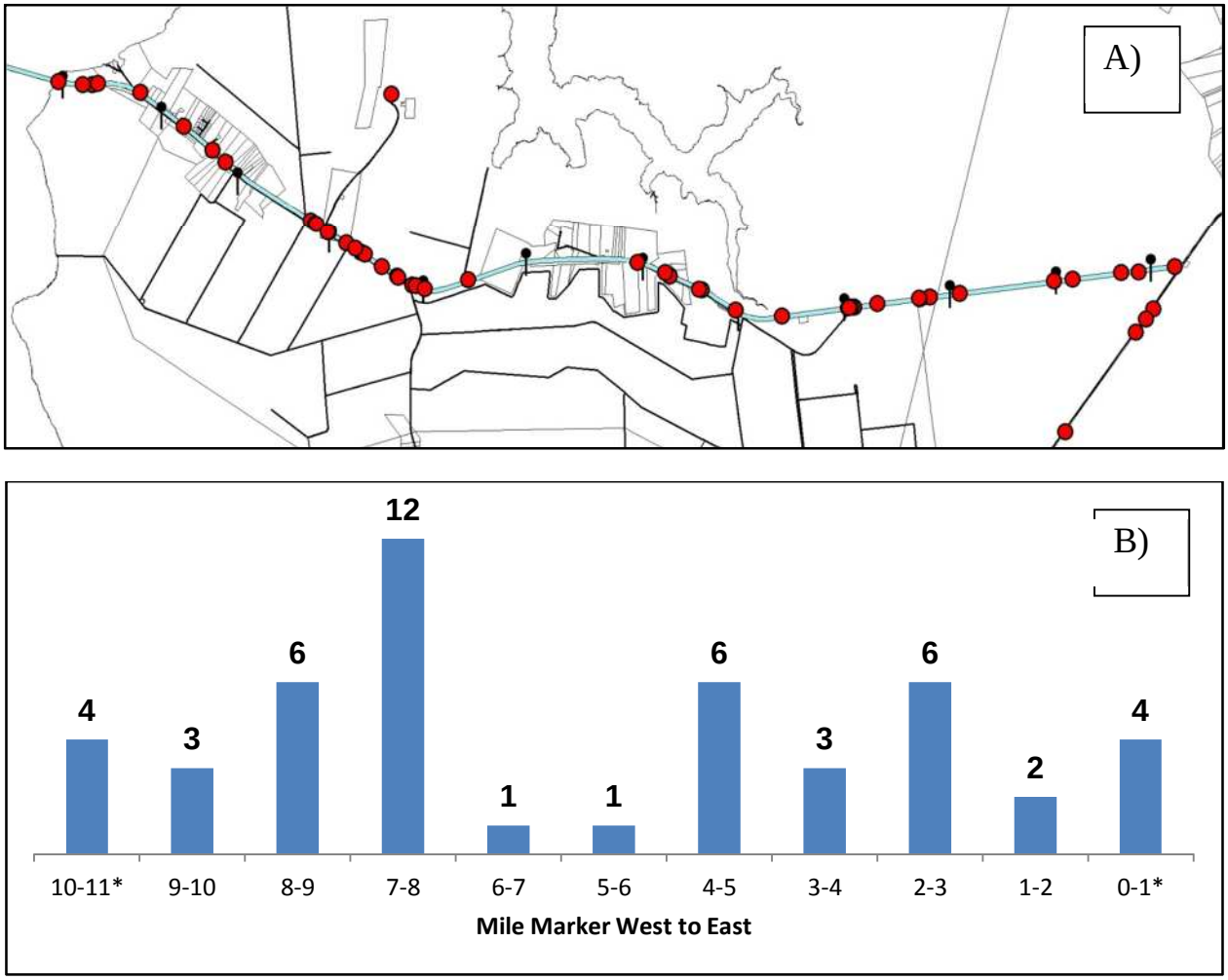

Figure 7. A) Locations and number of recorded black bear road mortalities on US 64 in Dare County, NC from 1993 – 2008. The red dots represent recorded bear mortalities and the black pins represent mile markers for the study area as defined by this project. B) The number of bear road mortalities per mile (aligned to match mile markers on Fig. 7A above). Note that mile 0-1* includes mortalities ~0.1 miles east of mile marker 0 (to the 64/264 intersection) and mile 10-11* includes mortalities from miles 10 – 11.2 (end point for study area at Alligator River Bridge).

Objective/Task 2: Identify significant wildlife crossing areas to determine where wildlife underpasses or other design features could be placed.

Highway Barb Wire Hair Snags

From March 2009 – March 2011 we collected 851 bear hair samples from the barb wire along US 64. From March 2010 – March 2011 we collected 613 from the 1.9 mile control area along US 264. During our pilot study (Nov.-Dec. 2008) of the barb wire hair set-up, we also collected 11 addition samples from US 64. In total, the samples represent 537 crossing events for US 64 (Fig. 8) and 205 crossing events for US 264 (Fig. 9).

From the 862 US 64 samples, we selected 443 (51.4%) of the highest quality samples for genetic analysis. Thirty-three of the submitted samples were removed by the lab due to inadequate follicle quantity or quality. Genetic analysis has been completed on the remaining 410 hair samples from US 64 resulting in 158 (38.5%) successfully identified individual bears from genotypes. The 158 samples represented 54 individual bears (42M:12F) that crossed US 64; 1 time (n=29), 2 times (n=10), 3 times (n=5), 4 times (n=3), 5 times (n=3), 6 times (n=3), and 24 times (n=1). Twenty-three of the bears known to cross US 64 were also genetically identified during capture events. Three bears (1M:2F) were identified as crossing and then later were killed by a vehicle strike on US 64. Three male bears crossed both US 64 and US 264.

We submitted 256 (41.8%) of the 613 hair samples collected from the US 264 control section of barb wire for genetic analysis: 2 of the 254 samples were removed by the lab due to inadequate follicle material. Genetic analysis has resulted in 105 (41.3%) positive genetic identity individual bears from genotypes. The 105 identities represent 27 individual bears (20M:7F) that crossed the 1.9 mile long control section of US 264.The 27 bears crossed US 264; 1 time (n=9), 2 times (n=5), 3 times (n=5), 4 times (n=3), 5 times (n=2), 6 times (n=1), 8 times (n=1), and 11 times (n=1). Eight (29.6%) of the 27 bears were genetically identified from hair collected during physical capture events in culvert traps. One of the 27 genetically identified bears documented crossing US 264 was later killed by a vehicle strike on US 264 and another was later killed in Stumpy Point (~10 miles to the South) for depredation activity at a dwelling.

We tested our delineation of a crossing event (successive barbs with bear hair) as a single bear crossing by genetically analyzing multiple samples from one event. We submitted at least two samples each from 90 different crossing events where multiple hair samples were collected. Twenty-four of the 90 crossing events had two or more samples successfully genetically indentified. Only 1 (4.2%) of the 24 events identified 2 different bears in the same event. The one multiple bear crossing event occurred at the most frequently crossed section of wire on the US 264 strand. The event had five consecutive barbs with bear hair, the 2nd and 3rd barb were identified as one bear whereas the 5th barb was identified as a different bear.

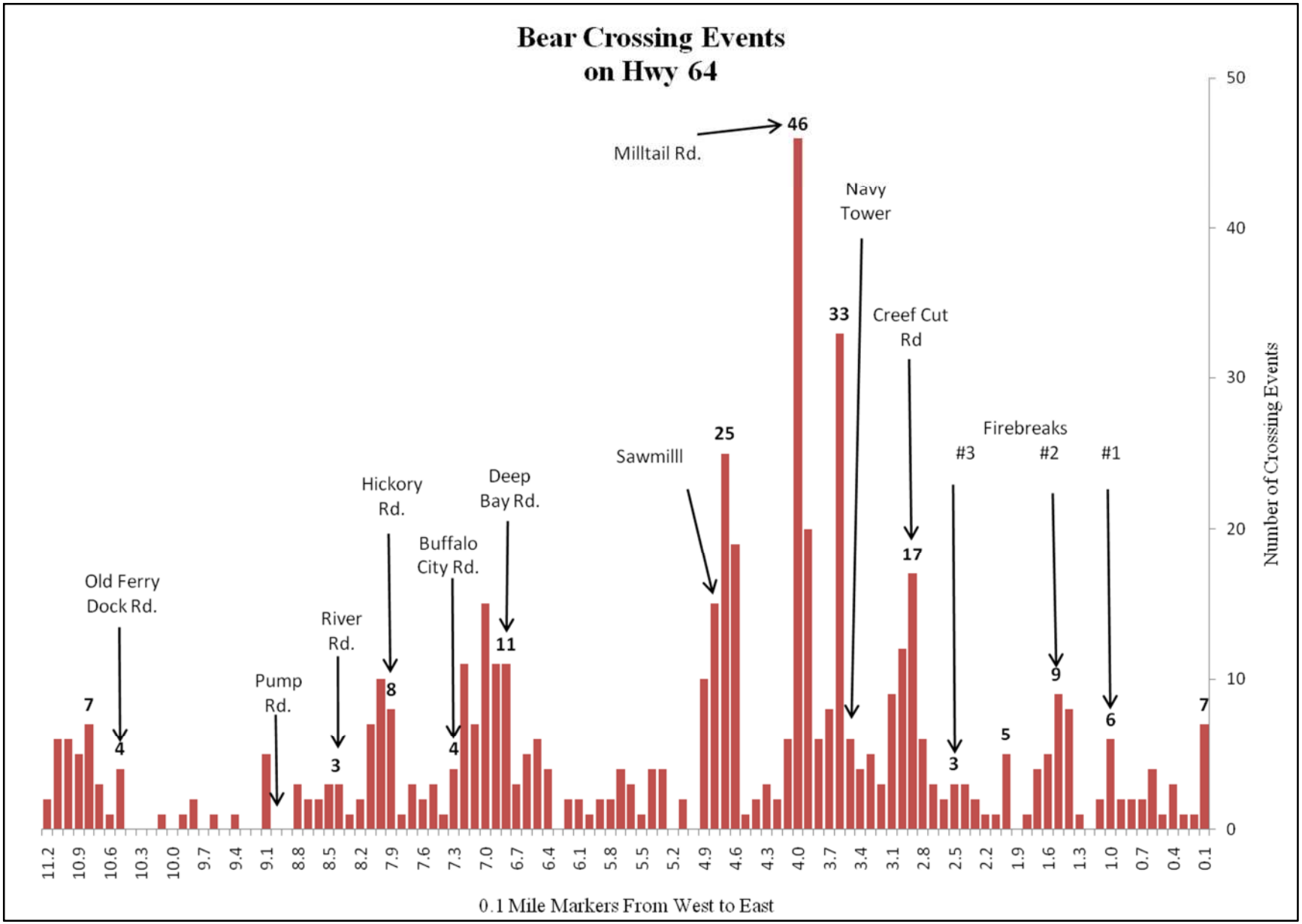

Figure 8. Bear crossing events (from barbed wire hair collection) on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011.

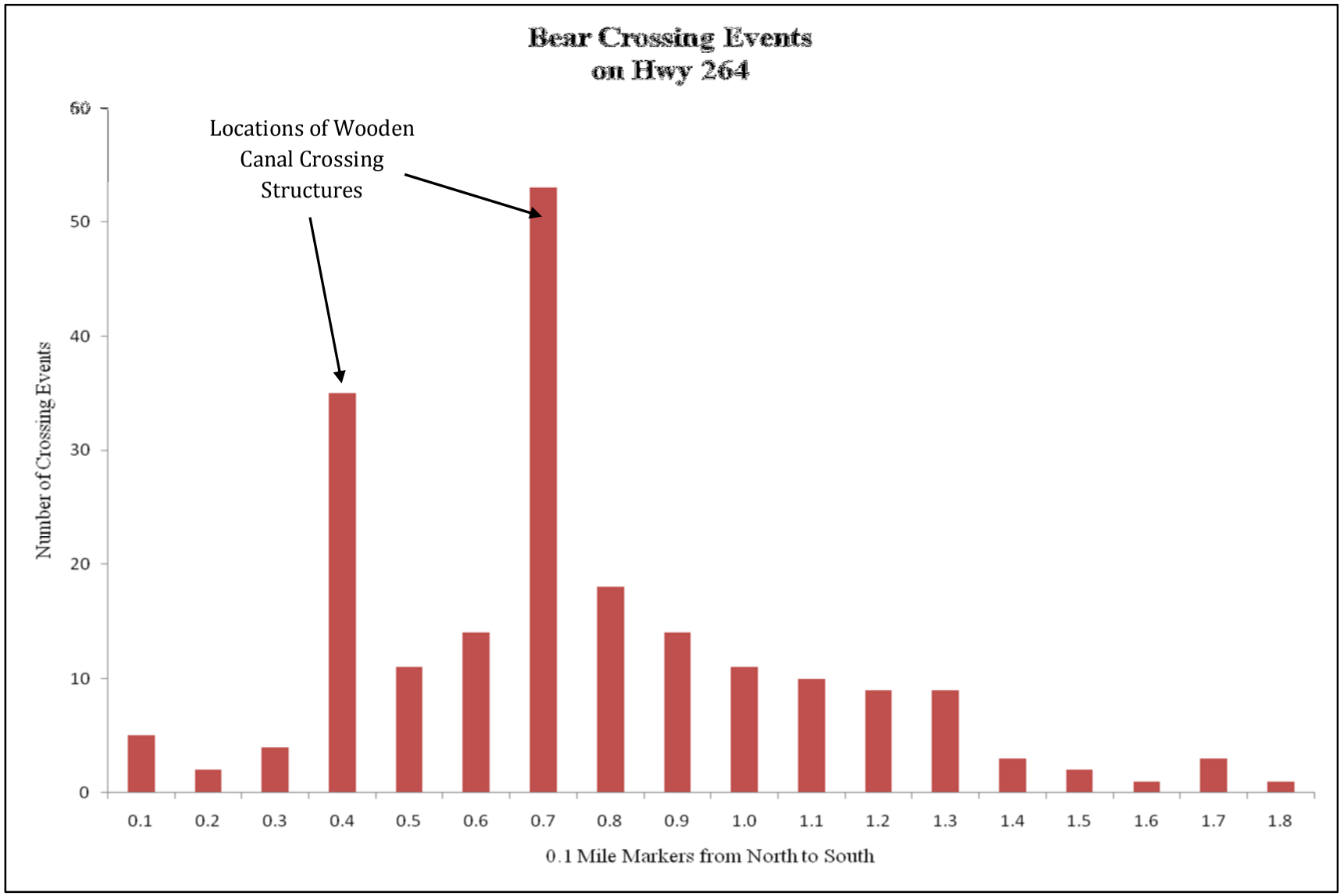

Figure 9. Black Bear crossing events (from barbed wire hair collection) on US 264 in ARNWR, Dare County, NC during March 2010 – March 2011.

Road-kill Surveys

We documented 15 road killed black bears, 8 white-tailed deer, and 1 red wolf along the US 64 study area (Fig. 10) from November 2008 through July 2011. Raccoons (n=49) and Virginia opossums (n=57) were the most abundant (Fig. 11) of the mid-sized mammal road kills. Eight other mid-sized mammal species (Fig. 12) accounted for only 28 of the 134 (Fig. 13) mid-sized mammal road kills we recorded. We also recorded 8 domestic animals (dogs and cats) but did not include them in the analysis. We recorded 82 small mammal road kills (Figs. 14 and 15) consisting of 9 separate species including 3 star-nosed moles, which are a North Carolina Species of Special Concern. We documented 75 bat road kills (Fig. 16) with the eastern red bat (n=36) as our most abundant bat species (Fig.17). We recorded two Rafinesque's big-eared bats, a North Carolina threatened species.

Bird road kills consisted of 1,153 individuals of 66 species (Table 2). We recorded large numbers of road kills for 5 species of birds; gray catbirds (n=39), American robins (n=50), swamp sparrows (n=98), prothonotary warblers (n=100), and yellow-rumped warblers (n=452). Most of the bird mortalities took place within a mile of the Alligator River Bridge (Fig. 18).

We documented 4,014 reptile road kills from 44 species (Table 3). We recorded 32 species with over 100 road kills and 3 species, the Banded water snake (n=227), northern water snake (n=267), and spotted turtle (n=442), with > 200 road kills each. The Eastern mud turtle alone accounted for 593 individual mortalities. We recorded at least one North Carolina Species of Special Concern, the timber rattlesnake (n=9). Spatially, reptiles tended to be recorded around more open areas such as the East Lake community and other small residential areas (Fig. 19).

Amphibians were, by far, the largest number of road killed mortalities we recorded with a total of 7,498 individuals from 18 species (Table 4). Frog road kills were the most abundant taxon within the amphibians; the southern leopard frog alone accounted for 2,071 individuals. The amphibian road kills tended to be located near the center and east of the study area (Fig. 20). The habitat in the eastern areas remains wetter than most of the western areas and is under the protected status of the USFWS.

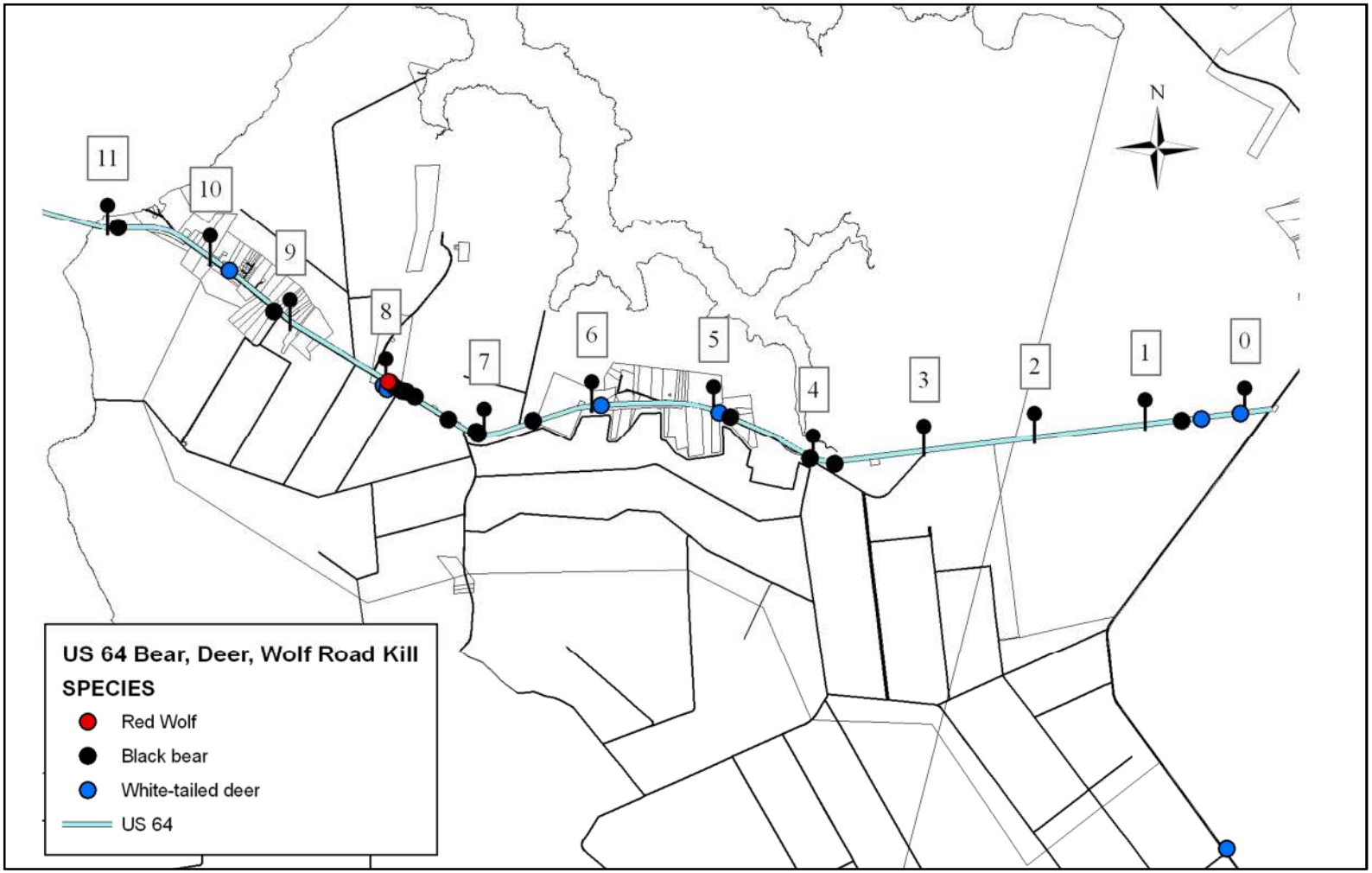

Figure 10. Black bear, white-tailed deer, and red wolf road kills on US 64 in ARNWR, Dare County, NC during November 2008 – July 2011. Black dots represent bears, blue dots represent deer, and the red dot represents the red wolf. Mile markers are denoted with black pins.

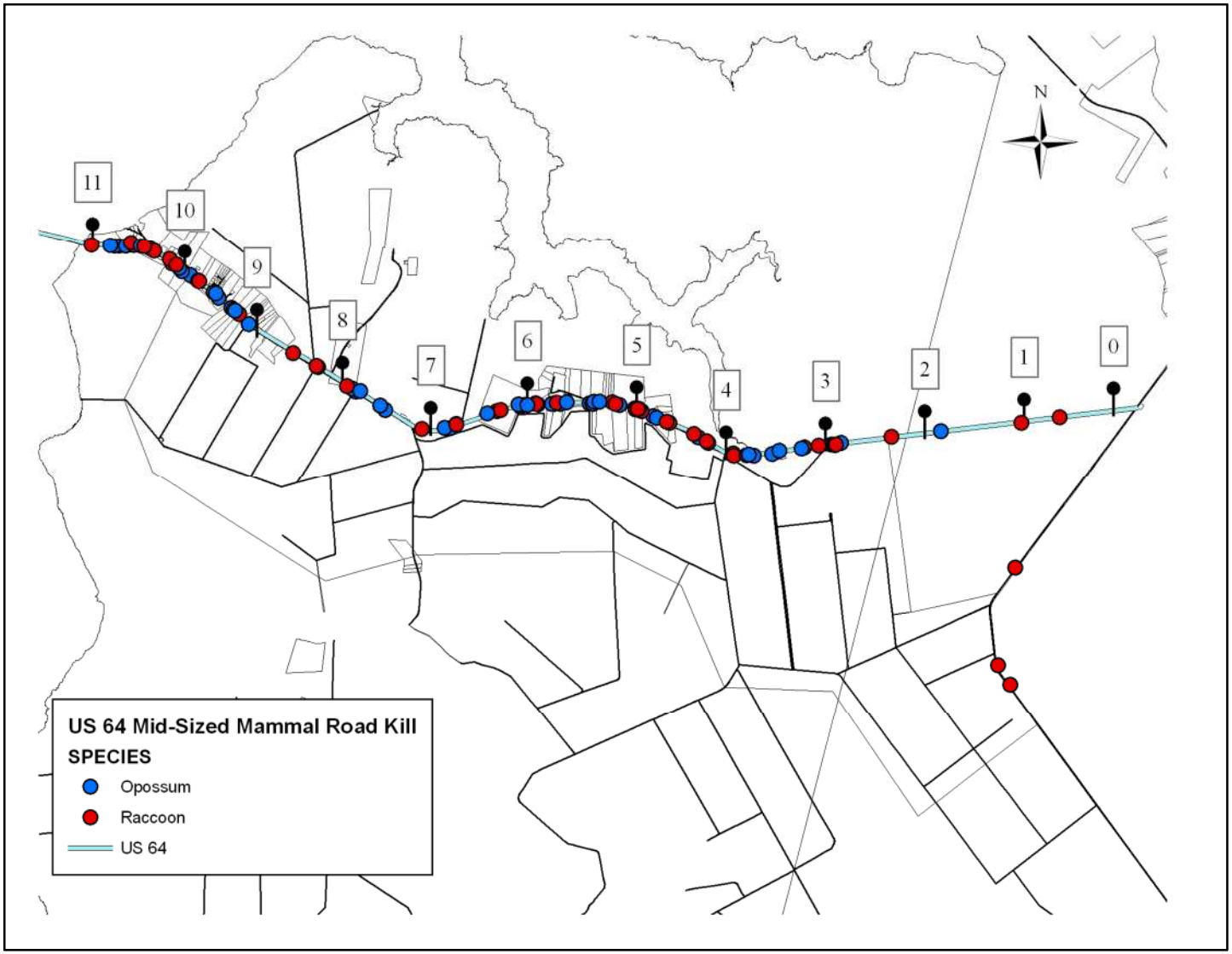

Figure 11. Raccoon and Virginia opossum road kills on US 64 and US 264 in ARNWR, Dare County, NC during March 2009 – March 2011.

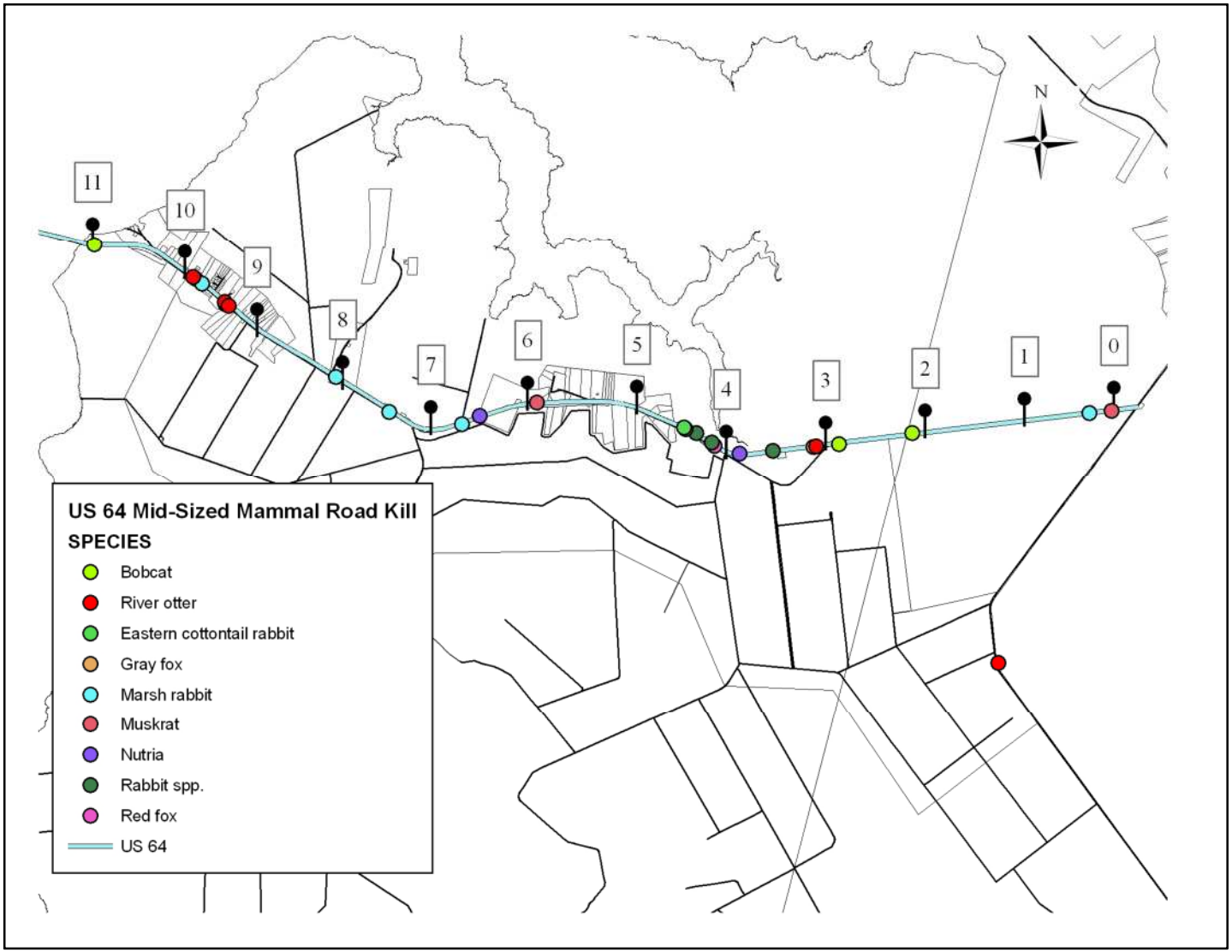

Figure 12. Mid-size mammal road kill locations, excluding raccoons and Virginia opossums, on US 64 and US 264 in ARNWR, Dare County, NC during March 2009 – March 2011.

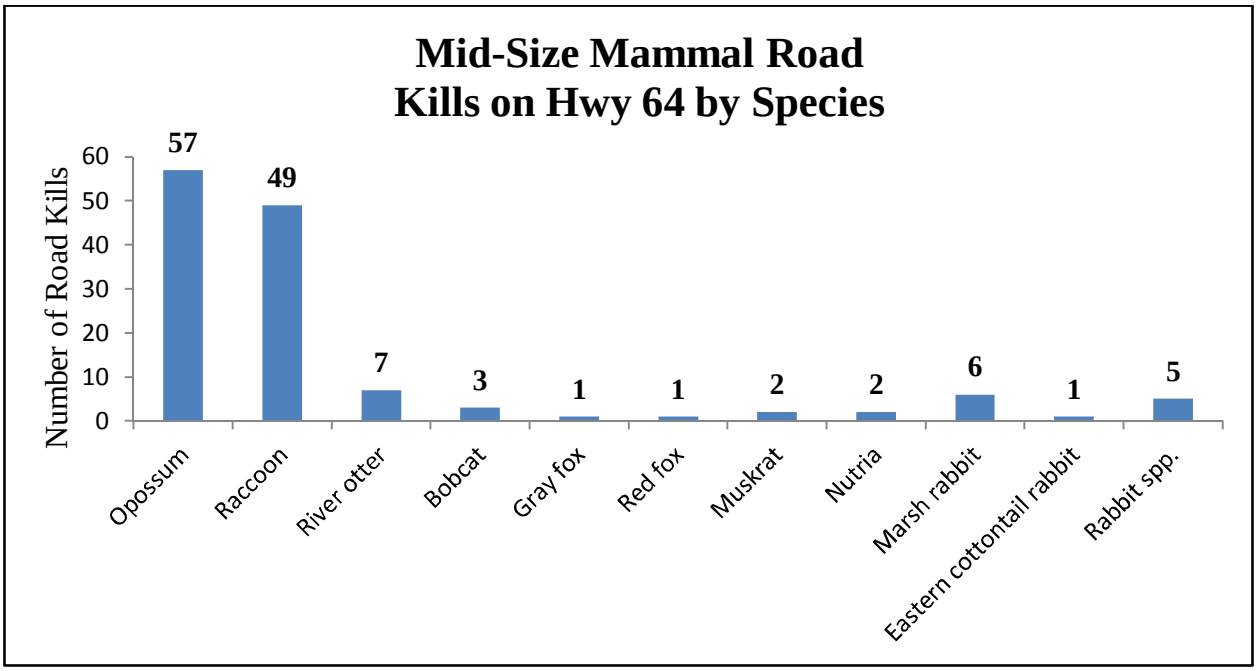

Figure 13. Mid-size mammal road kills on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011.

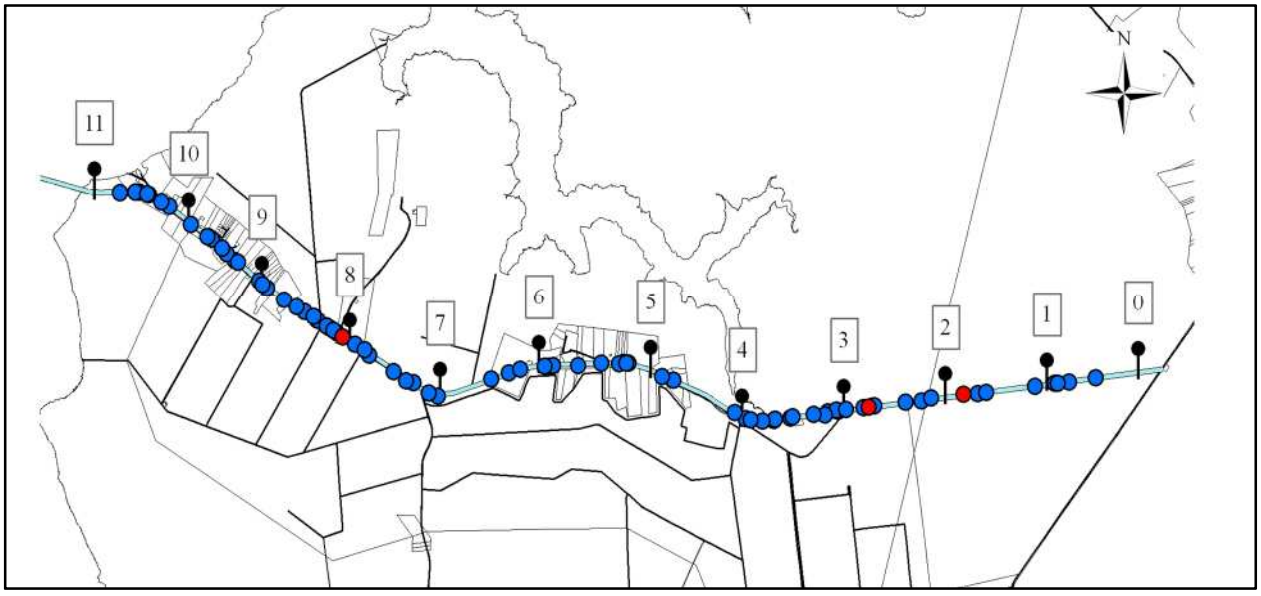

Figure 14. Small mammal road kills on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011. The 3 star-nosed moles (NC Species of Special Concern) are shown in red.

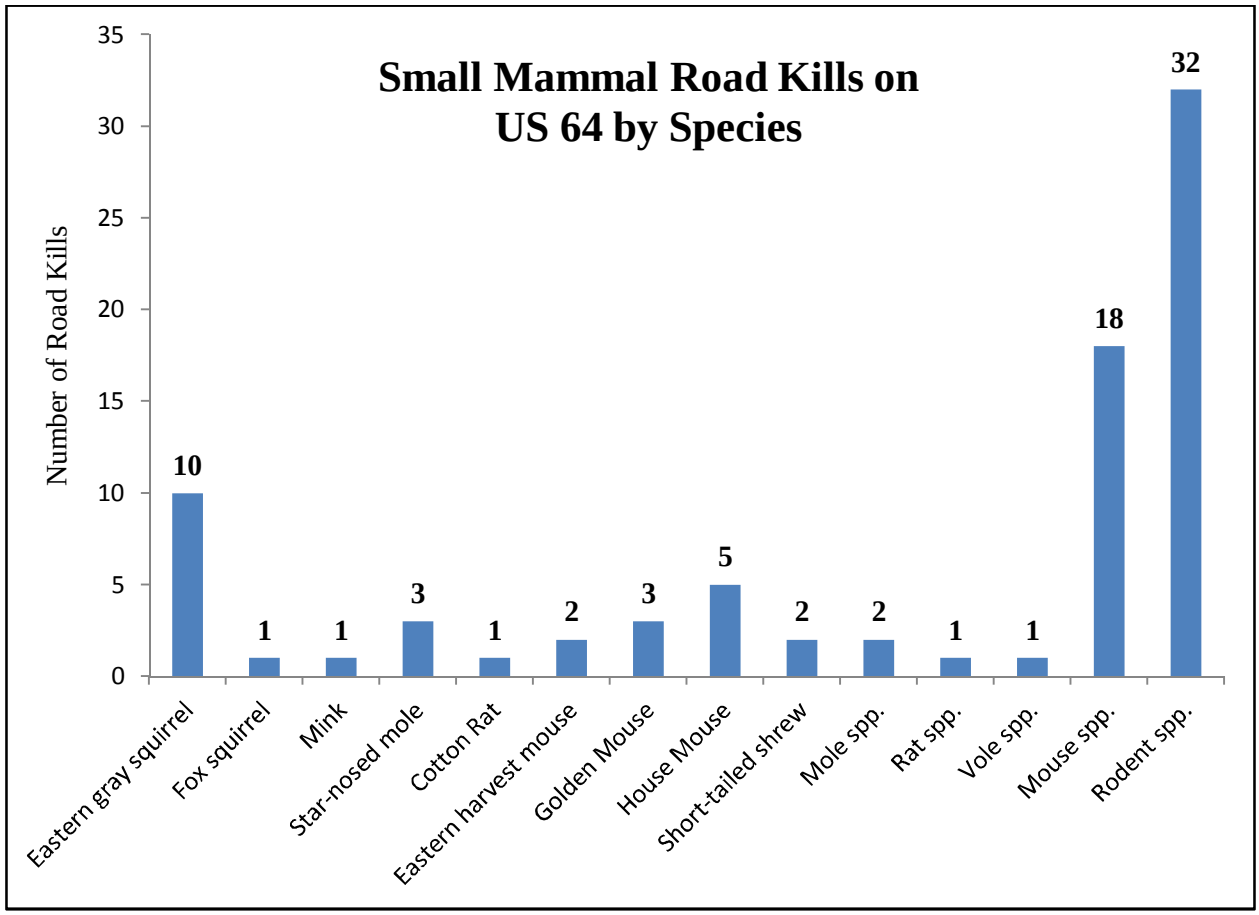

Figure 15. Small mammal road kills on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011.

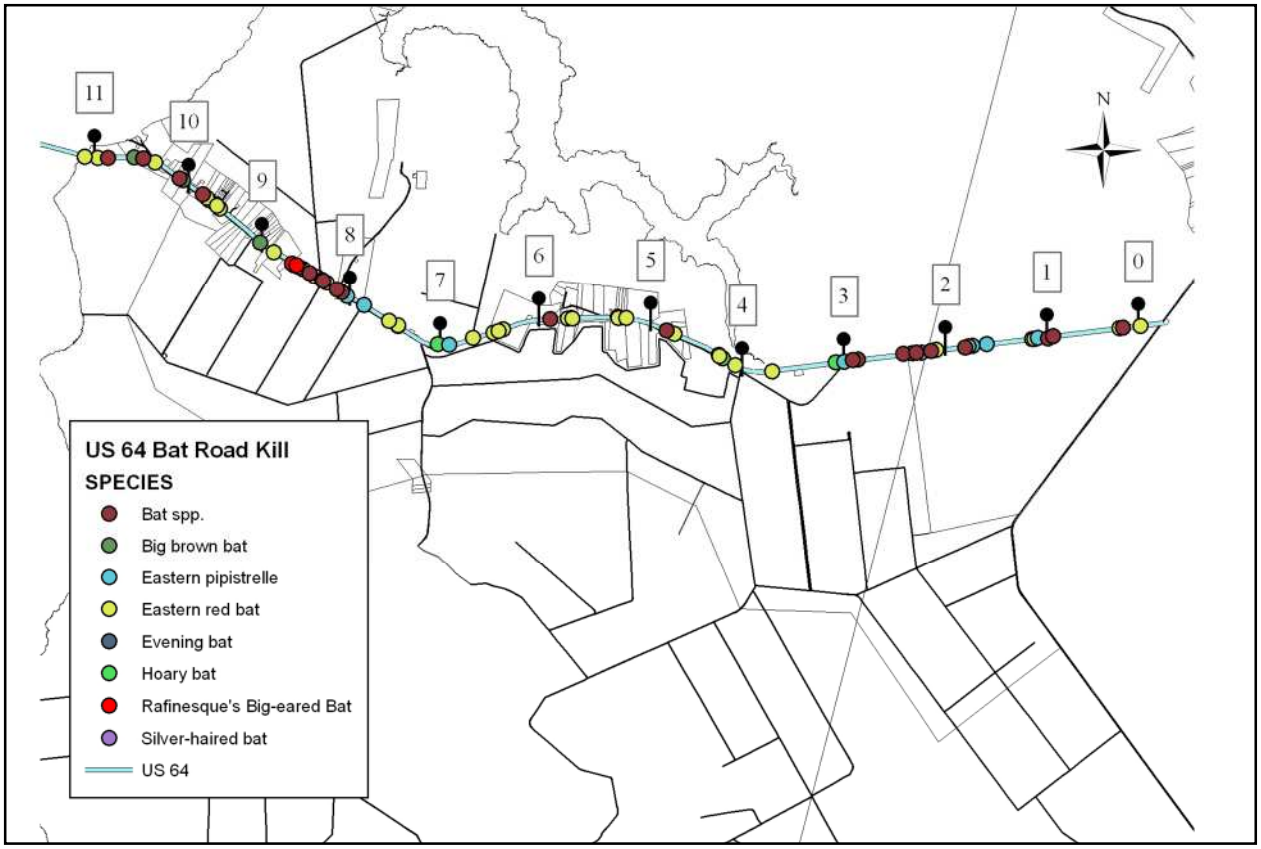

Figure 16. Bat road kills on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011.

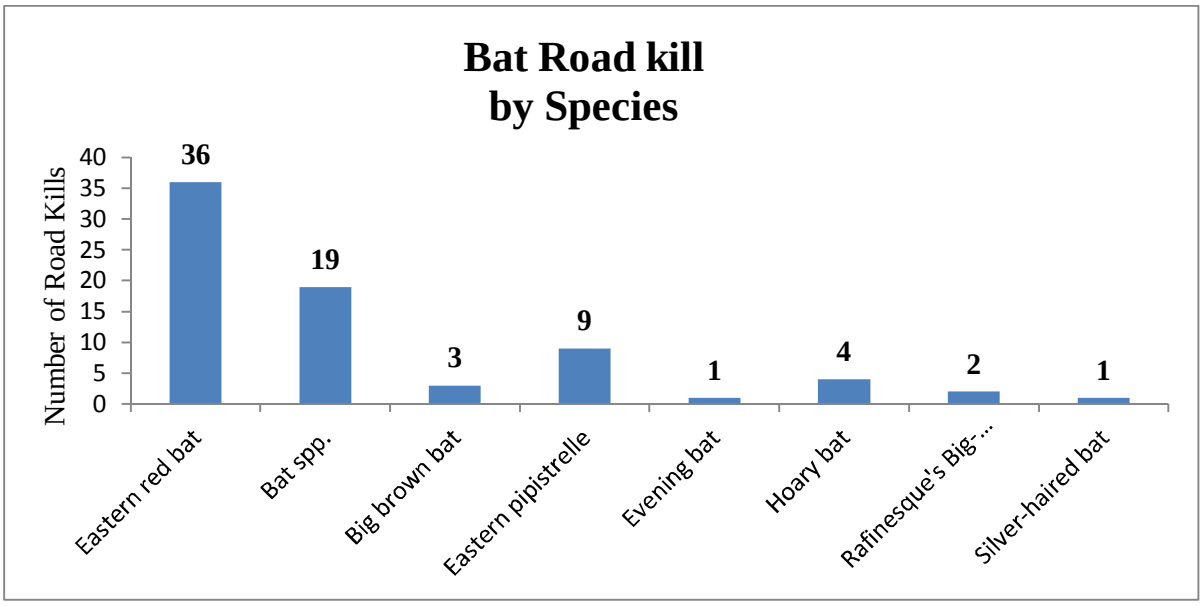

Figure 17. Bat road kill on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011.

Table 2. Bird road kills by species on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011.

Scientific name	Common name	Road kills
Acanthis flammea	Common redpoll	1
Accipiter striatus	Sharp-shinned hawk	1
Agelaius phoeniceus	Red-winged blackbird	1
Ammodramus maritimus	Seaside sparrow	8
Anthus rubescens	American pipit	1
Archilochus colubris	Ruby-throated hummingbird	28
Cardinalis cardinalis	Northern cardinal	1
Catharus guttatus	Hermit thrush	12
Ceryle alcyon	Belted kingfisher	2
Cistothorus palustris	Marsh wren	2
Coccyzus americanus	Yellow-billed cuckoo	8
Colaptes auratus	Northern flicker	5
Colinus virginianus	Northern bobwhite quail	9
Corvus brachyrhynchos	American crow	1
Dendroica coronata	Yellow-rumped warbler	452
Dendroica discolor	Prairie warbler	1
Dendroica dominica	Yellow throated warbler	1
Dendroica palmarum	Palm warbler	1
Dendroica pinus	Pine Warbler	1
Dryocopus pileatus	Pileated woodpecker	2
Dumetella carolinensis	Gray catbird	39
Fulica Americana	American coot	1
Gallinago delicata	Wilson’s snipe	1
Geothlypis trichas	Common yellowthroat	13
Helmitheros vermivorus	Worm-eating warbler	2
Hylocichla mustelina	Wood thrush	1
Icteria virens	Yellow-breasted chat	1
Larus argentatus	Herring gull	1
Larus atricilla	Laughing gull	1
Melanerpes carolinus	Red-bellied woodpecker	1
Melanerpes erythrocephalus	Red-headed woodpecker	3
Melospiza georgiana	Swamp sparrow	98
Melospiza melodia	Song sparrow	8
Mimus polyglottos	Northern mockingbird	2
Otus asio	Eastern screech-owl	18
Passer domesticus	House sparrow	3
Passerculus sandwichensis	Savannah sparrow	5
Passerina cyanea	Indigo bunting	7
Pelecanus occidentalis	Brown pelican	1
Phalacrocorax auritus	Double-crested cormorant	1
Picoides pubescens	Downy woodpecker	2
Poecile carolinensis	Carolina chickadee	6
Porzana carolina	Sora	1

Protonotaria citrea	Prothonotary warbler	100
Quiscalus major	Boat-tailed grackle	1
Quiscalus quiscula	Common grackle	3
Rallus limicola	Virginia rail	1
Regulus calendula	Ruby-crowned kinglet	11
Sayornis phoebe	Eastern phoebe	5
Scolopax minor	American woodcock	1
Seiurus aurocapillus	Ovenbird	2
Sialia sialis	Eastern bluebird	2
Sphyrapicus varius	Yellow-bellied sapsucker	5
Spinus tristis	American goldfinch	7
Spizella passerina	Chipping sparrow	2
Strix varia	Barred owl	3
Sturnus vulgaris	European starling	3
Tachycineta bicolor	Tree swallow	5
Thryothorus ludovicianus	Carolina wren	18
Toxostoma rufum	Brown thrasher	1
Troglodytes aedon	House wren	6
Troglodytes troglodytes	Winter wren	7
Turdus migratorius	American robin	50
Vireo solitarius	Blue-headed vireo	2
Zenaida macroura	Mourning dove	5
Zonotrichia albicollis	White-throated sparrow	1
Bird spp.		121
Songbird spp.		2
Sparrow spp.		18
Warbler spp.		5
Wren spp.		12

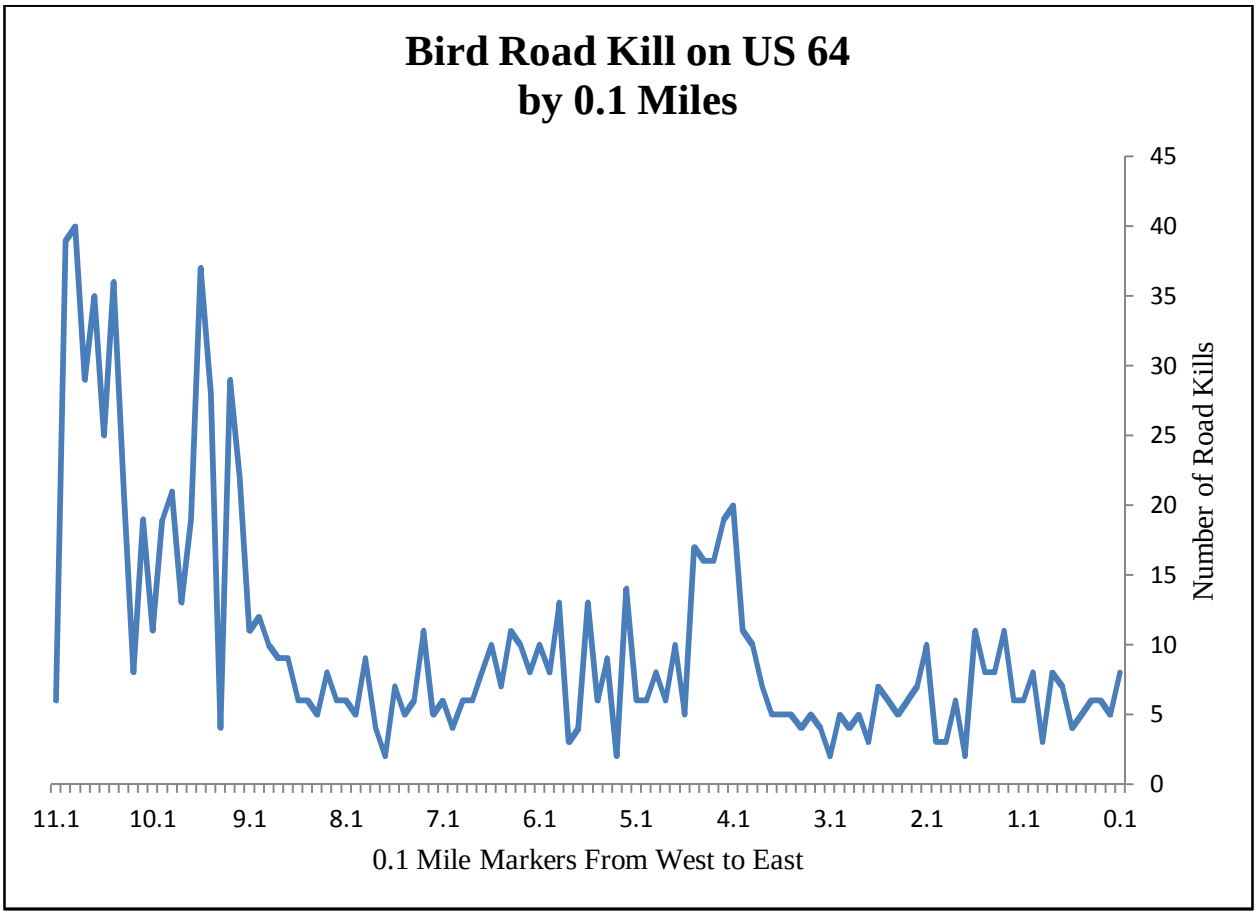

Figure 18. Bird road kills by 0.1 mile marker on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011.

Table 3. Reptile road kills by species on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011.

Scientific Name	Common Name	Road Kills
LIZARDS		
Anolis carolinensis	Green anole	56
Eumeces fasciatus	Five-lined skink	5
Eumeces laticeps	Broad-headed skink	4
Ophisaurus attenuates	Slender glass lizard	5
Ophisaurus ventralis	Eastern glass lizard	3
Scincella lateralis	Ground skink	2
Skink spp.		1
SNAKES		
Agkistrodon contortrix	Copperhead	43
Agkistrodon piscivorus	Cottonmouth	9
Carphophis amoenus	Worm snake	1
Cemophora coccinea	Scarlet snake	6
Coluber constrictor	Black racer snake	142
Crotalus horridus #(SSC)	Timber rattlesnake	9
Diadophis punctatus	Ringneck snake	3
Elaphe guttata	Corn snake	1
Elaphe obsoleta	Black rat snake	114
Farancia abacura	Mud snake	29
Farancia erytrogramma	Rainbow snake	26
Lampropeltis getula	Eastern king snake	7
Lampropeltis triangulum triangulum x elapsoides	Coastal Plain Milksnake	10
Nerodia erythrogaster	Red-bellied water snake	136
Nerodia fasciata	Banded water snake	227
Nerodia sipedon	Northern water snake	267
Nerodia taxispilota	Brown water snake	24
Opheodrys aestivus	Rough green snake	163
Regina rigida	Glossy crayfish snake	69
Seminatrix pygaea	Black swamp snake	36
Thamnophis sauritus	Eastern ribbon snake	29
Thamnophis sirtalis	Eastern garter snake	122
Virginia striatula	Rough earth snake	66
Snake spp.		348
Water snake spp.		68
TURTLES		
Chelydra serpentina	Snapping turtle	156
Chrysemys picta	Painted turtle	176
Clemmys guttata	Spotted turtle	442
Kinosternon subrubrum	Eastern mud turtle	593
Pseudemys rubriventris	Redbelly turtle	16
Pseudemys spp.	Cooter turtle	153
Sternotherus odoratus	Eastern musk turtle	10
Terrapene carolina	Eastern box turtle	124
Trachemys scripta	Yellowbelly slider	153

Trachemys scripta elegans	Red-eared slider	7
Turtle spp.		152

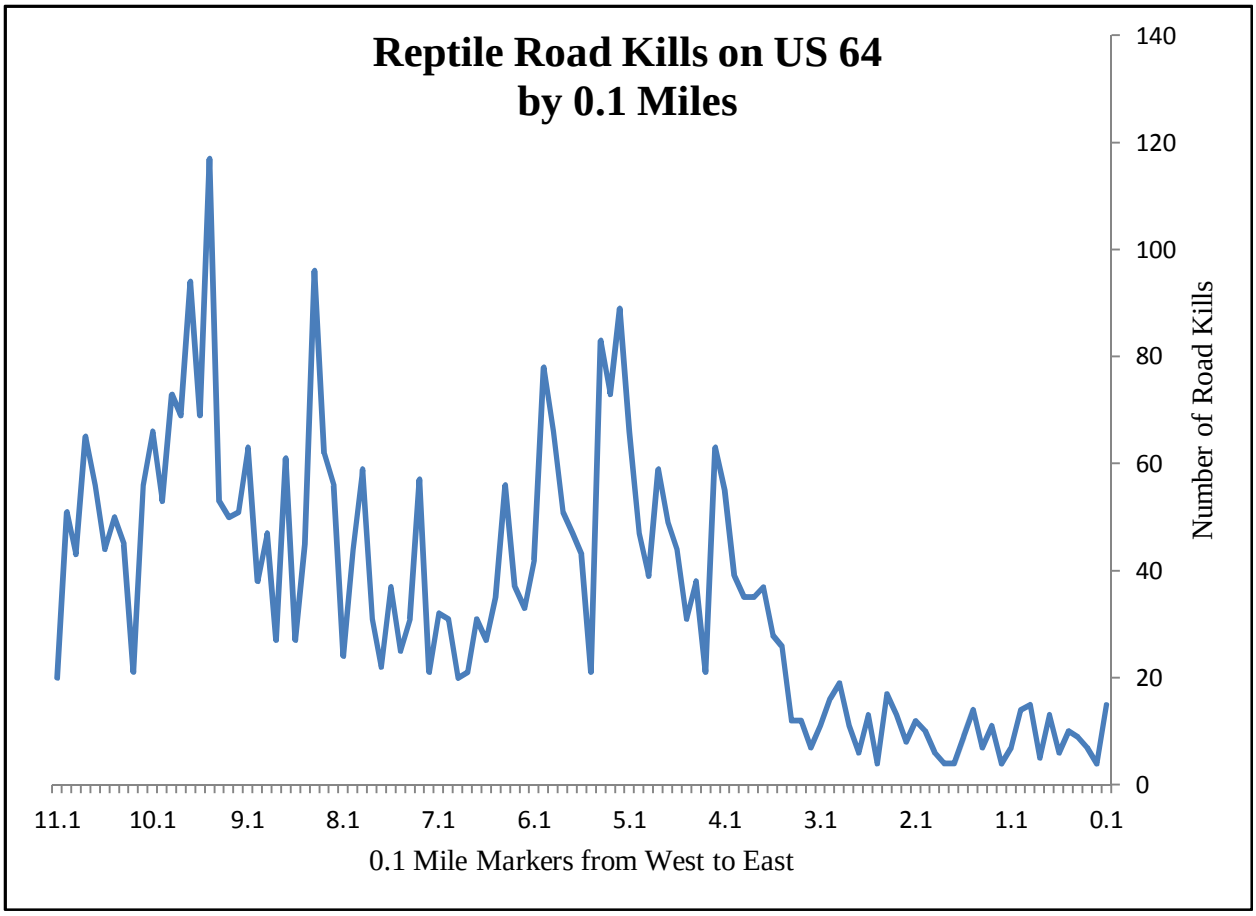

Figure 19. Reptile road kills by 0.1 mile marker on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011.

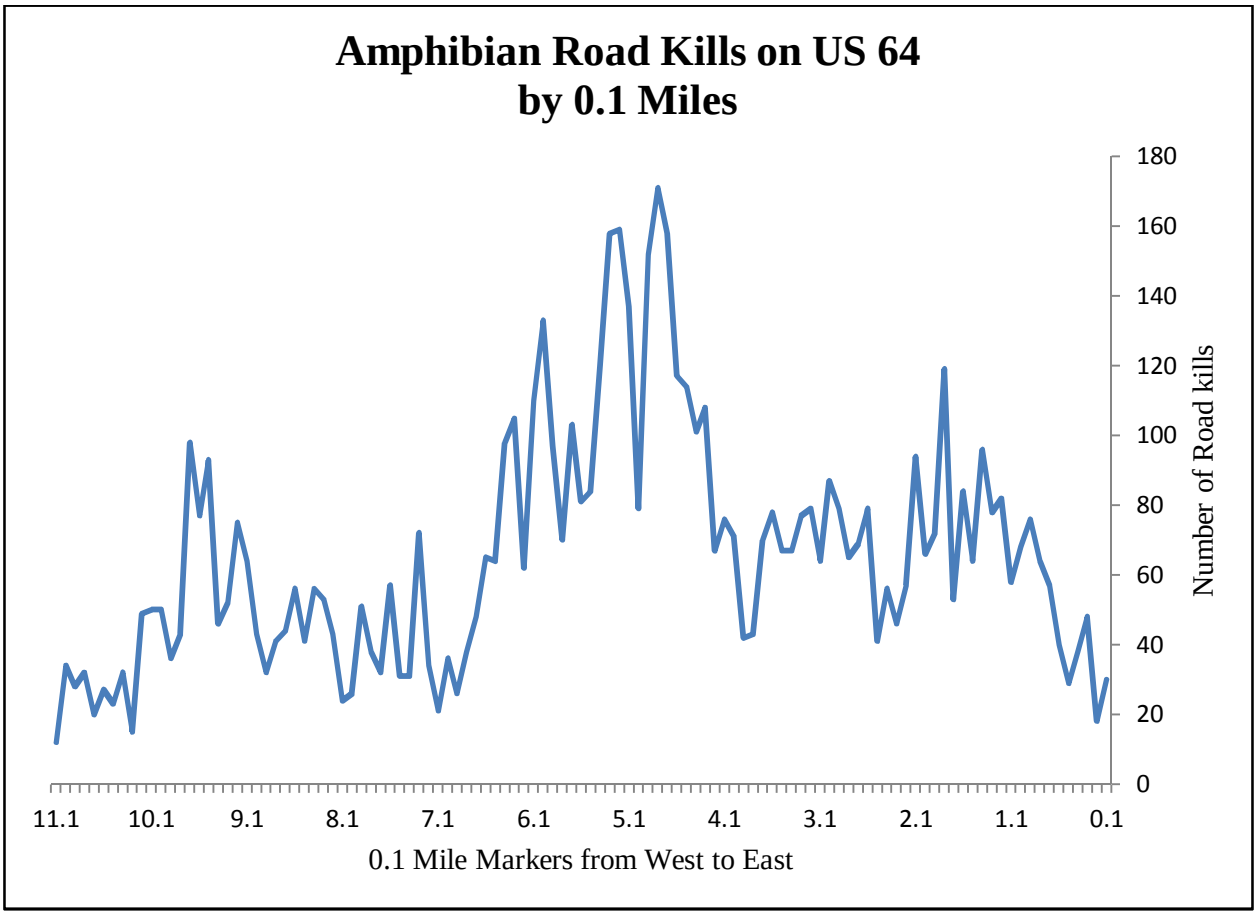

Figure 20. Amphibian road kills by 0.1 mile marker on US 64 in ARNWR, Dare County, NC during March 2009 – March 2011.

Table 4. Amphibian road kills by species on US 64 in ARNWR, Dare County NC during March 2009 – March 2011.

Scientific Name	Common Name	Road kills
FROGS		
Acris gryllus	Southern cricket frog	3
Hyla chrysoscelis	Cope's gray treefrog	66
Hyla cinerea	Green treefrog	741
Hyla femoralis	Pine woods treefrog	28
Hyla squirella	Squirrel treefrog	42
Rana catesbeiana	Bullfrog	191
Rana clamitans	Green frog	108
Rana palustris	Pickerel frog	12
Rana sphenocephala	Southern leopard frog	2071
Rana virgatipes	Carpenter frog	47
Frog spp.		1999
Treefrog spp.		92
TOADS		
Bufo americanus	American toad	75
Bufo fowleri	Fowler's toad	13
Bufo quercicus	Oak Toad	2
Bufo terrestris	Southern toad	654
Toad spp.		1208
SALAMANDERS		
Plethodon chlorobryonis	Atlantic coast slimy salamander	2
OTHERS		
Amphibian spp.		126
Gastrophryne carolinensis	Eastern narrow-mouthed toad	12
Scaphiopus holbrookii	Eastern spadefoot	6

Remote Camera Surveys

We logged over 3,800 remote camera trap nights from 12 stations set-up at guard rail breaks along US 64 through ARNWR. We photo-captured 260 black bears (Fig. 21) and 170 white-tailed deer (Fig. 22) from 11 of 12 and 10 of 12 different camera stations, respectively, during the period of ~ June 2009 – March 2011. Other abundant wildlife recorded during photo-trapping included; bobcats (n=209) and raccoons (n=208) (Fig. 23). We recorded 177 red wolves and 120 wild canids; however, they are discussed in a companion study and are not included in this analysis. We also photo-captured a small number of birds (passerines, vultures, and, one red-shouldered hawk) turtles, and snakes.

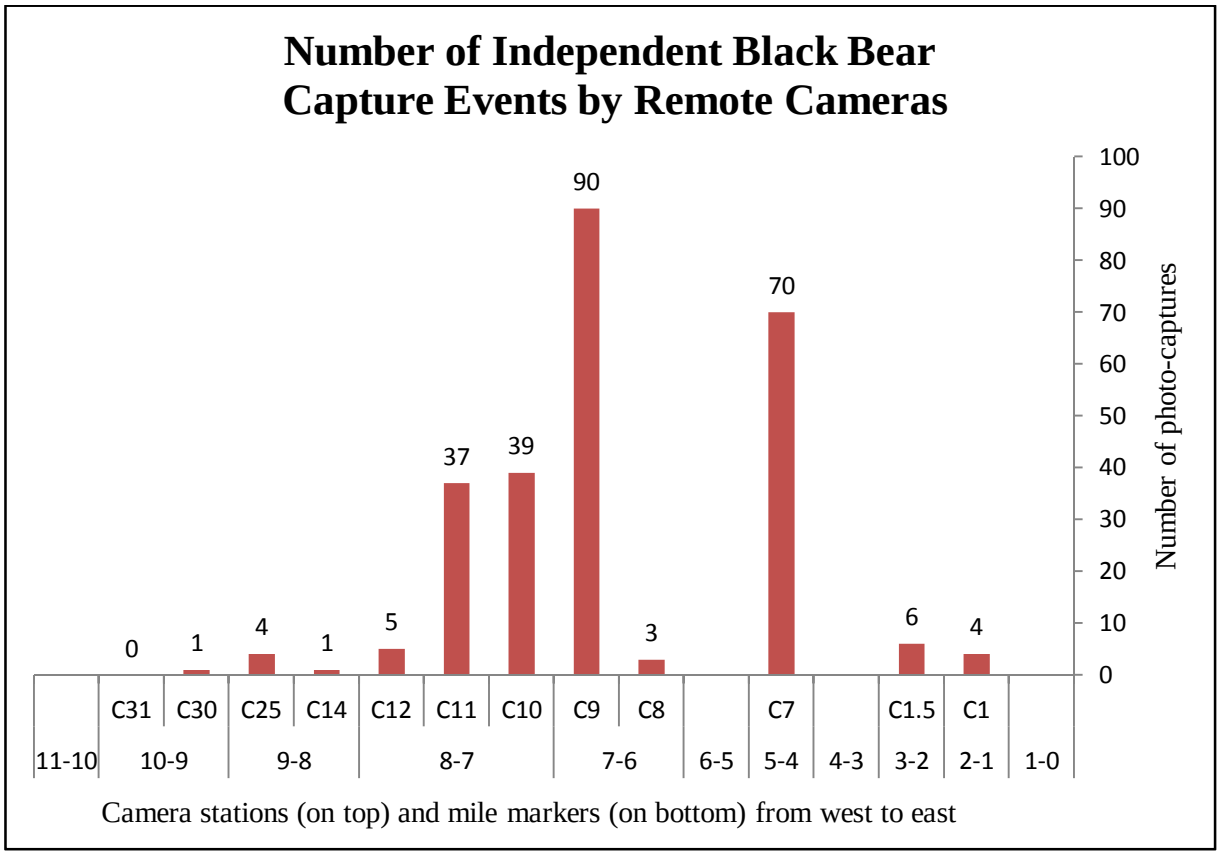

Figure 21. Distribution of black bears captured by remote camera on US 64 through ARNWR from June 2009 – March 2011.

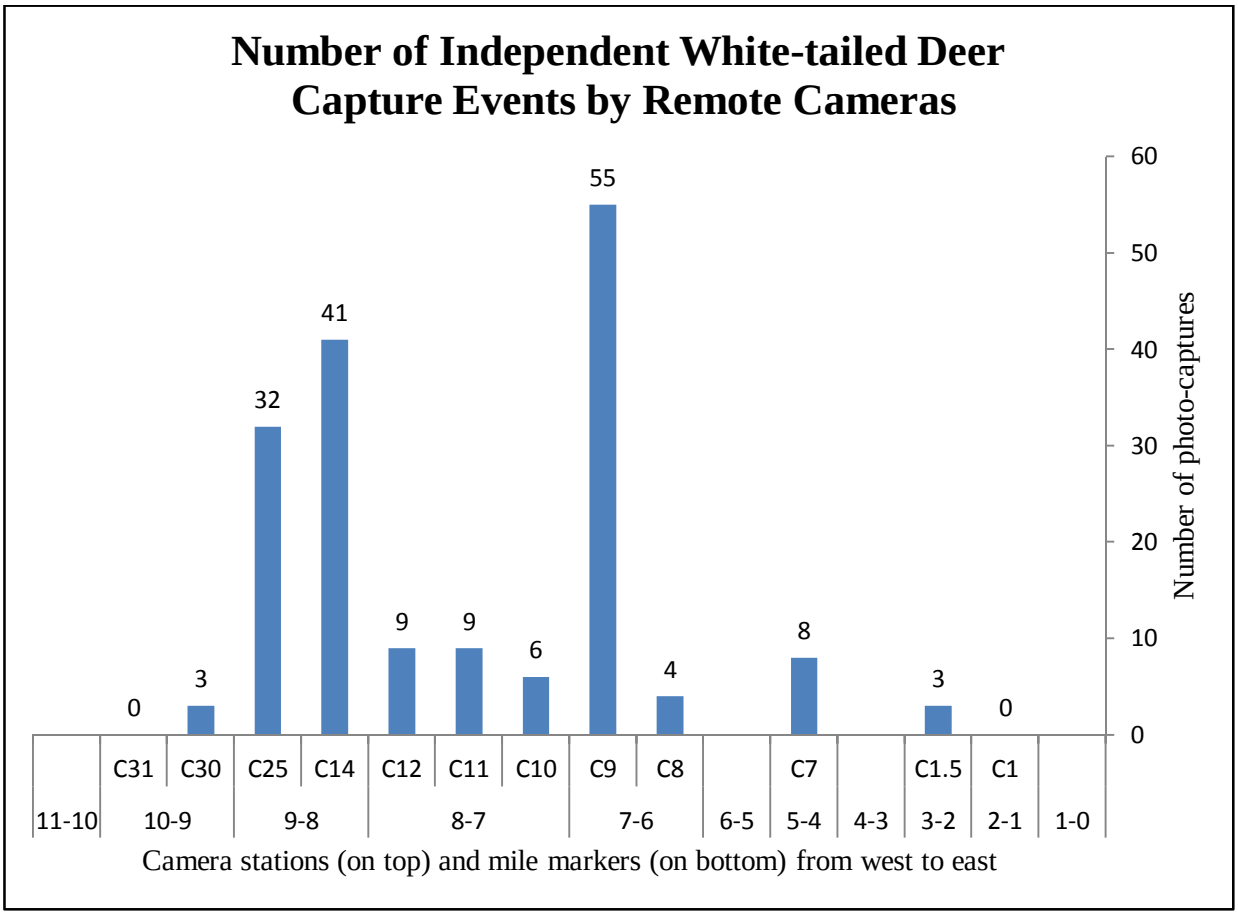

Figure 22. Distribution of white-tailed deer captured by remote camera on US 64 on ARNWR from June 2009 – March 2011.

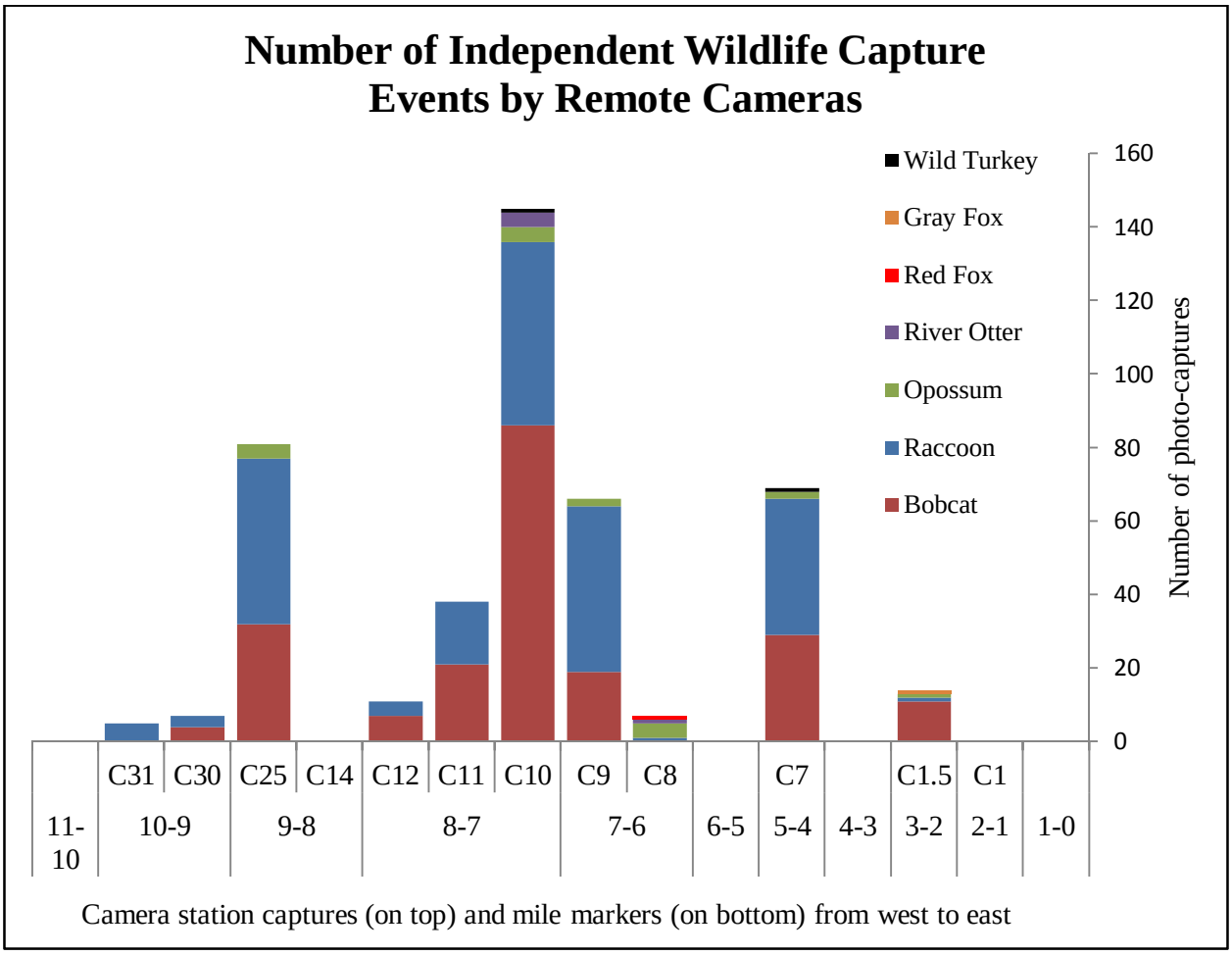

Figure 23. Distribution of various wildlife species captured by remote cameras along US 64 on ARNWR from June 2009 – March 2011.

Wildlife Driving Surveys

We drove the entire length of US 64 round trip from the US highway 64/264 intersection to the Alligator River Bridge and a 5-mile section south along US 264 to Borrow Pit Rd, 135 times between March 4, 2009 and March 2, 2010 (Fig. 24). Overall, we detected terrestrial wildlife on 31 (23.0%) of the driving surveys. We detected terrestrial wildlife along the US 64 survey site on 28 (20.7%) survey occasions; black bears were detected on just 3 (2.2%) of these surveys (2 sunset and 1 sunrise). We detected white-tailed deer on 19 surveys along US 64 and on 2 surveys on US 264. Detection of white-tailed deer was nearly equally successful during survey periods 22:00 – 24:00 (n=7), 24:00 – 02:00 (n=7), and sunset (n=6); sunrise was least successful with only 1 detection.

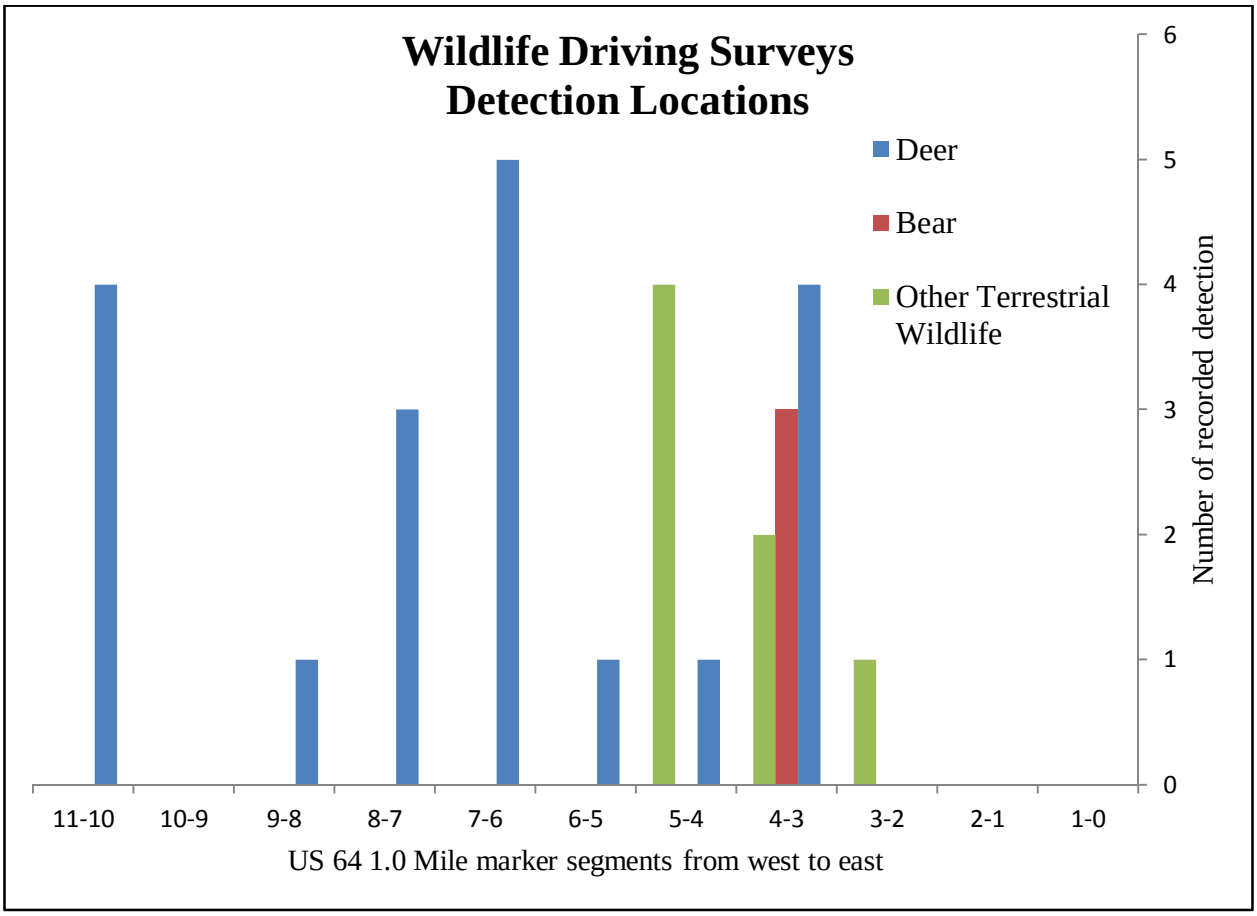

Figure 24. Distribution of terrestrial wildlife recorded during driving surveys performed from March 2009 – March 2010 on US 64 through ARNWR, Dare County, NC.

GPS Radio Collar Crossing Data

We deployed 30 GPS radio collars on 57 (30M:27F) individual bears over the study period. We used cotton break-away spacers in 2009 (Hellgren et al., 1988), which broke within 1-13 months, and leather break-away spacers in 2010, which lasted 2-19 months. The average number of highway crossings by 49 bears collared 30 or more days was 1.99 crossings every 100 days (0.0199 crossings per day). Seventy-eight percent (18/23) of collared female and 50% (13/26) of collared male bears did not cross either highway. An adult female with at least 1 cub crossed US 264 3 times before being killed on the highway 7 days after we collared her. A second adult female was killed on US 264 23 days after we collared her; she crossed the highway 15 times in that period (0.65 crossings/day). The total number of crossings by individual bears varied with age and sex (Table 5). Bears were documented crossing almost every mile section of US 64, but the greatest number of crossings (n=27) took place between mile markers 3 and 4 (Fig. 25).

Table 5. Documented crossings of US 64 and 264 within ARNWR by black bears during June 2009 – June 2011, Dare County, NC.

# Crossings	Females				Males			
	Senior 10+	Adult 5-10	Sub-adult 2-4	Yearling 0-1	Senior 10+	Adult 5-10	Sub-adult 2-4	Yearling 0-1
1		1						
2	1	1	1		1	1	1	
3		1*					1	
4						1	3	
6							1	
8							1	
11		1						
12							1	
13							1	
15		1*						
41							1	
Total Crossings	2	32	2	0	2	6	97	0

* Road killed bears wearing a GPS radio collar at the time of death. Total crossings is the number of bears time the number of crossings (i.e. 1 adult female bear crossing the highway 15 times = 1 * 15)

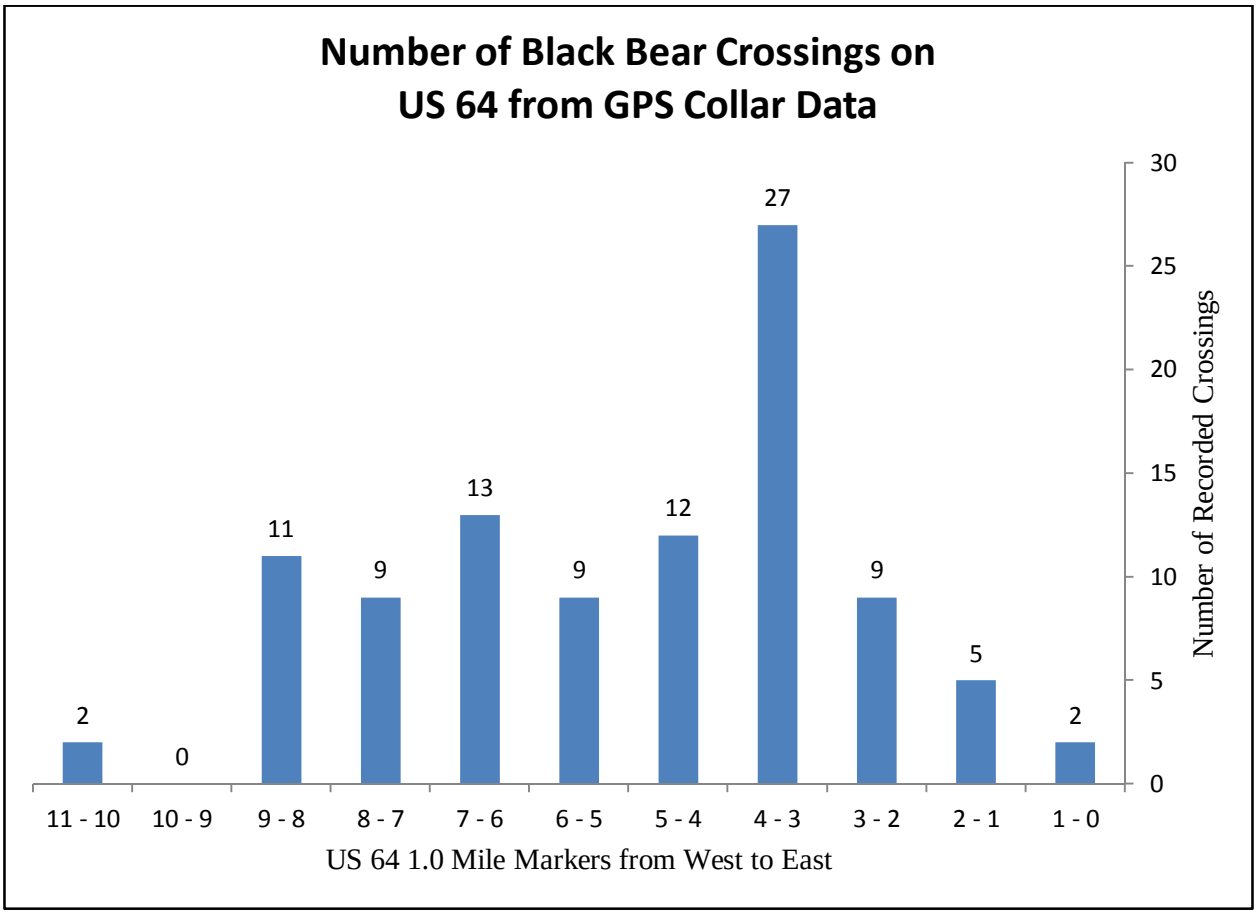

Figure 25. Distribution of black bear crossings of US 64 determined from GPS radio collars during June 2009 – June 2011 within ARNWR, Dare County, NC.

Objective/Task 3: Determine seasonal movement patterns, reproductive success and survival of black bears along highway improvement corridor on Alligator River National Wildlife Refuge.

GPS Radio Collar Data

Black Bear Seasonal Movements

Twenty-two bears (8M:14F) with GPS radio collar data spanning at least 90 days and 2 seasons were examined for seasonal movement patterns. We recorded spring movements for 4 male bears (Fig. 26); 3 traveled extensively along US 64 and crossed the highway in multiple locations. One of the 3 expanded its range into the far NE section of the refuge and along the western edge of the Manns Harbor residential community. The fourth male bear spent the spring along 264 on the eastern side of ARNWR. Female bear (n=11) movements in spring were concentrated directly around the winter den areas with gradual movements towards the ARNWR farm field areas (Fig. 27).

During summer, male bears (n=8) used ARNWR farm fields and the southern forested areas of ARNWR (Fig. 28). One male bear briefly traveled into the Dare Bombing Range (DBR), and 2 traveled into the area north of US 64 around the South Lake area. Female bears (n= 14) traveled throughout ARNWR farm field areas during spring as well as the forested areas to the south (Fig.29). One female bear traveled into the DBR and 1 female bear briefly traveled northward across US 64.

During fall, male bears (n=7) concentrated their movements within the farm field areas (Fig. 30). Two male bears ventured north of US 64, 1 extensively behind the East Lake community. Female bears (n=14) again used ARNWR farm fields and the southern refuge sections during fall: 2 bears crossed US 64 into the near northern area (Fig. 31).

Six male bears remained collared during 2 winter seasons; 2 denned or were inactive and 4 were active. One denned north of US 64 during the 2010 – 2011 winter season. The second inactive bear spent the winter in northern Hyde County and the far southern portion of ARNWR (Fig.32). Two of the 4 male bears that remained active split their time between farm fields and wood lots while the remaining 2 active bears stayed within wooded stands throughout the winter.

Thirteen of 14 female bears spent at least 2 months in a winter den (Fig. 33). Female #543 did not settle into one location, but continued to move within a wood block adjacent to Milltail road during the entire season. All 14 female winter ranges were located entirely within wooded blocks of habitat on ARNWR. One female bear denned in a small wood block ~235 meters (0.15 miles) from US 64 near Milltail Rd. Two other female bears denned adjacent to the farm field edges while 1 female bear crossed US 64 to den in the northern area of ARNWR.

Two female bears moved ~18 kilometers (~12 miles) from the center forested areas of ARNWR to the southeastern area near the community of Stumpy Point (Fig. 34). One of the bears, a 19

year old, left the wooded area south of ARNWR farm fields on 8/1/2009 and returned to the same area on 9/12/2009. The other female (9 yr old) made the trip in 10 days from 12/20/2010 – 12/30/2010, and also returned to the wooded areas from where she started.

We documented 1 long distance movement from ARNWR through Hyde County and into Tyrrell County by a 10 – 11 year old male bear (Fig. 35). This bear stayed in Tyrrell County through the fall and winter seasons; however, its GPS collar failed in early 2011. A 5-year old collared male bear traveled south into Hyde County where he was later found dead of an unknown cause.

From hunter check data we documented 3 additional male bears, ear tagged during our study on ARNWR, harvested in Hyde County. The 3 bears were ages 3, 8, and 10-11 years old and had thus moved through ARNWR to the agricultural fields and hunt club lands to the south.

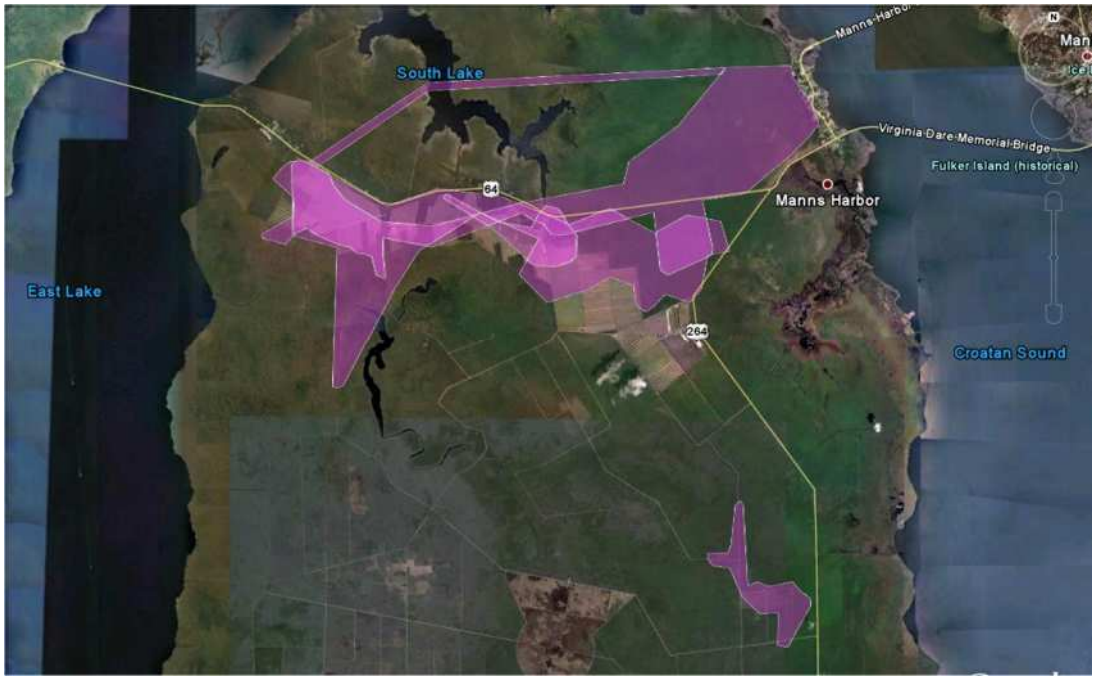

Figure 26. Spring 2010 spatial distribution of 4 male bears on ARNWR, Dare County, NC.

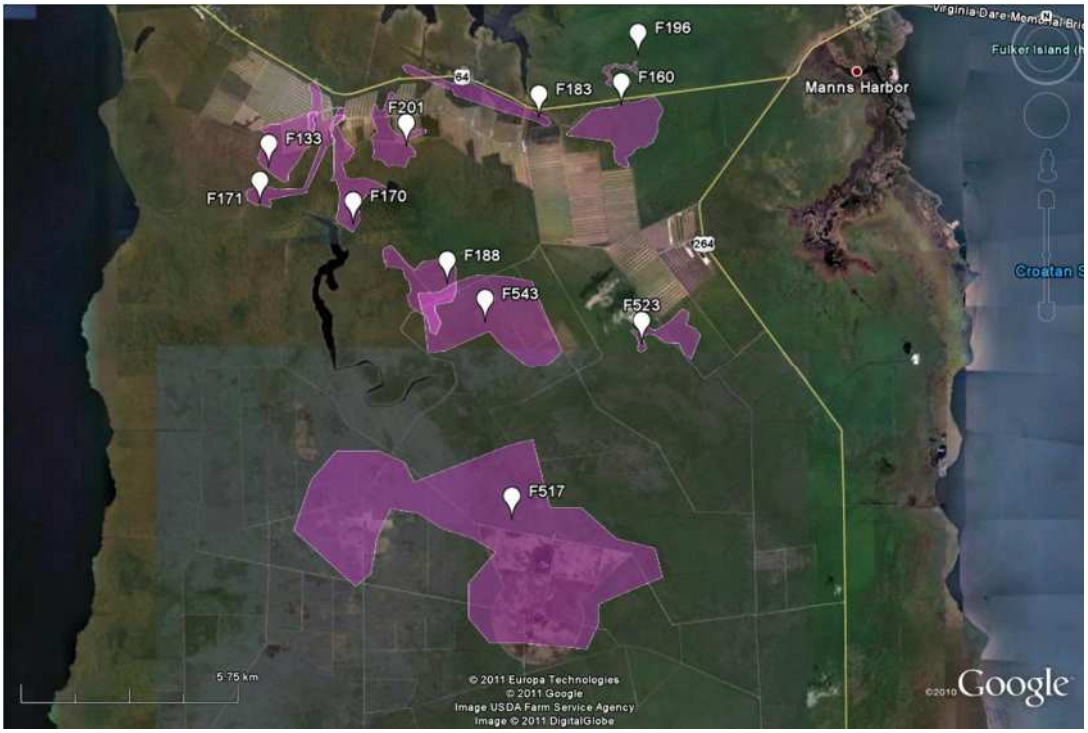

Figure 27. Spring 2010 spatial distribution of 11 female bears on ARNWR, Dare County, NC. White pins mark winter den locations except for bear F543, which did not den, but continued to move throughout the winter

Figure 28. Summer 2009 and 2010 spatial distribution of 8 male bears on ARNWR, Dare County, NC.

Figure 29. Summer 2009 and 2010 spatial distribution of 14 female bears on ARNWR, Dare County, NC.

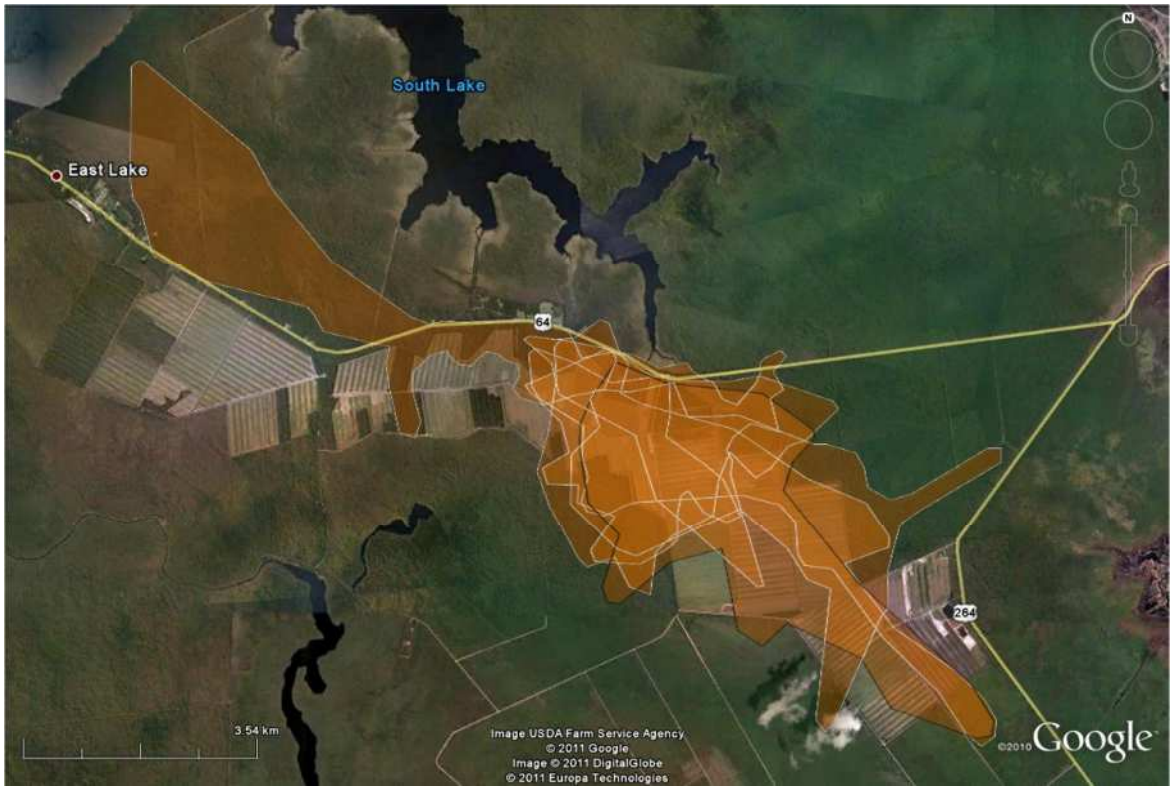

Figure 30. Fall 2009 and 2010 spatial distribution of 7 male bears on ARNWR, Dare County, NC.

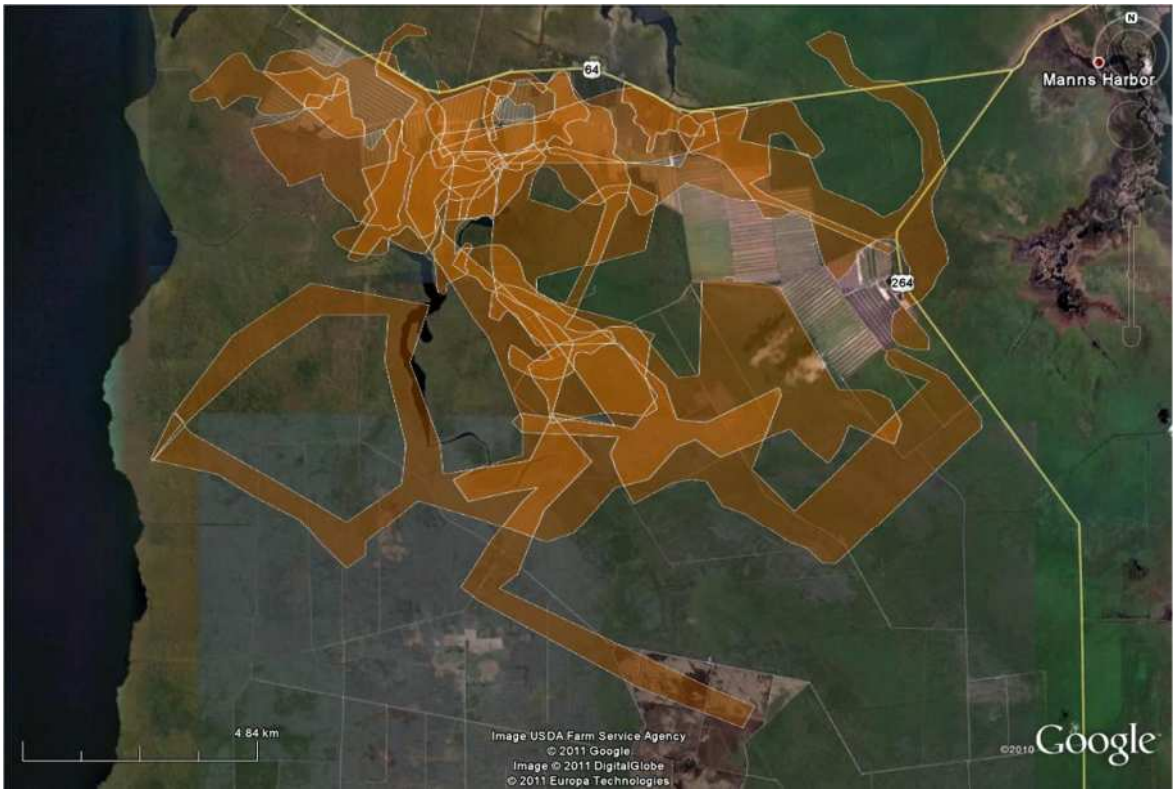

Figure 31. Fall 2009 and 2010 spatial distribution of 14 female bears on ARNWR, Dare County, NC.

Figure 32. Winter 2010 spatial distribution of 6 male bears on ARNWR, Dare County, NC.

Figure 33. Winter 2010 den locations and spatial distributions identified for 14 female bears on ARNWR, Dare County, NC. White pins indicate den sites except for F543, which did not den, but constrained her movements to the highlighted area.

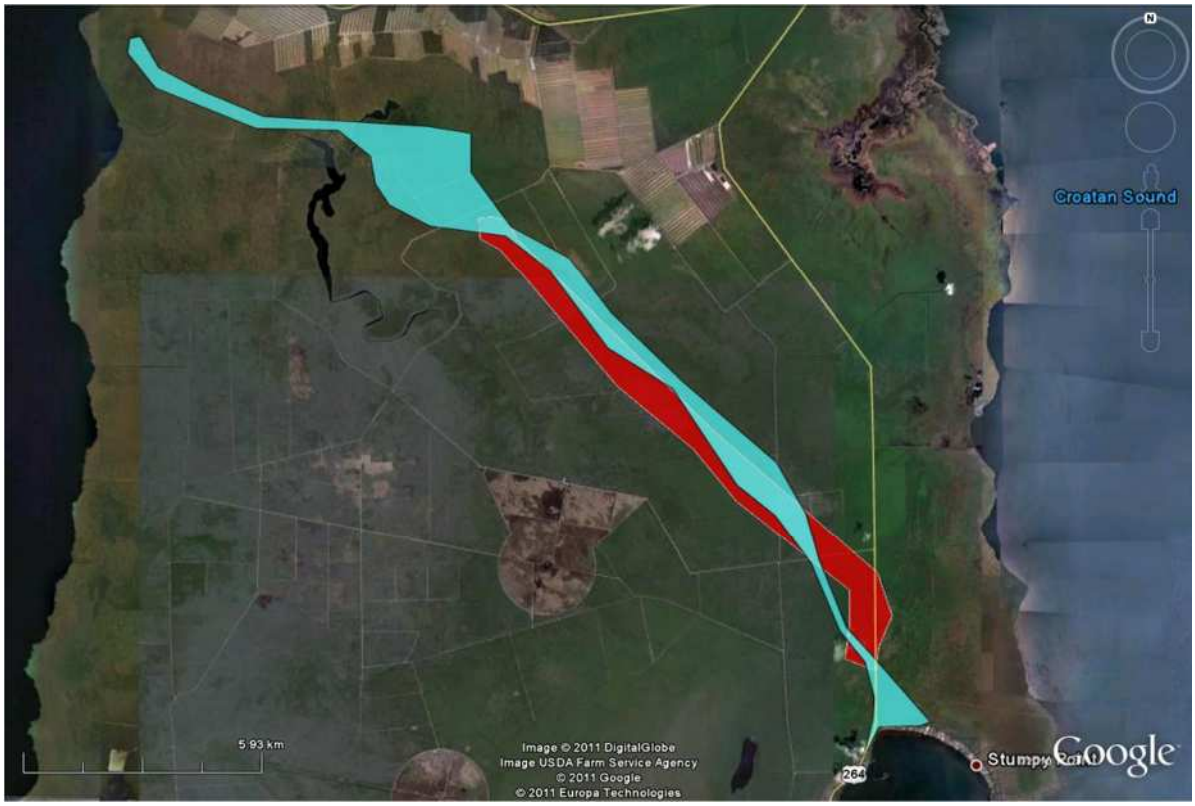

Figure 34. Long distance movements by 2 female bears on ARNWR, Dare County, NC. The blue area represents a round trip movement of a 19-year old from the far north western corner of the study area to the Stumpy Point residential area and back again. The female's movement and return took place between 8/1 – 9/12/2009. The red area depicts the movements of a 9-year old bear from the central wooded area of ARNWR to just north of Stump Point and back again, which took place from 12/20 – 12/30/2010.

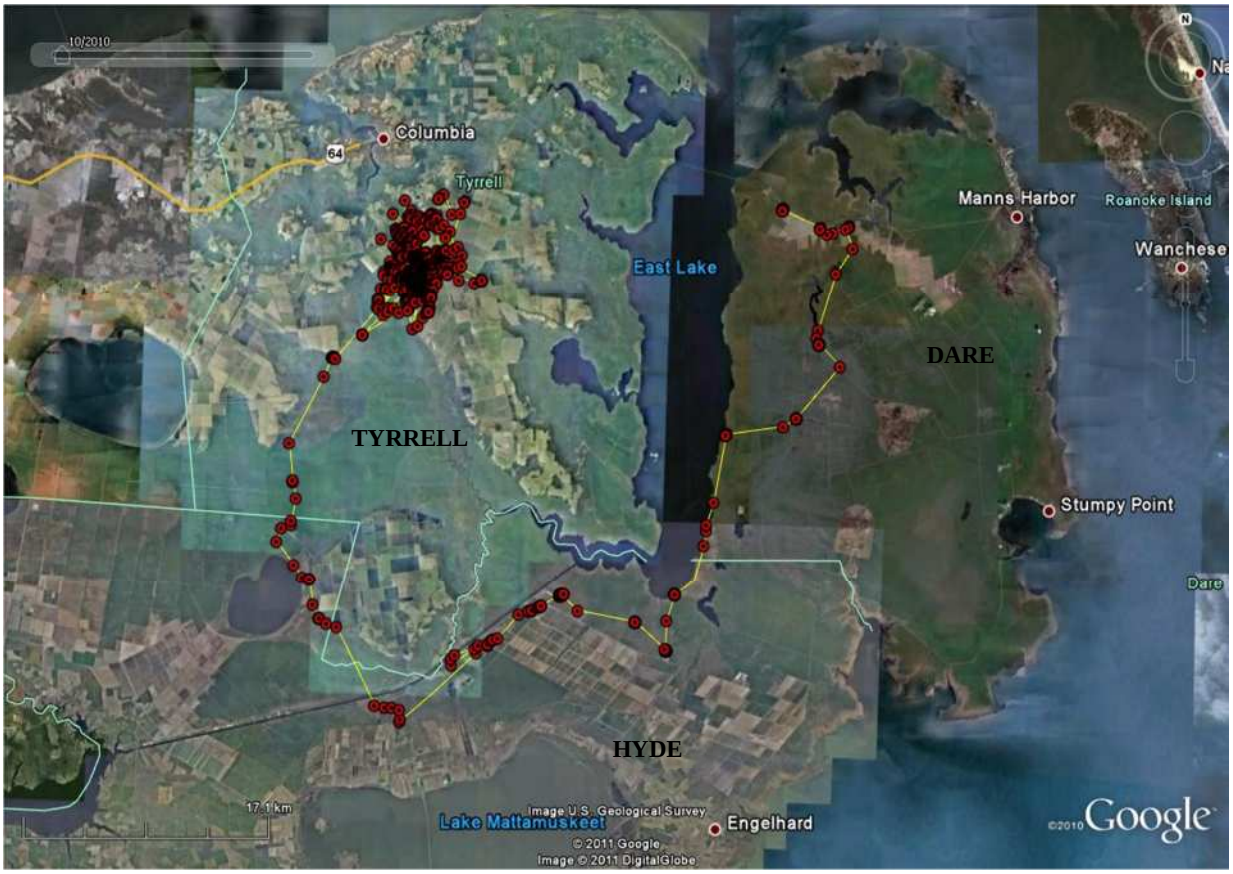

Figure 35. Movement pattern of a 10-11 year old male radio collared on ARNWR, Dare County, NC on 5/11/2010. The bear traveled approximately 64 miles to end up in Tyrrell County, NC on 6/2/2010.

Black Bear Reproductive Data

In 2009 we live trapped 13 female bears, 11 of which were of reproductive age (≥ 3 years old). Three female bears, ages 5-6, 5, and 6-7 had 3, 2, and 1 cubs, respectively, at the time of capture. During 2010, 15 of 16 female bears captured were of reproductive age. Two of the females (ages 6-7 and 13) had 3 cubs each. One female captured in 2009 with 3 cubs was re-captured in 2010 with 2 yearlings present.

We located 6 dens sites in 2011; 1 each: root wad, hollow tree base, ground den, and blown down tree, and 2 elevated nest dens. From GPS radio data we determined that at least 6 other female bears denned during the winter season, but with unknown den types or reproductive outcomes (Table 6). Our den visits (n=5) documented 2 dens with no detected reproduction, 1 den with 3 cubs present, and 2 dens with at least 2 cubs present. We discovered the consumed remains of at least 2 cubs (determined by counting the undigested claws) when we re-visited one den site of a 9-year old bear that had denned close to US 64. The 3 bears documented to have reproduced in 2011 were ages 7, 8, and 9. We also obtained reproductive information from 5 of the pre-molar teeth submitted for aging. Results from the tooth analysis documented age at first birth as early as 3 years and up to 5 years old. The oldest age bear that reproduced was 16 years old (Table 6).

Table 6. Summary of reproductive data on female bears monitored during 2009 – 2011 in Dare and Tyrrell Counties, North Carolina.

Female bear no. (year)	Age of bear	Years of reproduction from tooth	Reproduction data from capture	Reproduction data from den visit	Reproduction data from other source
128 (09')	5	4?	2 cubs	NA	NA
133 (09')	6	NA	3 cubs	NA	NA
133 (10')	7	NA	2 yearlings	NA	NA
133 (11')	8	NA	NA	3 cubs	NA
142 (09')	12	5, 8, 10, ??	None	NA	NA
160 (09')	11	4, 6, 8, 10	Lactating	NA	NA
156 (09')	7	NA	1 cub	NA	1 cub at RK
160 (10')	12	4, 6, 8, 10	Lactating	NA	NA
170 (11')	9	NA	None	at least 2 cubs	NA
183 (10')	9	NA	None	2 cubs (dead)	NA
188 (11')	21	NA	None	Solitary	NA
201 (10')	17	5, 7, 9, 12, 14, 16	None	NA	NA
208 (10')	13	NA	3 cubs	NA	NA
482 (10')	7	NA	3 cubs	NA	NA
543 (10')	9	3, 5, 7, 9?	None	NA	Visual – Solitary
Tyrrell Road Kill (09')	3	NA	NA	NA	1 cub at RK

RK = road kill

Black Bear Mortality Data

We identified 184 individual bears (132M:52F) on ARNWR, and the immediate areas of Dare County NC. These include captured bears and bears killed on the highway from 11/3/08 – 8/17/10 (21.7 months), and bears identified from roadside barbed wire hair collected from 3/15/09 – 5/24/10 (14.5 months). Thirty-five (23M:11F:1U; 19.0%) of the 184 died within Dare County (including road kills on 64 and 264 south to Stumpy Point, Dare Landfill harvest, and mortalities in the residential areas of Manns Harbor and East Lake). Three additional male bears originally identified within the study area were killed during the bear hunting seasons and one died of unknown causes in Hyde County. One GPS collared female was killed on US 264 in Hyde County. Within our marked samples of mortalities, male mortality rate (20.5%; n=27/132) was lower than the female mortality rate (23.1%, n=12/52). We obtained ages for 39 of the 40 mortalities; 30.8% (n=12) were cub – 2 year olds, 33.3% (n=13) were 3 – 5 year olds, 25.6% (n=10) were 6 – 10 year olds and 10.3% (n=4) were 11 or more years old.

Table 7. Summary of mortality data during 2008 – 2011 in Dare, Tyrrell, and Hyde Counties, North Carolina.

US 64/ARNWR - Bear Mortalities									
	County	Date	Cause	Location	Sex	Weight	Age	Repro.	Notes
1	Dare	11/2/2008	Roadkill	64	M	262	U		
2	Dare	1/11/2009	Roadkill	64	M	200	2		
3	Dare	4/16/2009	Roadkill	64	M	233	4		
4	Tyrrell	6/3/2009	Roadkill	64	M	~80	~1		No tooth found
5	Dare	6/11/2009	Roadkill	64	M	~300	9		Floater
6	Tyrrell	6/23/2009	Roadkill	64	M	~250	3		All four limbs removed
7	Tyrrell	7/10/2009	Roadkill	64	F	90	3	1 cub	1 cub seen with mother - returned to woods
8	Dare	7/15/2009	Roadkill	264	F	104	8	3,5,7 y.o.	Repro determined from teeth
9	Tyrrell	7/15/2009	Roadkill	94	M	~80	2		
10	Dare	7/28/2009	Illegal Kill	Manns Harbor	M	270	3		
11	Dare	8/1/2009	Roadkill	64	F	107	2	3?	Looked to had recently breed
12	Dare	8/2/2009	Roadkill	64	F	121	7	Not lactating	Teeth failed to detect repro
13	Dare	9/12/2009	Roadkill	264	F	108	6-7	1 cub	Teeth failed to detect repro, GPS Collared #156
14	Dare	10/5/2009	Roadkill	64	M	250	4		Tag #124
15	Dare	10/14/2009	Roadkill	64	F	243	10	4,7,9 y.o.	Repro determined from teeth
16	Dare	11/10/2009	Harvested	Dare Landfill	M	422	7		Tag #143 GPS collared
17	Dare	11/24/2009	Roadkill	264	F	39	cub		

18	Tyrrell	11/25/2009	Roadkill	64	M	155	2		
19	Dare	12/8/2009	Roadkill	264	M	135	2		
20	Hyde	12/?/2010	Harvested	Hyde County	M		3		Tag #150
21	Dare	12/29/2009	Roadkill	264	F	~165	13	4,7,10,12	Repro determined from teeth
22	Dare	1/18/2010	Roadkill	264	M	126	2		
23	Dare	4/30/2010	Defensive	Stumpy Point	M	295	6		
24	Dare	5/10/2010	Roadkill	264	M	58	3		
25	Dare	5/12/2010	Roadkill	64	F	180	4	4	Lactating but no cub seen
26	Tyrrell	5/22/2010	Roadkill	64	M	~250	4		
27	Dare	6/4/2010	Roadkill	264	M	290	5		
28	Tyrrell	6/9/2010	Roadkill	64	M	~450	5		
29	Dare	7/1/2010	Roadkill	64/264	M	55	2		
30	Dare	7/2/2010	Defensive	Mashoes Rd.	M	207	5		Tag #159
31	Dare	7/11/2010	Roadkill	264	F	105	5	Not lactating	GPS collard #179
32	Dare	7/11/2010	Roadkill	264	M	~150	2		Tag #121
33	Dare	8/6/2010	Roadkill	264	M	84	1		Tag #191
34	Dare	8/8/2010	Roadkill	264	M	39	1		
35	Dare	9/10/2010	Roadkill	64	U	~100	3		
36	Dare	10/30/2010	Roadkill	64	F	120	14	14	Lactating but no cub seen
37	Hyde	11/9/2010	Harvested	Hyde County	M	475	10-11		Tag #173
38	Dare	11/11/2010	Roadkill	64	M	87	1		
39	Hyde	11/12/2010	Harvested	Hyde County	M	545	8		Tag #166
40	Tyrrell	11/29/2010	Roadkill	64	M	135	1		
41	Dare	12/2/2010	Roadkill	64	M	174	1		
42	Dare	12/13/2010	Depredation	Old Ferry Landing	M	190	2		Tag #118 (GPS collared at one time)
43	Dare	12/15/2010	Roadkill	64	F	165	5	5	Lactating but no cub seen
44	Hyde	8/19/2010	Unknown	Lux Farms	M	?	3		Tag #175 - GPS collared
45	Dare	1/20/2011	Defensive	East Lake	M	153	2-3		Tag #137 yearling cap in 2009
46	Hyde	10/10/2011	Roadkill	264 - Engelhard	F	121	21		Tag #B517, GPS collars at the time of RK
47	Dare	11/11/2011	Harvested	Dare Landfill	M	630	9		Tag #154 (Folta 704)
48	Dare	11/14/2011	Harvested	Dare Landfill	M	677	9-10		Tag #103/190

DISCUSSION

This section provides a summary and compilation of the results of this study. For ease of interpretation refer to the following map (Fig. 36) for all mile marker references.

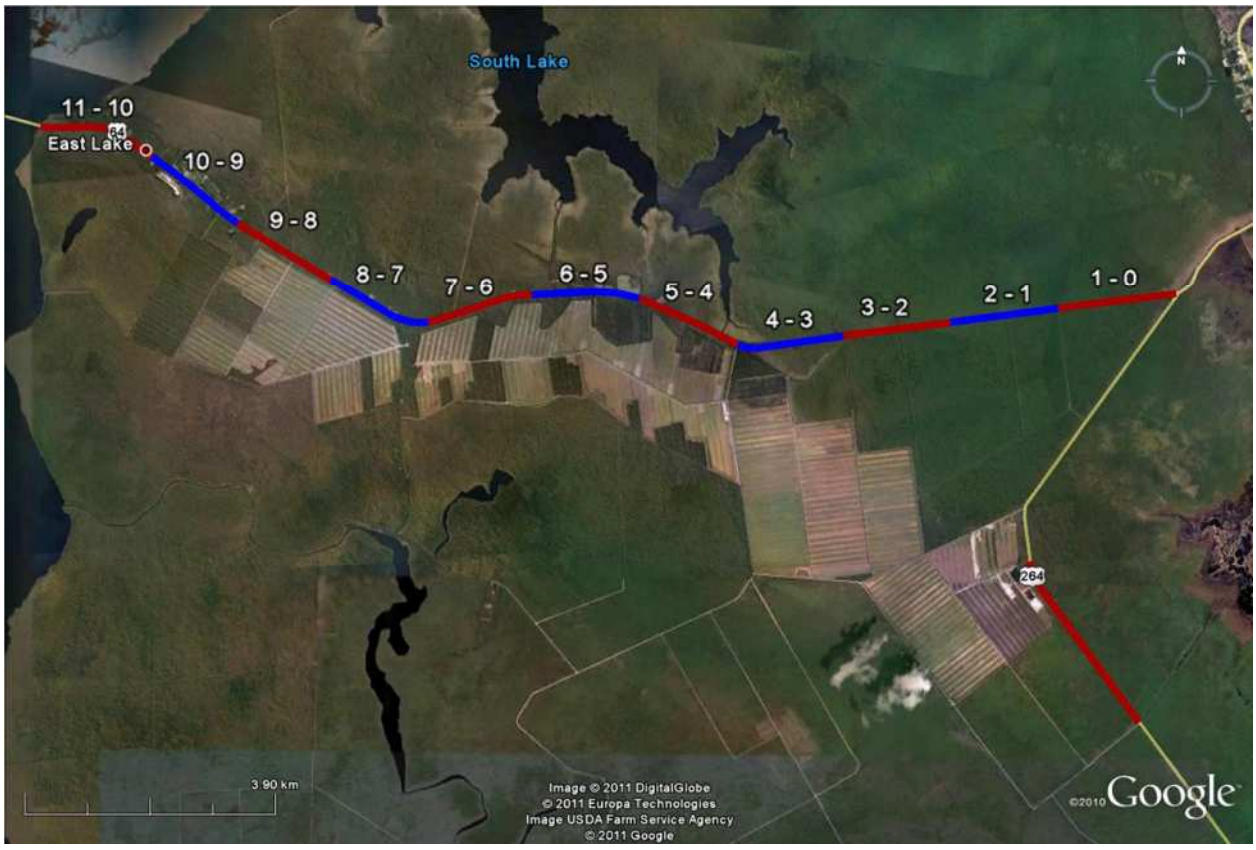

Figure 36. Map of the primary study area with one mile sections color delineated along US 64 through ARNWR in Dare County, NC. The US 264 1.9 mile segment is shown as one colored segment.

* Note: section 0 - 1 includes a 0.1 mile section, which extends east to the Hwy 64/264 intersection. This section did not have barbed wire in place, but all other data collection methods (GPS crossings, focal species road kill, and driving surveys) were performed and analyzed as though it was within the 0 – 1 mile segment. Section 10 – 11 is actually 1.2 miles long; and extends to the bridge rail, which is covered by barbed wire.

Highway Barbed Wire Hair Snags

Wildlife biologists are increasingly using DNA-based monitoring of populations with noninvasive genetic sampling methods (Waits & Paetkau 2005, Long et. al. 2008). Barbed wire bear hair collection has proven to be a very effective non-invasive technique for obtaining population level data. We built on a genetic database established by Tredick (2009) within ARNWR and successfully re-captured 25 black bears that she had genetically identified in 2003 and 2004. Wills (2008) strung 2.3 km (~1.4 miles) of barbed wire along a roadway to identify bear crossing locations within the Great Dismal Swamp National Wildlife Refuge in order to determine the placement of a wildlife underpass. Our use of ~22 miles (2 strands x 11.2 miles) of barbed wire strung alongside a highway constitutes the longest known deployment of barbed wire for DNA monitoring of wildlife populations.

Contrary to previous studies that found that black bears crossed roads at low rates and avoided habitats adjacent to highways (Berlinger et al. 1990, Brody and Pelton 1989, Carr and Pelton 1984, Kasworm and Manley 1990, and Wooding and Maddrey 1994) we recorded a very high number of road crossings and sign (e.g., tracks, scat). It appears that all areas adjacent to US 64 were occupied by bears. The highway barbed wire hair collection method was the most effective and efficient technique we employed to document black bear road crossings (n= 537 crossing events on US 64). Since the entire highway study area is bordered by a guardrail system with wood support post, it was relatively straight forward to install barbed wire and monitor the entire roadway with an almost equal effort (the only breaks in the barbed wire were drive way and road entrance breaks). The technique provided not only precise location and temporal data on bear highway crossings, but a wealth of genetic data. The genetic data clarified some important considerations in the analysis and interpretation of raw crossing counts. Genetic identification provided the sex and individual identity of black bears that crossed the highway, which aided in the interpretation of data to examine behavioral traits such as road crossing “happy” bears (i.e., bears that crossed the road frequently), or male/female sampling biases. It is important to note that we have no estimate of the number (percentage) of bear crossings that went undetected. All genetic data is detailed in Appendix I.

Only 1 of 52 individual bears was identified as a US 64 crossing “happy” bear (crossing 24 times) whereas 27 bears (51.9%) crossed or were detected only once. We recorded similar results on the US 264 control site where a total of 28 bears crossed the road with 2 bear crossing “happy” bears (crossing 11 times each) and 10 (35.7%) bears crossing only once. Road crossings were heavily skewed towards male bears (65M:18F). Our genetic identity success rate, was very low (39.7%), likely because our samples were degraded by hair sample quality and quantity, and environmental conditions. Although Wills (2008) had a much smaller sample (n=23) from his road side hair collection he also had low success rate (60.9%) for individual genetic identification, thus there may be an inherent difficulty in collecting quality samples from such a road side set-up. Because of our low success rate, our attempts to test the validity of counting

each crossing event as an individual bear became significantly more important. Twenty-four of 90 crossing events produced genetic identities from 2 or more samples collected from a single crossing event (i.e., samples from adjacent barbs). Only 1 of the 24 events identified multiple bears from hair samples collected at the site. However this one event occurred along the most heavily crossed section of barbed wire on US 264 during an unusually prolonged collection period (~4 weeks). Thus, we are confident that the majority of crossing events, whether identified by bear hair on a single barb or by hair on 3-5 adjacent barbs, were from a single bear. The barbed wire crossing events revealed 6 locations where bear crossing activity was high: mile sections; 1 – 2, 2.9 – 4, 4.6 – 4.9, 6.4 – 7.3, 7.9 – 9.1, and 10.5 – 11.2 (Fig. 37).

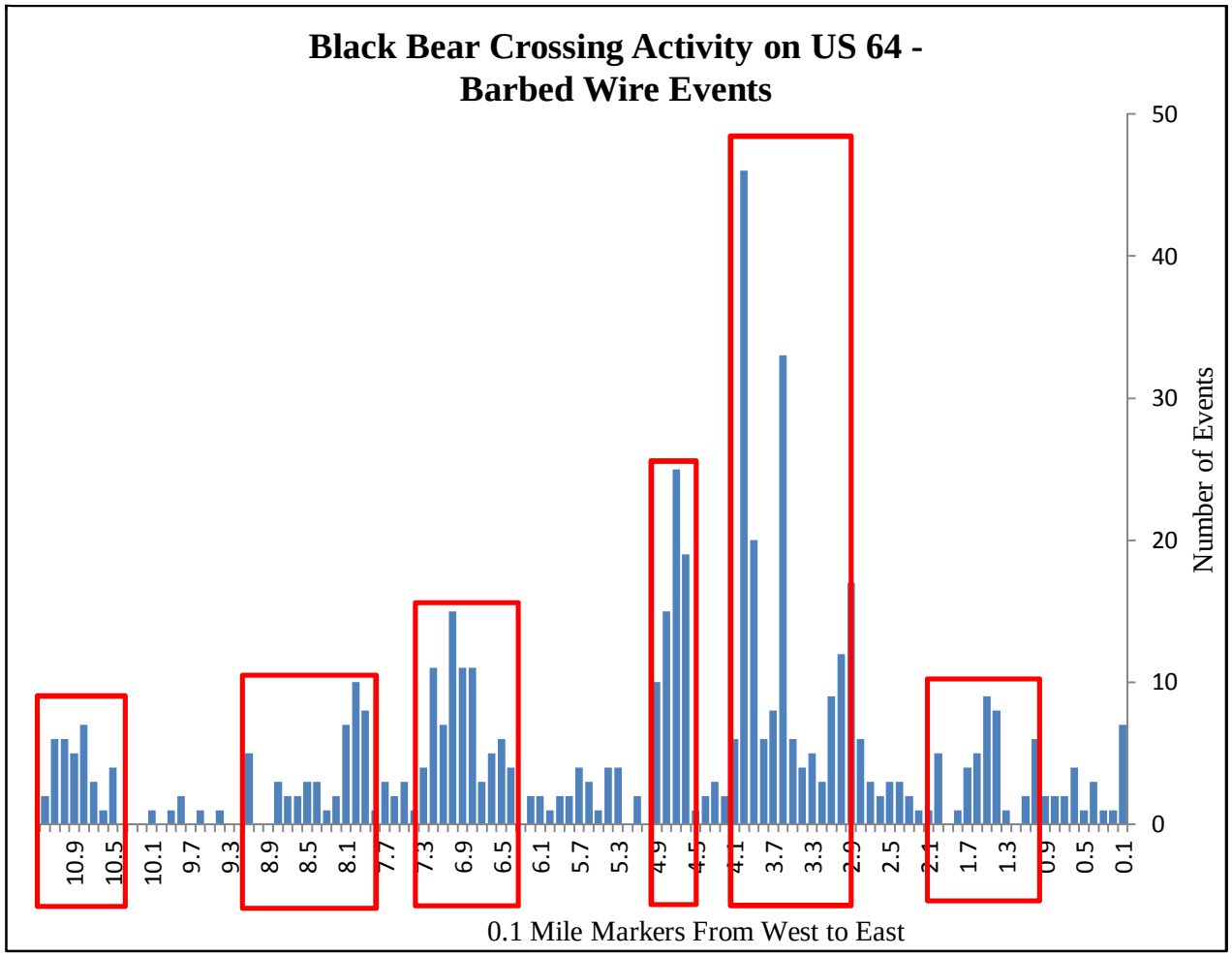

Figure 37. Black bear crossing activity on US 64 in ARNWR, Dare County, NC, during March 2009 – March 2011 as determined from barbed wire hair traps. Boxed areas identify high priority crossing sites.

Road Kill Surveys

Reptiles, Amphibians, and Small Mammals

Wetlands, such as those of ARNWR, are one of the most productive and diverse ecosystems with reptiles and amphibians representing a significant portion of that diversity (Ashley and Robinson 1996). US 64 bisects large areas of wetlands and deep water canals that are the preferred habitat of many amphibians and reptiles. Road kills have been shown to be highest for species with preferred habitat directly adjacent to roadways (Cain et al. 2003, Foreman et al. 2003), therefore it is not surprising our road kill surveys documented such an astounding number of reptiles and amphibians. The most numerous animals recorded in the surveys were frogs (n=5,400) and toads (n=1,970). For reptiles the species with the highest number of road kills was the mud turtles (n=593) and nearly as many spotted turtle (n= 442). Amphibian and reptile road kills occurred throughout the entire length of US 64 on ARNWR, but amphibians were more numerous in miles 0 – 8 whereas reptiles were more numerous in miles 8 – 11 (Fig. 38). With the exception of the first 4 miles on the eastern end of the study area, the relative number of amphibian and reptile mortalities mirrors each other across the study area. Reptiles appeared to favor roadside areas in the dryer more exposed sections in the west of ARNWR while amphibians favored the roadside areas in the east with more mature tree cover and wetter conditions.

Habitat on ARNWR is homogeneous and lacks open fresh bodies of water, thus, we documented no areas of mass road mortality such as those reported by Smith (2011) in Tyrrell County. While there are some obvious peak locations in the overall number of road kill incidents both for amphibians and reptiles, the data do not lend themselves to delineating specific crossing areas that are more important than others (i.e., the entire length of highway 64 through ARNWR has high crossing activity for these taxa). We recorded a relatively small number of small mammal road kills (n=82) and their spatial distribution closely mirrored reptile distribution (found throughout, but more common in drier areas). The notable small mammal road-kill was the star-nosed moles (n=3) found at miles 1.8, 2.7, and 8.2. Our data suggest the most effective approach for significantly reducing road kill incidents of amphibians, reptiles, and small mammals would involve numerous passage-ways, either natural or man-made, distributed at regular intervals throughout the entire length of the proposed road expansion area though ARNWR.

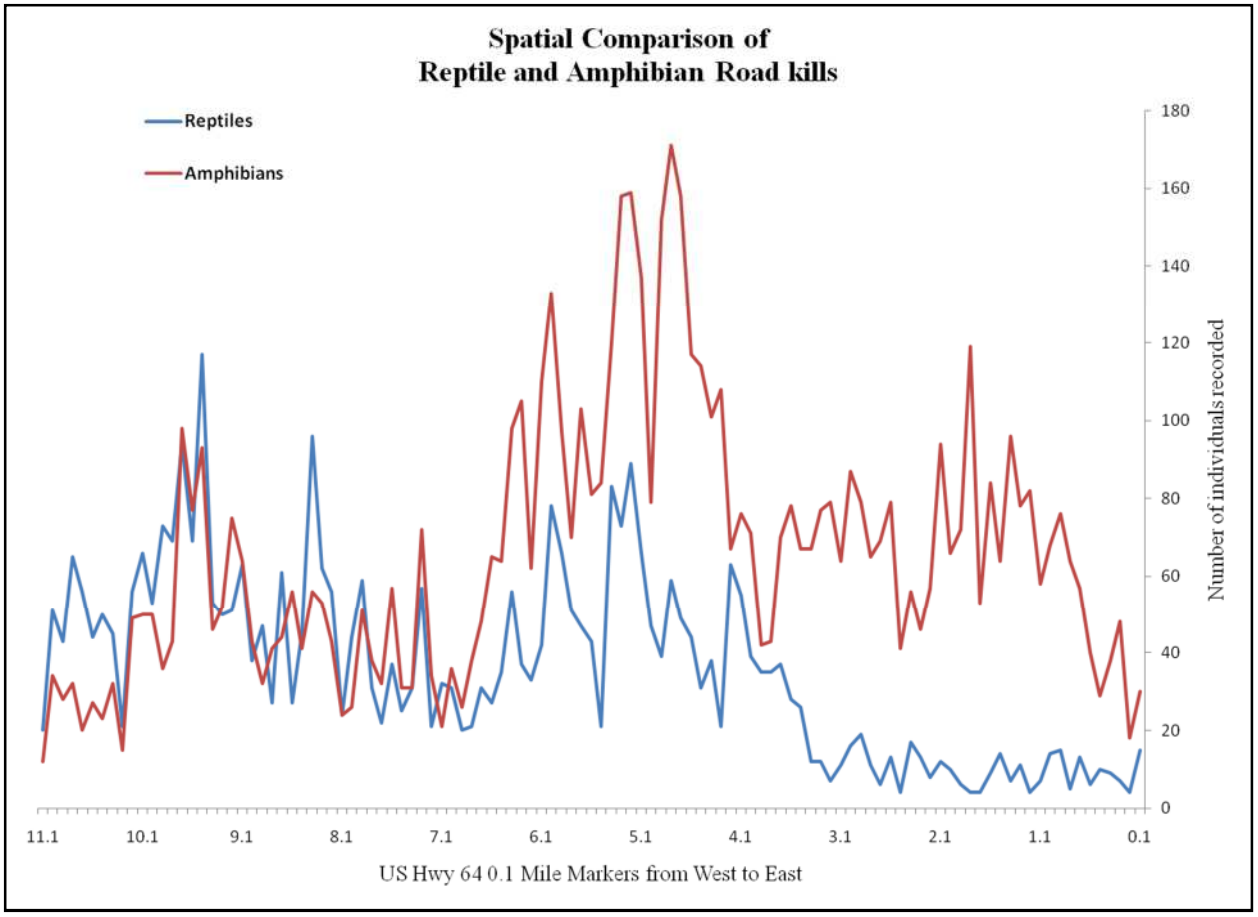

Figure 38. Reptile and amphibian road kills recorded along US 64 through ARNWR in Dare County, NC from March 2009 – March 2011.

Bats and Birds

Bats and birds present an intriguing dilemma when investigating the effects on and mitigation of wildlife vehicular road kills and road construction. While some have concluded that direct road kills do not exert a significant pressure on the overall population of most bird species (Leedy and Adams, 1982; Bennett, 1991), traffic disturbance on birds has not been well documented (Reijen et al. 1997). Zande et al. (1980) caution that road impact assessments that disregard disturbance and possibly long distance effects (i.e. effects far from the immediate roadside areas) should be rejected outright. Since crossing structures are normally designed for terrestrial species, mitigation techniques for bats and birds have not been given full considerations (Jacobson, 2005). There has been little research on the effects of highways on bats (Russell et al. 2009). This project's extensive data may draw attention to the plight these animals likely face on roadways throughout the United States. We documented 75 bat road kills with the eastern red bat alone accounting for 34 records. We also documented 2 road kills of the North Carolina

threatened Rafinesque's big-eared bat in mile section 8 – 9. We documented bat road kills dispersed throughout the highway study area with a slight increase occurring at mile sections 4 – 5 (n=3) and 8 – 9 (n=4).

We collected a significant number of bird road kills (n=1,153) including multiple species of owls, hawks, and woodpeckers, a brown pelican, and 452 yellow-rumped warblers. ARNWR is located on a major migratory pathway and serves as wintering grounds for hundreds of bird species, therefore highway impacts (i.e. road kills, habitat loss, and traffic disturbance) on birds should be of utmost importance when considering the impacts of any project within the refuge. The bird road kill spatial data are skewed towards mile segments 10 – 11 and 9 – 10 where yellow-rumped warblers were killed during the fall and winter sampling occasions. Otherwise birds were found throughout the highway study area and again show no clear road kill hotspots. The bird road kill data, excluding the yellow-rumped warbler, exhibited a slight increase in mile sections 4 – 5, 5 – 6, and 6 – 7. These are areas of the roadway where the habitat consists of mature trees that were relatively close to the road on both sides. We postulate this caused the birds feeding on the roadside to fly over the roadway upon take off. We witnessed this behavior on many occasions when cars approached a flock of birds on the roadside. To significantly reduce the number of bird road kills along US 64 in the ARNWR a more in-depth study of the bird species, their habitat and food preferences, as well as their behavioral response to passing automobiles would be required. Habitat manipulation may help reduce bird strikes on the highway.

Mid-Sized Mammals

Virginia opossums (n=57) and raccoons (n=49) were the dominant road kill species of the mid-sized mammals. Spatially, these two species were found far more commonly in mile sections 10 – 11, 9 – 10, 5 – 6, and 4 – 5, all areas where human disturbance of the landscape is highest. From the contiguous wetland areas of mile sections 0 – 3 we recorded only 5 road kills of each species. We recorded 6 river otter road kills, 4 of them within mile segment 9-10. Three of the 4 river otter strikes were killed within a 0.10 of a mile segment at 9.5. Although we had 209 confirmed bobcat crossings from the remote camera data, we recorded only 2 road kill incidents at mile segments 1 – 2 and 1 at 10 – 11. We recorded both a single red and gray fox road kill in mile segment 3 – 4. We also documented the presence of the invasive nutria with one road kill each at mile segments 3 – 4 and 5 – 6. Since most of the mid-sized mammal road kills were recorded in areas with higher human residence, educating residents about proper pet food/garbage storage may be the most effective strategy for reducing road strikes in this area.

White-tailed Deer and Black Bear

We recorded 8 white-tailed deer (2M:3F:3U) road kills during surveys performed from November 2008 – July 2011. White-tailed deer are not overly abundant on ARNWR, estimated at less than 15 deer per square mile (NCWRC, unpublished data), but we still suspect that other

road-kills occurred that were removed either by motorist or the USFWS – Red Wolf Recovery Team (for baiting and feeding red wolves) without our knowledge. Typically, white-tailed deer are most frequently involved in vehicular collisions (Conover et al. 1995, Romin and Bissonette 1996) yet on ARNWR, we recorded twice as many black bear road kills within the same time period. The white-tailed deer that were recorded were found throughout the highway study area from mile segment 0 – 1 (n=2) through 4 – 5, 5 – 6, 7 – 8, 8 – 9, and 9 – 10 each with 1 road kill. White-tailed deer road kill locations overlapped with locations of black bear road kills with the exception of 1 deer strike at mile 6.0, which was >0.5 miles from the nearest bear kill.

During November 2008 – July 2011 we recorded 15 (8M:6F:1U) road killed black bears along US 64 on ARNWR in Dare County NC. We combined our data with 48 historical black bear road kills documented by the USFWS and the North Carolina Wildlife Resources Commission from January 1993 – November 2008 and found that over the last 19 years 63 (35M:20F:8U: $\bar{x}$=3.32/year) black bear road kills have occurred along the 11.3 miles of US 64 on ARNWR. The sex ratio of bear strikes was slightly skewed towards males (63.6%), mostly due to younger bears. Bear road kills by age were: 6 cubs (2M:2F:2U), 9 yearlings (7M:2F), 17 sub-adults - aged 2 – 4 years old (13M:3F:1U), and 31 adults (13M:13F:5U). One road killed bear of note was a 24 year old male killed on May 13, 2002. The sex ratio of prime-aged bears (5 - ~15) killed on the highway was identical (12M:12F), but in the long term, the loss of adult females will have a greater impact on the bear population due to the "lost" reproductive potential.

Adult male bears apparently were more successful at crossing the highway safely than adult female bears (3 of 10 female bears we documented crossing US 64 or 264 later died on the highway whereas only 1 of 43 males fell into this category). Thus, the most important cohort of the black bear population (reproductive aged females) seems to be potentially more susceptible to road mortality if a road crossing is attempted. Over the past 19 years black bear road kills have been recorded within every mile segment of US 64. The data indicate at least 6 black bear road kill hotspots at mile segments; 0 – 1, 1.9 – 3, 4.0 – 4.7, 7.1 – 8.3, 9.3 – 9.9, 10.8 – 11.2 (Fig. 39).

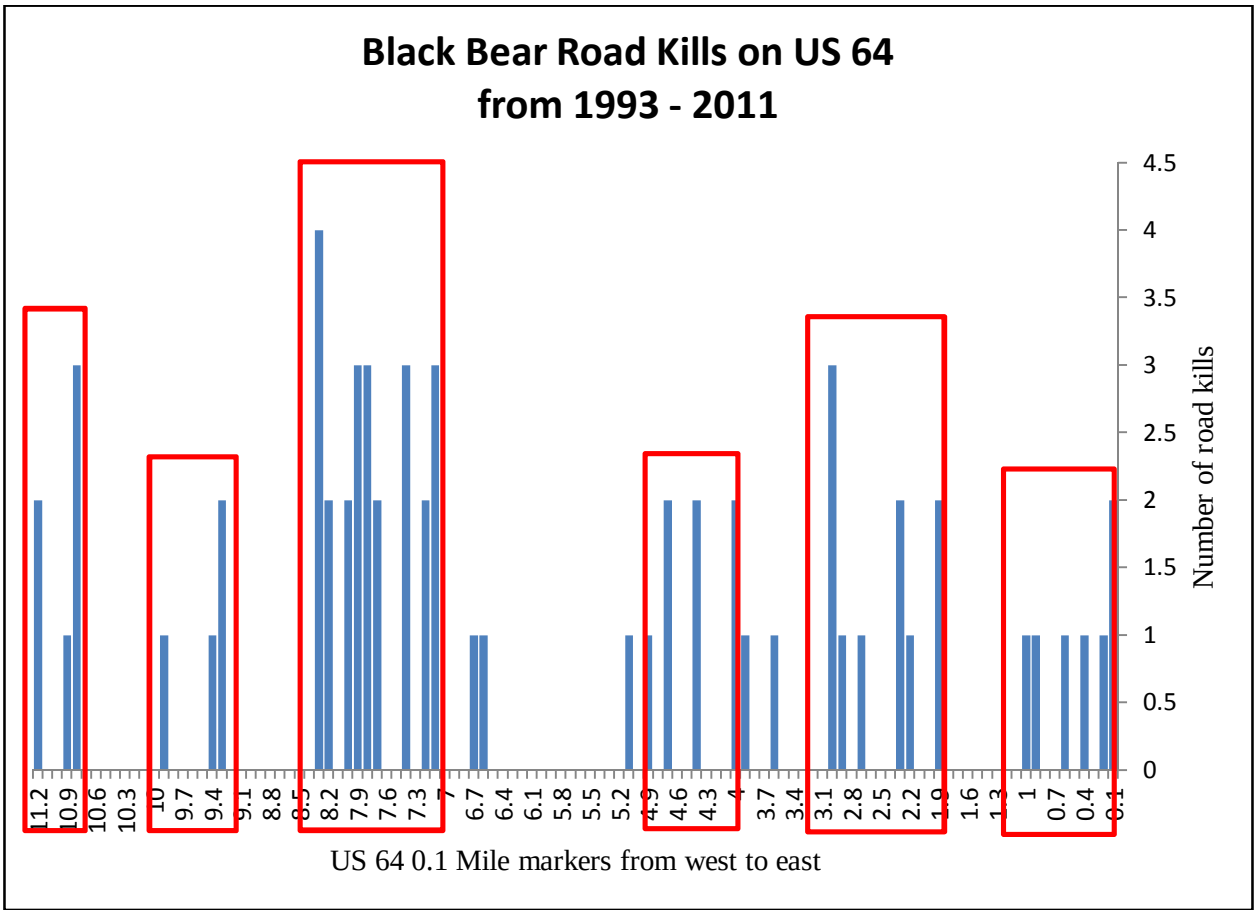

Figure 39. Black bear road kills on US 64 within ARNWR in Dare County, NC, determined from road kill records and surveys from Jan 1993 – July 2011. Boxed areas pinpoint important bear strike locations

Remote Camera Surveys

We deployed remote cameras to record animal movements along US 64 on ARNWR at breaks in the barbed wire hair snares. For the most part, remote cameras performed quite efficiently. The maximum effective sampling area for each camera was less than 10 meters (~33ft) wide (the width of the largest guard rail opening) and yet we still photo captured 260 black bears, 170 white-tailed deer and over 200 bobcats and raccoons at 12 stations and > 3,800 trap nights. We lost some cameras due to theft and vandalism and one high quality camera was destroyed in a vehicular accident.

The remote camera data we collected is somewhat complicated to interpret due to inherent variability in camera quality as well as the non-systematic placement methodology we used. Ideally, the data should be standardized to determine the number of independent animal captures

at one site per 100 trap nights (Long et al. 2008) in order to compare one camera site's success to another's. We plan to eventually conduct this analysis, but for this project we wanted to compare camera trapping results with raw numbers of barb wire crossing events, GPS radio collar crossings, and road kill incidents. Therefore, we analyzed the camera trapping data by examining the number of independent black bear and white-tailed deer crossings at each site.

Only the western most camera station (C31) failed to photo-capture at least one bear during this project. We recorded a high number of black bears at camera stations C7 (n=70) – located at mile 5.8, C9 (n=90) – located at mile 7.9, C10 (n=39) – located at mile 8.4, and C11 (n=37) – located at mile 8.8. Since photographed bears were not individually recognizable we could not determine how many different bears were photographed at each station. Station C7 is a wooded canal cross to the south with a wood lot on the opposite side of the highway. C9 is Hickory Rd., an ARNWR year-round gated access road and C10 is River Rd. a year round open public access road. C9 and C10 are only 0.5 miles apart and access the same field to the south of US 64. There is also an open access road on the north side of the highway almost directly across from C10 that would provide access into the northern areas of ARNWR. C11 is a wooded canal cross to the south with a wooded/wet area on the opposite side of the highway.

White-tailed deer were most frequently captured at camera stations C9 (n=55) – located at mile 7.9, C14 (n=41) – Pump Rd. located at mile 9, and C25 (n=32) – western access road to Dare County borrow pit at mile 9.8. Pump Rd. is a year-round open access road to the south into ARNWR. C25 is a grassed over, year-round gated access road to the Dare County borrow pit area to the south of US 64.

Other notable wildlife captured on photographs includes 86 photo-captured bobcats at camera station C10, 32 at station C25, and 29 at C7. Raccoons were recorded at 10 of the 12 stations including 50 at C10, 45 at C9 and C25, and 37 at C7.

The remote camera data highlights the importance of roads and trails, with direct access to the highway, in providing large mammals access to habitats on both side of US 64. Black bear and white-tailed deer high priority crossing spots identified by remote camera include mile segments; 4 – 5, 6 – 7, 7 – 8, and 8 – 9 (Fig. 40).

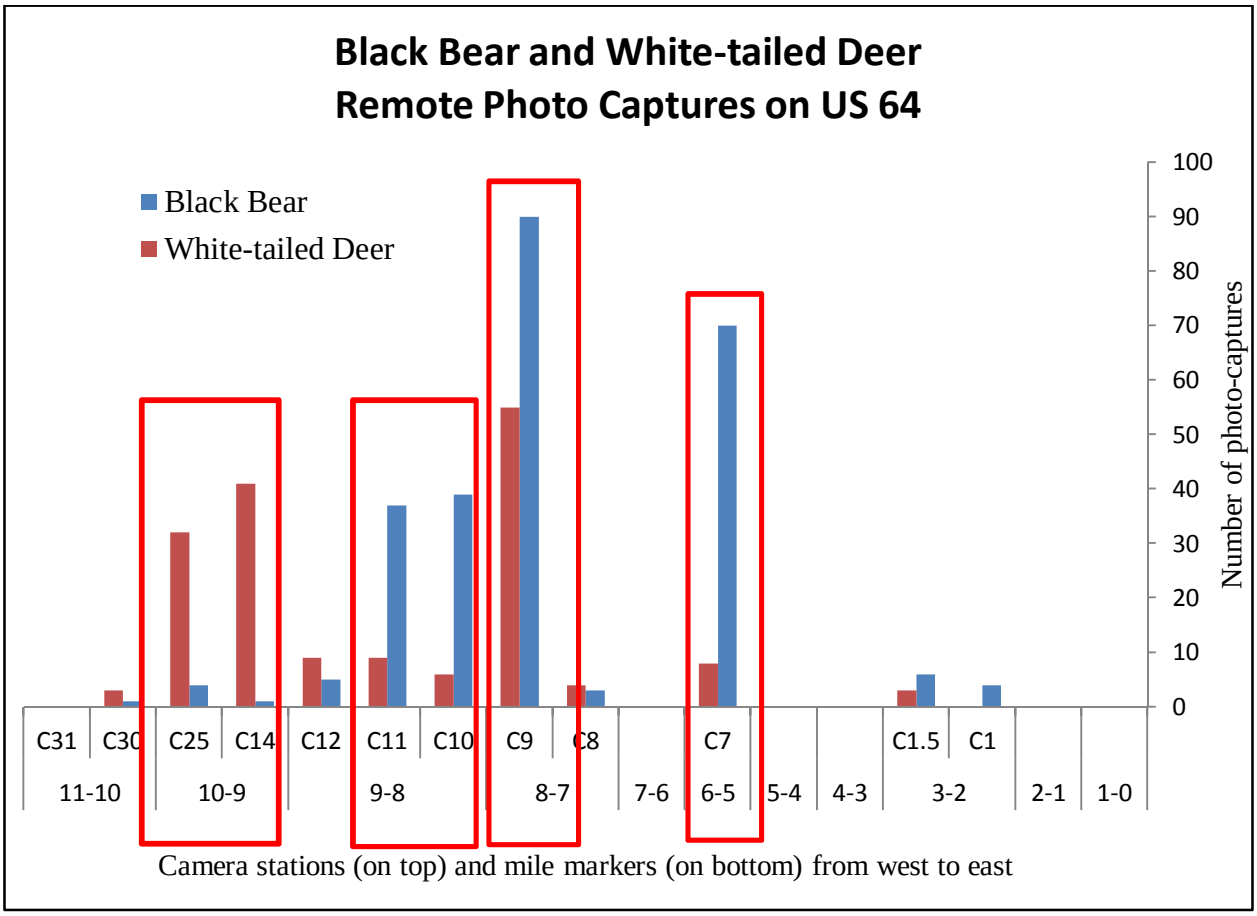

Figure 40. Black bear and white-tailed deer crossing locations on US 64 in ARNWR, Dare County, NC, determined from remote photo trapping surveys from June 2009 – March 2011. Boxed areas are locations of high black bear and white-tailed deer activity.

Wildlife Driving Surveys

We recorded bear sightings on 3 and white-tailed deer on 19 of 135 wildlife driving surveys performed from March 2009 – March 2010. All 3 of the bears were sighted within mile segment 3-4. During 2009 we regularly sighted black bears in this particular area either crossing US 64 or feeding in the NCDOT roadside wildflower plot. White-tailed deer greatly reduce their potential for mortality from vehicular traffic by accessing the roadway edges at late hours when traffic is substantially reduced. Our low detection rate for white-tailed deer suggest a low density deer population on the refuge or, at least, that deer used the roadside infrequently. The surveys doubled our location data sample size when combined with deer road kills, yet still suggest both a low density of deer and little use of the US 64 roadside on ARNWR. The driving surveys detailed an expanded range of white-tailed deer use along the highway corridor than had been

detected by other means. It is also worth noting that "Other" wildlife sightings (Fig. 26), i.e. everything not black bear or white-tailed deer, was highest in mile segment 4 – 5, an area of no bear and only 1 white-tailed deer sighting. The observations at this particular segment likely was due in large part to a downed tree that raccoons and Virginia opossums were regularly seen using to cross the canal. Black bear and white-tailed deer crossing hotspots, as detected by the driving surveys, were mile segments; 3 – 4, 6 – 7, 7 – 8, and 10 – 11 (Fig. 41).

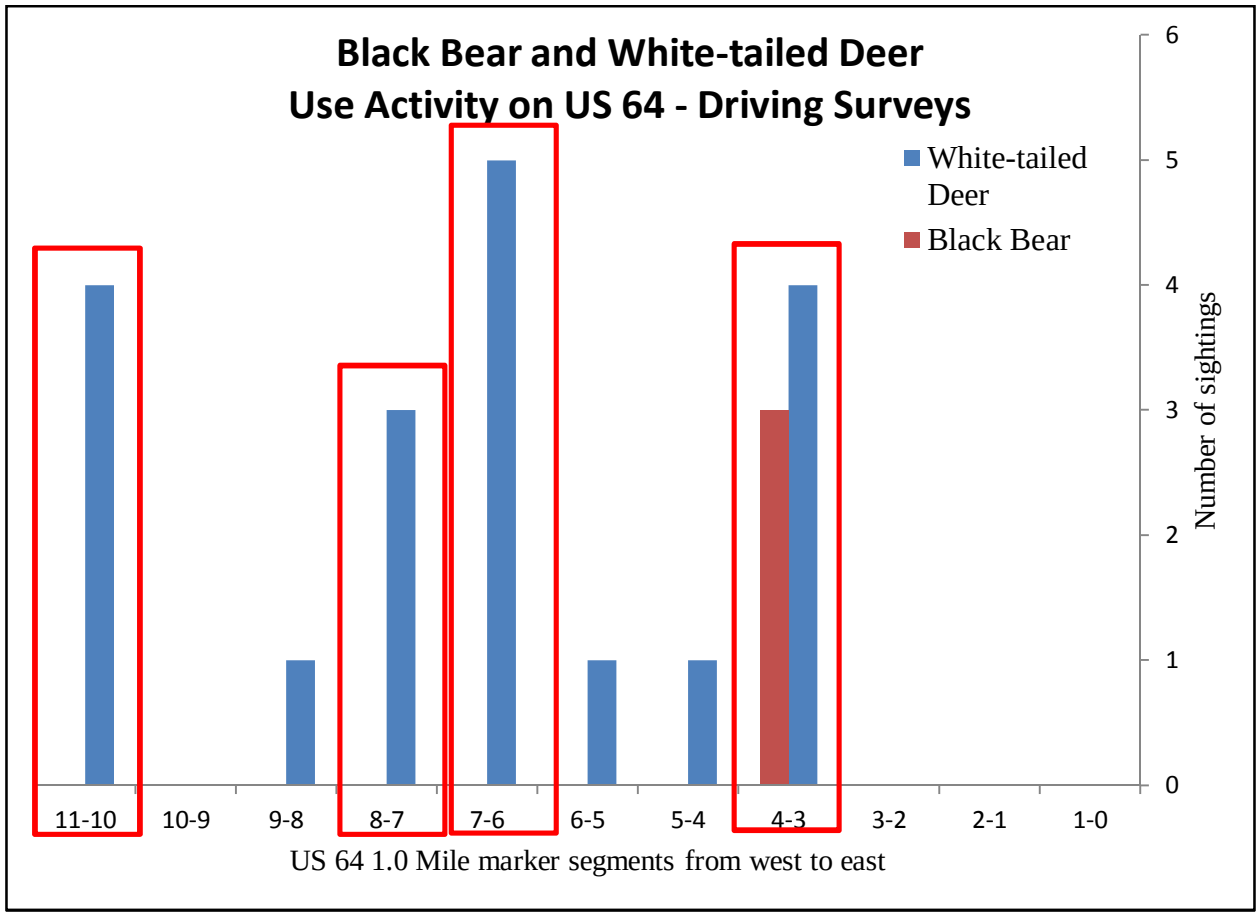

Figure 41. Black bear and white-tailed deer sightings on US 64 within ARNWR in Dare County, NC, determined from 135 driving surveys performed March 2009 – March 2010. Boxed areas are locations where deer and bears were most frequently sighted.

GPS Radio Collar Crossing Data

Like previous studies (Lewis 2007, Brody and Pelton, Kaczensky et al.2003, and Manvill 1983) a majority (34/49, 69.3%) of the black bears with GPS collars in ARNWR used US 64 as a boundary for their movements and home ranges (Figs. 26 and 28 – 31). The movement and home range data for black bears in ARNWR shows an intense use and reliance on the farm fields throughout the refuge. The spatial arrangement of fields and small wood blocks seems to be optimal for black bear occupation.

Fifteen (11M:4F) of 49 bears (26M:23F) collared for at least 30 days, crossed US 64 99 times. One female black bear crossed both US 64 and US 264. With the exception of 1 bear, females crossed US 64 no more than twice; the one exception crossed US 64 4 times at mile segment 3 – 4, twice at mile segment 1 – 2, and once at mile segment 0 – 1. This individual female bear also crossed US 264 4 times. Previous studies of black and grizzly bears found that males crossed roads less frequently and used the habitat adjacent to roads less often than females (Chruszcz et al. 2003, Mattson et al. 1987, McLellan and Shackleton 1988). Conversely, collared male bears along US 64 on ARNWR crossed the road more frequently than females as only 3 male bears crossed the road less than 3 times and one male bear crossed US 64 41 times across 4 adjacent mile segments; 1 – 2 (n=2), 2 – 3 (n=7), 3 – 4 (n=23), and 4 – 5 (n=9).

The US 64 black bear crossings recorded by the GPS collars were distributed across all US 64 mile segments with the exception of mile segment 9 – 10. The residential community of East Lake is almost entirely contained within this mile segment. Thus, it appears that black bears in ARNWR actively avoid crossing the highway in the community area likely due in some part to the presence of humans as other studies have also noted (Lewis et al. 2011). The highest number of US 64 crossings was within mile segment 3 – 4 (n=27) (Fig. 27). Three other segments contained more than 10 crossings; 4 – 5 (n=12), 6 – 7 (n=13), 8 – 9 (n=11). Crossings were evenly distributed across the 7-mile stretch between segments 2-9 excluding the one stand out segment (3 – 4) inflated by 1 male bear. Thus, no one location in this segment appears more important than any other.

CONCLUSIONS

Employing all our data sources we identified 6 locations along highway 64 on ARNWR that were important crossing areas for black bears and white-tailed deer (Fig.42).

Location #1 is from mile 0 (US 64/264 intersection) to mile 2 and was identified as a crossing hotspot for black bears by barbed wire hair surveys, GPS radio collar data, and road kill events. For white-tailed deer location #1 was identified as a crossing hotspot by road kills. Three permanent fire breaks exist to the south of US 64 and are likely movement corridors for both bears and deer. Many black bear and white-tailed deer road kills occurred near the US 64/264 intersection (both on 64 and 264).

Location #2 is from mile 2.9 to 4.0 and was identified as a crossing hotspot for black bears by barbed wire hair surveys, road kill data, driving surveys, and GPS collar location data. It was also identified as a white-tailed deer crossing hotspot by driving surveys. This area includes the gated Creef Cut road in the east and extends west to Milltail Road. Bears are especially active in this area crossing the highway to access the farm fields at the end of Creef Cut road to the south and forested wetland areas to the north. A gated fence at Creef Cut road and extended fencing south along Milltail Creek road may decrease the occurrence of bears accessing US 64 directly from either of these roads. The current alignment of US 64 at Milltail Road includes a fairly sharp turn and thus somewhat of an elevated hazard for motorist and wildlife alike.

Location #3 is from mile 4 – 5.3. This section has its own crossing needs, but would also serve to extend the important crossing area #2 further west. It has been identified as an important crossing area for bears by barbed wire hair surveys and road kill surveys. It is also an important crossing area for white-tailed deer as determined by road kill surveys and driving surveys. To the south are farm fields on ARNWR, which extend nearly up to US 64 in what is acting as a wildlife movement funnel directly towards US 64 and slightly drier areas, and the closed Dare County landfill.

Location #4 is from mile 6.4 – 7.4. Black bears were identified crossing here from road kill incidents and GPS collar location data. White-tailed deer were identified crossing here from road kill surveys and driving surveys. This section extends from Buffalo City road 1.0 miles to the east. Black bears, white-tailed deer, bobcats and canids were all photo-captured at a wooded canal cross located at mile 5.8. This canal cross should either be included in the fencing for structure #4 or be removed so as to funnel wildlife to the crossing structure location. There is also a year round open access road (Deep Bay road) to the north that extends all the way to Deep Bay on South Lake and has vegetated side roads extending west. White-tailed deer and black bears are known to use both Deep Bay and the side roads for travel corridors. Deep Bay road

provides access to a very large area of habitat to the north of US 64. Here again fencing extending down Deep Bay road may limit wildlife access to US 64 via the road.

Location #5 is undoubtedly the most important bear crossing area identified. It extends from mile 7.4 to 9. It has been identified as a high use bear crossing area from the barbed wire hair surveys, road kill surveys, camera surveys, and GPS collar location data. We also identified it as an important white-tailed deer crossing area from road kill, camera, and driving surveys. This section extends from Buffalo City road west to the first residence of the East Lake community. This section recorded many black bear road crossings and suffered the most road kills of any section surveyed. There are two access roads to the north and two to the south, thus making for easy wildlife movement into all areas of ARNWR. This most important crossing area is centered at Hickory road itself (a year round gated farm field access road). If Hickory road was closed to motorized use at US 64 it could continue to be maintained for ARNWR personnel access and it would continue to act as a US 64 wildlife crossing corridor. Since Hickory road is such a well established travel corridor it would likely encourage bears, deer, wolves, and the suite of mid-sized mammals to use any installed wildlife crossing structure. Again, fencing would be advised along both sides of Buffalo City road, Lake Neighborhood road, and Brier Hall road.

Location #6 is located at mile 10.4 and extends right up to the existing Alligator River bridge. The area is considered an important bear and deer crossing area as identified by barbed wire hair surveys, road kill surveys, and GPS collar location data for bears and from driving surveys for deer. White-tailed deer also were identified crossing in the 9 – 10 mile segment, but since the East Lake community lies almost entirely within that section we realize the limitations of crossing structure placement in the area. We also acknowledge the difficulty in placing a crossing structure right at the landing of a bridge, and therefore suggest that with proper fencing an extended bridge landing would create an effective wildlife crossing access area with minimum road or bridge design alterations.

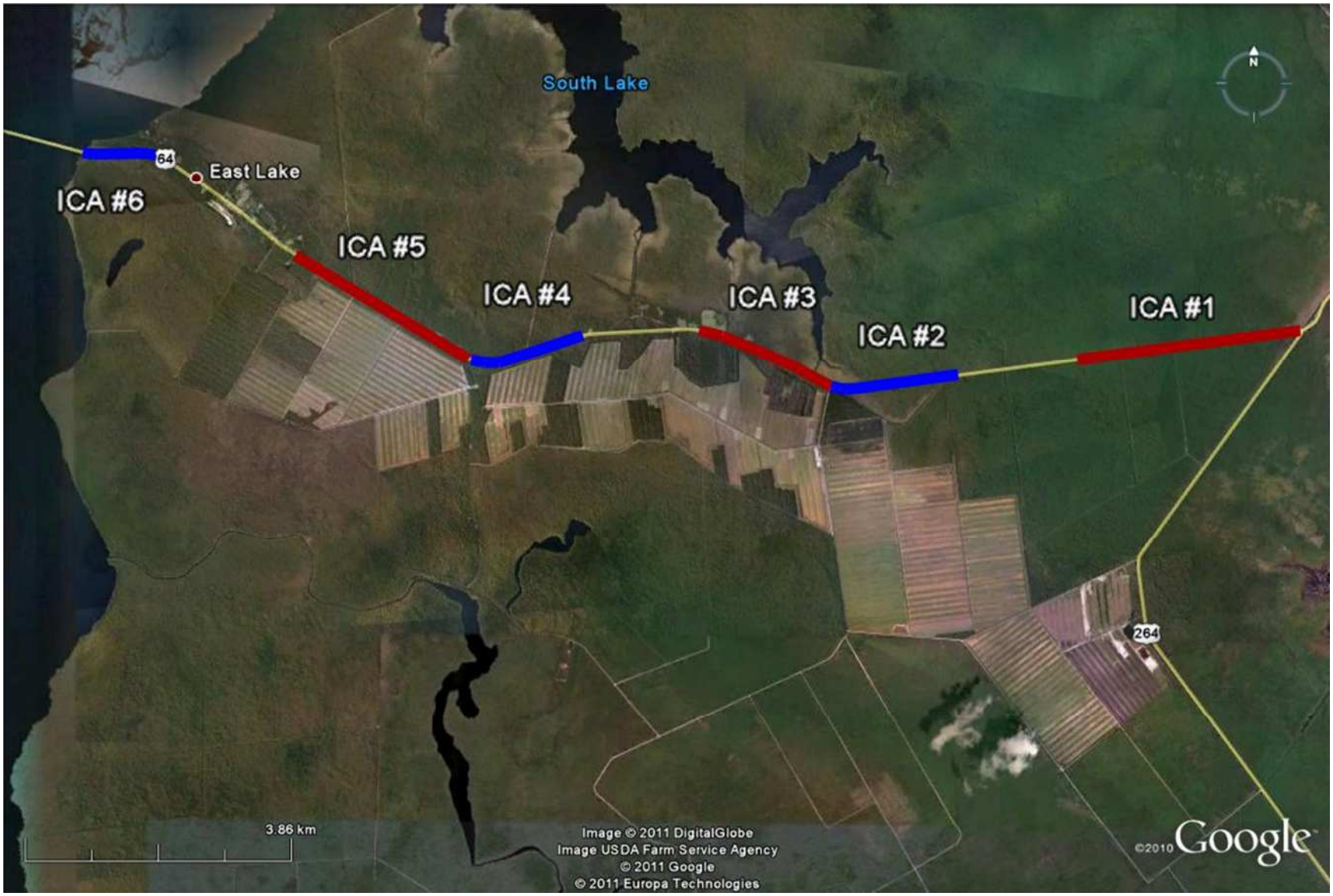

Figure 42. Map of the overall black bear and white-tailed deer important crossing areas (ICA) for US 64 on ARNWR, Dare County NC, compiled from all research methods performed during this study, 2009 – 2011.

LITERATURE CITED

Alexander, S.M., and N.M. Waters. 1999. Decision support applications for evaluating placement requisites and effectiveness of wildlife crossing structures. Proceedings of the Third International Conference on Wildlife Ecology and Transportation (FL-ER-73-99). Pages 237-246.

_____. 2000. The effects of highway transportation corridors on wildlife: a case study in Banff National Park. Transportation Research Part C 8:307-320.

Allen, T.G. 1999. Black bear population size and habitat use on Alligator River National Wildlife Refuge, North Carolina. M.S. Thesis, University of Tennessee, Knoxville, USA.

Ashley, E.P. and J.T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway. Lake Erie, Ontario. Canadian Field Naturalist, 110(3): 403-412.

Barnum, S. 2001. Preliminary analysis of locations where wildlife crosses highways in the southern Rocky Mountains. Proceedings of the 2001 International Conference on Ecology and Transportation. Pages 565-573.

_____. 2003 Identifying the best locations to provide safe highway crossing opportunities for wildlife. Proceedings of the 2003 International Conference on Ecology and Wildlife. Pages 246-252.

Bennett, A.F. 1991. Roads, roadsides and wildlife conservation: a review in nature conservation 2: The role of corridors. D.A. Saunders and R.J. Hobbs, eds. Surrey Beatty and Sons. 442 pp.

Beringer, J.J., S.G. Seibert, and M.R. Pelton. 1990. Incidence of road crossing by black bears on Pisgah National Forest, North Carolina. International Conference on Bear Research and Management 8:85-92.

Bissonette, J.A. 2007. Evaluation of the use and effectiveness of wildlife crossings. Final Report, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, NCHRP 25-27.

Brandenburg, D. 1995. Effects of roads on the behavior and survival of black bears in coastal North Carolina. MS Thesis, University of Tennessee, Knokville, USA.

Brody, A.J., and M.R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. Wildlife Society Bulletin 17:5-10.

Cain, A.T., V.R. Tuovila, D.G. Hewitt, and M.E. Tewes. 2003. Effects of a highway and mitigation projects on bobcats in Southern Texas. Biological Conservation 114:189-197

Carr, P.C. and M.R. Pelton. 1984. Proximity of adult female black bears to limited access roads. Proceedings of Annual Conference of the Southeast Association of Fish and Wildlife Agencies. 38:70-77.

Chruszcz, B., A.P. Clevenger, K.E. Gunson, and M.L. Gibeau. 2003. Relationships among grizzly bears, highways, and habitat in the Banff-Bow Valley, Alberta, Canada. Canadian Journal of Zoology 81:1378-1391.

Clevenger, A.P. 1998. Permeability of the trans-Canada highway to wildlife in Banff National Park: Importance of crossing structures and factors influencing their effectiveness. Proceedings of the International Conference on Wildlife Ecology and Transportation (Fl-ER-69-98). Pages109-119.

Clevenger, A.P., and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14:47-56.

_____. 2003. Long-term, year-round monitoring of wildlife crossing structures and the importance of temporal and spatial variability in performance studies. Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. C.L. Irwin, P. Garrett, K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pages 293-302.

_____. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation 121:453-464.

Clevenger, A.P., B. Chruszcz, and K.E. Gunson. 2001. Highway mitigation fencing reduces wildlife-vehicle collisions. Wildlife Society Bulletin 29:646-653.

Clevenger, A.P., J. Wierzchowski, B. Chruszcz, and K. Gunson. 2002. GIS-generated, expert-based models for identifying wildlife habitat linkages and planning mitigation passages. Conservation Biology 16:503-514.

Conover, M.R., W.C. Pitt, K.K. Kessler, T.J. Dow, and W.A. Sanborn. 1995. Review of human injuries, illness, and economic losses caused by wildlife in the United States. Wildlife Society Bulletin 23:407-414.

Dodd Jr., C.K., W.J. Barichivich, and L.L. Smith. 2004. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation 118:619-631.

Donaldson, B.M. 2005. The use of highway underpasses by large mammals in Virginia and factors influencing their effectiveness. Final Report to the Virginia Transportation Research Council, 06-R2. Pages 1-34.

Evink, G.L., P. Garrett, D. Zeigler, and J. Berry (eds). 1996. Trends in addressing transportation related wildlife mortality. Proceedings of the transportation related wildlife mortality seminar (Fl-ER-58-96). Pages not numbered.

_____. 1998. Proceedings of the International Conference on Wildlife Ecology and Transportation. FL-ER-69-98. Florida Department of Transportation, Tallahassee, FL. 263 pages.

Feldhammer, G.A., J.E. Gates, D.M. Harman, A.J. Loranger, and K.R. Dixon. 1986. Effects of interstate highway fencing on white-tailed deer activity. Journal of Wildlife Management 50(3):497-503.

Folta, J.E. 1998. Reproduction, survival, and denning ecology of black bears on the Dare County Peninsula, North Carolina. M.S. Thesis, University of Tennessee, Knoxville, USA.

Forman, R.T.T., D. Sperling, J.A. Bissonette, A.P. Clevenger, C.D. Cutshall, V.H. Dale, L. Fahrig, R. France, C.R. Goldman, K. Heanue, J.A. Jones, F.J. Swanson, T. Turrentine, and T.C. Winter. 2003. Road ecology; science and solutions. Island Press, Washington, D.C., USA

Foster, M.L., and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23:95-100.

Gagnon, J.W., N.L. Dodd, R.E. Schweinsburg, and A.L. Manzo. 2005. Comparison of wildlife underpass usage along State Road 260 in Central Arizona. Proceedings of the 2005 International Conference on Ecology and Transportation. Pages 534-544.

Gibeau, M.L., and IK. Heuer. 1996. Effects of transportation corridors on large carnivores in the Bow River Valley, Alberta. Proceedings of the Transportation Related Wildlife Mortality Seminar (FL-ER-58-96). Pages not numbered.

Gloyne, C.C., and A.P. Clevenger. 2001. Cougar (*Puma concolor*) use of wildlife crossing structures on the Trans-Canada highway in Banff National Park, Alberta. Wildlife Biology 7:117-124.

Hardy, A., A.P. Clevenger, M. Huijser, and G. Neale. 2003. An overview of methods and approaches for evaluating the effectiveness of wildlife crossing structures: emphasizing the science in applied science. Proceedings of the 2003 International Conference on Ecology and Transportation. Pages 319-330.

Huijser, M. 2006. National Cooperative Highway Research Program NCHRP Project 20-5, Synthesis of Highway Practice 37-12.

Jackson, S.D. 1999. Overview of transportation related wildlife problems. Proceedings of the Third International Conference on Wildlife Ecology and Transportation (FL-ER-73-99). Pages1-4.

Jackson, S,D., 2000. Overview of transportation impacts on wildlife movements and populations. Pp. 7-20 *in* Messmer, T.A. and B. West (eds), Wildlife and highways: Seeking solutions to an ecological and socio-economic dilemma. The Wildlife Society, Bethesda, MD.

Jackson, S.D., and C.R.Griffin. 1998. Toward a practical strategy for mitigating highway impacts on wildlife. Proceedings of the International Conference on Wildlife Ecology and Transportation. Pages 17-22.

_____. 2000. A strategy for mitigating highway impacts on wildlife. Pp. 143-159 *in* Messmer, T.A. and B. West (eds), Wildlife and highways: Seeking solutions to an ecological and socio-economic dilemma. The Wildlife Society, Bethesda, MD.

_____. 2000. In:Messmer, T.A., B. West (Ed

Jacobson, S.L. 2005. Mitigation measures for highway-caused impacts to birds. USDA Forest Service General Technical Report, PSW-GTR-191:1040-1050.

Jauger, J.A.G. and L. Fahrig. 2004. Effects of road fencing on population persistence. Conservation Biology 18:1651-1657.

Johnson, K.G. and M.R. Pelton. 1980. Prebaiting and snaring techniques for black bears. Wildlife Society Bulletin 8:46-54

Jones, M.D., G.S. Warburton, and M.R. Pelton. 1995. Models for predicting occupied black bear habitat in coastal North Carolina. International Conference on Bear Research and Management 10:203-207.

_____, F.T. Van Manen, T.W. Wilson, and D.R. Cox. 2010. Wildlife underpasses on U.S. 64 in North Carolina: Integrating management and science objectives. Pp. 223-238 *in* Beckmann. J.P., A.P. Clevenger, M.P. Huijser, and J.A. Hilty (eds), Safe Passages: Highways, Wildlife, and Habitat Connectivity. Island Press, Washington D.C.

Kaczensky, P., F. Knauer, B. Krze, M. Janozovic, M. Adamic, and H. Gossow. 2003. The impact of high speed, high volume traffic axes on brown bears in Slovenia. Biological Conservation 111, 191–204.

Kasworm, W.F. and T.L. Manley. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. International Conference on Bear Research and Management 8:79-84.

Kendall, K.C., L.H. Metzgar, D.A. Patterson, and B.M. Steele. 1992. Power of sign surveys to monitor population trends. Ecological Applications 2(4):422-430.

Kindall, J.L. 2004. Spacial ecology of black bears prior to construction of a 4-lane highway in eastern North Carolina. M.S. Thesis, University of Tennessee, Knoxville, USA.

Kindall, J.L., and F.T. van Manen. 2007. Identifying habitat linkages for black bears in eastern North Carolina. Journal of Wildlife Management 71:487-495.

Klein, L. 1999. Usage of GIS in wildlife passage planning in Estonia. Proceedings of the Third International Conference on Wildlife Ecology and Transportation (FL-ER-73-99). Pages179-184.

Klinger, M.H. 2001. Case study in implementing an effective environmental compliance monitoring program for highway construction projects. Proceedings of the 2001 International Conference on Ecology and Transportation. Page 294.

Kobler, A., and M. Adamic. 1999. Brown bears in Slovenia: identifying locations for construction of wildlife bridges across highways. Proceedings of the Third International Conference on Wildlife Ecology and Transportation (FL-ER-73-99). Pages 29-38.

Krawchuk, A., K.W. Larsen, R.D. Weir and H. DAVIS. 2005. Passage through a small drainage culvert by mule deer, *Odocoilus hemionus*, and other mammals. Canadian Field-Naturalist 119:296-298.

Land, D. and M. Lotz. 1996. Wildlife crossing designs and use by Florida panthers and other wildlife in southwest Florida. Proceedings of the Transportation Related Wildlife Mortality Seminar (Fl-ER-58-96). Pages not numbered.

Leedy, D.L. and Adams, L.W. 1982. Wildlife Considerations in Planning and Managing Highway Corridors. Report No. FWHA-TS-82, Office of Research, Federal Highway Administration, US Department of Administration, Washington 212pp.

Lehnert, M.E., L.A. Romin, J.A. Bissonette. 1996. Mule Deer-highway mortality in northeastern Utah: causes, patterns, and a new mitigation technique. Proceedings of the Transportation Related Wildlife Mortality Seminar (FL-ER-58-96). Pages not numbered.

Lewis, J.S., The effects of human influences on black bear habitat selection and movement patterns within a highway corridor, M.Sc. Thesis, University of Idaho, Moscow (2007).

_____, J.L. Rachlow, J.S. Horne, E.O. Garton, W.L. Wakkinen, J. Hayden, and P. Zager. 2011. Identifying habitat characteristics to predict highway crossing areas for black bears within a human-modified landscape. Landscape and Urban Planning 101:99-107.

Lloyd, J., A. Casey, and M. Trask. 2005. Wildlife hot spots along highways in northwestern Oregon. Proceedings of the 2005 International Conference on Ecology and Transportation. Pages 680-686.

Long, R.A., P. MacKay, W.J. Zielinski, and J.C. Ray (eds). 2008. Noninvasive survey methods for carnivores. Island Press, Washington D.C. 385 pp.

Manville, A.M., 1983.Humanimpact on the black bear in Michigan's lower peninsula. International Conference on Bear Research and Management. 5, 20–33.

Martorello, D.A. 1998. Ecology of black bears in coastal North Carolina. M.S. Thesis, University of Tennessee, Knoxville, USA.

Mattson, D.J., R.R. Knight, and B.M. Blanchard. 1987. The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. International Conference of Bear Research and Management 7:259–273.

McCollister, M.F. and F.T. Van Manen. 2010. Effectiveness of wildlife underpasses and fencing to reduce wildlife-vehicle interaction. Journal of Wildlife Management 74(8):1722-1731.

McCoy, K. 2005. Effects of transportation and development on black bear movement, mortality, and use of the highway 93 corridor in NW Montana. M.S. Thesis, University of Montana, Missoula, USA.

McLellan, B.N., and D.M. Shackleton. 1988. Grizzly bears and resource extraction industries: effects of roads on behavior, habitat use, and demography. Journal of Applied Ecology 25:451-460.

Mills,L.S., J.J. Citta, K.P. Lairs, M.K. Schwartz, and D.A. Tallman. 2000. Estimating animal abundance using noninvasive DNA sampling: promise and pitfalls. Ecological Applications 10:283-294.

Mowat, G., and C. Strobeck. 2000. Estimating population size of grizzly bears using hair capture, DNA profiling, and mark-recapture analysis. Journal of Wildlife Management 64:183-193.

Ng, S.J., J.W. Dole, R.M. Sauvajot, S.P.D. Riley, and T.J. Valone. 2004. Use of highway undercrossings by wildlife in southern California. Biological Conservation 115:499-507.

Reijnen, R. and R. Foppen. 1997. Disturbance by traffic of breeding birds: evaluation of the effect and considerations in planning and managing road corridors. Biodiversity and Conservation 6: 567-581.

Rodriguez, A., G. Crema, and M. Delibes. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. Journal of Applied Ecology 33:1527-1540.

_____. 1997. Factors affecting crossing of red foxes and wildcats through non-wildlife passages across a high-speed railway.

Romin, L.A., and J.A. Bissonette. 1996. Deer-vehicle collisions: Status of state monitoring activities and mitigation efforts. Wildlife Society Bulletin 24:276-283.

Ruediger, B. 1996. The relationship between carnivores and highways. Proceedings of the Transportation Related Wildlife Mortality Seminar (FL-ER-58-96). Pages not numbered.

_____. 2001. High, wide, and handsome: designing more effective wildlife and fish crossings for roads and highways. Proceedings of the International Conference on Ecology and Transportation. Pages 509-516.

_____, and M.DiGiorgio. 2007. Safe Passage: A user's guide to designing effective highway crossings for carnivores and other wildlife. www.safecarnivorepassage.org.

Russell, A.L., C.M. Butchkoski, L. Saidak, and G. F. McCraken. 2009. Road-killed bats, highway design, and the commuting ecology of bats. Endangered Species Research 8: 49-60.

Scheick, B.K., and M.D. Jones. 1999. Locating wildlife underpasses prior to expansion of highway 64 in North Carolina. Pages 247-251 in G.L. Evink, P. Garrett, and D. Zeigler, editors, Proceedings of the International Conference on Wildlife Ecology and Transportation. FL-ER-73-99, Florida Department of Transportation, Tallahassee, FL.

_____. 2000. US highway 64 wildlife highway underpass placement. Final Project Report. Division of Wildlife Management, North Carolina Wildlife Resources Commission. 17pp.

Singleton, P.H., J.F. Lehmkuhl, and W. Gaines. 2005. Using weighted distance and least-cost corridor analysis to evaluate regional-scale large carnivore habitat connectivity in Washington. Proceedings of the 2005 International Conference on Ecology and Transportation. Pages 583-594.

Smiley, J.D., and L. Lively. 2001. Ensuring environmental compliance through mitigation monitoring programs. Proceedings of the 2001 International Conference on Ecology and the Environment. Page 295.

Smith, D.J., L.D. Harris, and F.J. Mazzotti. 1996. A landscape approach to examining the impacts of roads on the ecological function associated with wildlife movements and movement corridors: problems and solutions. Proceedings of the Transportation Related Wildlife Mortality Seminar (FL-ER-58-96) Pages not listed.

_____. 1998. Highway-wildlife relationships: development of a decision-based wildlife underpass road project prioritization model on GIS with statewide application. Final Report to the Florida Department of Transportation, Contract Number B-9943.

_____ 2011. Cost effective wildlife crossing structures which minimize the highway barrier effects on wildlife and improve highway safety along 64, Tyrrell County, NC. Draft Final Report. UCF_NCDOT Contract No.MA2009-03. 89pp. + appendices.

Spellerberg, I. 1998. Ecological effects of roads and traffic: a literature review. Global Ecology and Biogeography 7:317-333.

Thompson, L.M. 2003. Abundance and genetic structure of two black bear populations prior to highway construction in eastern North Carolina. M.S. Thesis, University of Tennessee, Knoxville, USA.

Thompson, L.M., F.T. van Manen, and T.L. King. 2005. Geospacial analysis of allele presence patterns among American black bears in eastern North Carolina

Tredick, C.A. 2005. Population abundance and genetic structure of black bears in coastal North Carolina and Virginia using noninvasive genetic techniques. M.S. Thesis, Virginia Tech, Blacksburg, USA.

Tredick, C. A. and M.R. Vaughan. 2009. DNA-based population demographics of black bears in coastal North Carolina and Virginia. Journal of Wildlife Management, 73(7): 1031–1039.

U.S. Department of Transportation. Bureau of Transportation Statistics. 2006. National Transportation Statistics 2006. Washington, DC, U.S. Government Printing Office.

Van der Zande, A.N., W.J. ter Keurs, and W.J. van der Weijden. 1980. The impact of roads and the densities of four bird species in an open field habitat – evidence of a long-distance effect. Biological Conservation 18 (4):299-321.

Van Dyke, F.G., R.H. Brocke, and H.G. Shaw. 1986. Use of road track counts as indices of mountain lion presence. Journal of Wildlife Management 50:102-109.

Van Manen, F.T., M.D. Jones, and B.K. Scheick. 2001. Determining the potential mitigation effects on wildlife passageways on black bears. Proceedings of the International Conference on Ecology and Transportation. Pages 435-446.

Waits, L.P., and J.L. Leberg. 2000. Biases associated with population estimation using molecular tagging. Animal Conservation 3:191-199.

_____ and D. Paetkau. 2005. Noninvasive genetic sampling tool for wildlife biologist: A review of applications and recommendations for accurate data collection. Journal of Wildlife Management 69(4):1419 – 1433.

Waller, J.S., and C. Servheen. 1999. Documenting grizzly bear highway crossing patterns using GPS technology. Proceedings of the Third International Conference on Wildlife Ecology and Transportation. Pages 21-23.

_____. 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. Journal of Wilflife Management 69:985-1000.

Ward, A.L., J.J. Cupal, G.A. Goodwin, and H.D. Morris. 1976. Effects of highway construction and use on big game populations. U.S. Department of Transportation, Federal Highway Administration. Springfield, VA. 98pp.

Whit, P.A., and M. Ernst. 2004. Second Nature: improving transportation without putting nature second. Surface Transportation Policy Project, Defenders of Wildlife, www.defenders.org.

White, T.H., Jr., M.K. Oli, B.D. Leopold, H.A. Jacobson, and J.W. Kasbohm. 1996. Field evaluation of Telazol and ketamine-xylazine for immobilizing black bears. Wildlife Society Bulletin 24:521-527.

Wills, J. and M. Vaughan. 2001. Method to monitor travel corridor use by black bears along the eastern boundary of the Great Dismal Swamp National Wildlife Refuge. Proceedings of the 2001 International Conference on Ecology and Transportation. Pages 529-532.

Wills, J.2008. DNA-based hair sampling to identify road crossings and estimate population size of black bears in Great Dismal Swamp National Wildlife Refuge, Virginia. M.S. Thesis, Virginia Tech, Blacksburg, Virginia, USA.

Wooding, J.B. and R.C. Maddrey. 1994. Impacts of roads on black bears. Eastern Workshop of the Black Bear Research and Management 12:124-129.

Wray, S., P. Reason, D. Wells, W. Cresswell, and H. Walker. 2005. Design, Installation, and monitoring of safe crossing points for bats on a new highway scheme in Whales. Proceedings of the 2005 International Conference on Ecology and Transportation. Pages 369-379.

APPENDIX I

Table A. Summary of genetic "captures" of bears employing all the data sources and collection methods used from November 2008 – March 2011 within ARNWR, US 64 and US 264 in Dare County, NC.

Bear ID	Sex	Age	Mortality	Capture	Hwy 64 barbed wire	Hwy 264 barbed wire
915-0001	M	Adult	ROAD KILL - 64			
915-0002	M	Adult	ROAD KILL - 64		1	
915-0008	M	3	ILLEGAL - 64			
915-0009	F	2	ROAD KILL - 64			
915-0010	F	7	ROAD KILL - 64			
915-0011	F	10	ROAD KILL - 64		6	
915-0012	F	Cub	ROAD KILL - 264			
915-0014	M	2	ROAD KILL - 264			
915-0015	F	13	ROAD KILL - 264			
915-0016	M	2	ROAD KILL - 264			
915-0019	M	6-7	ILLEGAL - 264			
915-0020	M	2-3	ROAD KILL - 264			
915-0021	F	4	ROAD KILL - 64			
915-0023	M	5	ROAD KILL - 264			
915-0025	M	2	ROAD KILL - 264/64			
915-0026	M	1	ROAD KILL - 264			
915-0027	M	?	ILLEGAL - 264			3
AR03-055	M	9	ROAD KILL - 64			
1054-0029	F	14	ROAD KILL – 64			
1054-0030	M	1	ROAD KILL – 64			
1054-0032	M	1	ROAD KILL – 64			
915-1278	F	5	ROAD KILL – 64		1	
1054-0034	M	?	HARVESTED – DB RANGE			
AR04-028	F	?	HARVESTED – DB RANGE			
1054-0036	F	?	HARVESTED – DB RANGE			
AR03-049	M	?	HARVESTED – DARE LANDFILL			
AR04-677	M	?	HARVESTED – DARE LANDFILL			
915-1381	M	?	REMOVAL - 264			3
915-0101	M	4		101		
915-0102	M	3		102	1	

915-0105	M	4		105	6	
915-0106	M	3		106		
915-0107	M	4		107		
915-0109	M	7		109		
915-0111	M	4		111		
915-0116	M	4		116	5	
AR03-044	M	9-10		117		
915-0118	M	2	DEPREDATION - 64	118		
915-0119	M	3		119		
915-0120	M	4		120	1	
915-0121	M	2	ROAD KILL - 264	121		3
915-0122	M	5		122		
915-0123	M	4		123		
915-0124	M	4	ROAD KILL - 64	124		
915-0125	M	4		125	2	
915-0126	M	1		126		
915-0127	F	1		127		
915-0128	F	5		128		
915-0129	M	4		129	1	
915-0130	F	7-8		130		
915-0132	F	13-15		132		
915-0133	F	6-7		133		
915-0134	F	2		134		
915-0135	M	3		135	1	
915-0136	M	1		136		
915-0137	M	2	ILLEGAL - 64	137		
915-0139	F	8		139		
915-0140	M	3		140	2	
915-0141	M	2		141		4
915-0143	M	7	HARVEST – DARE LANDFILL	143		
915-0144	M	2		144	1	
915-0145	M	2		145	4	
915-0146	M	7		146	1	
915-0147	M	4		147		
915-0148	M	2		148	1	11
915-0149	M	7		149		
915-0150	M	3	HARVEST - HYDE	150		
915-0151	M	3		151		
915-0152	M	4		152		
915-0153	M	3		153		3

915-0155	M	4		155		2
915-0156	F	6-7	ROAD KILL - 264	156		
915-0157	M	4		157		
915-0158	M	5		158		5
915-0159	M	5	ILLEGAL - 64	159		
915-0161	M	20		161	1	
915-0162	M	4		162		
915-0163	M	5		163	2	
915-0164	M	4		164		
915-0165	M	4-5		165		
915-0166	M	8	HARVEST - HYDE	166		
915-0168	M	2		168		
915-0169	M	3		169		
915-0171	F	3		171		
915-0172	F	14-16		172		
915-0173	M	10-11	HARVEST - HYDE	173		
915-0174	M	3		174	2	
915-0175	M	5	UNK. CAUSE - HYDE	175		
915-0176	M	2		176		4
915-0177	M	4-5		177		5
915-0178	M	3		178		
915-0179	F	4	ROAD KILL - 264	179		1
915-0180	M	3		180	1	4
915-0181	M	5		181	2	
915-0184	M	5		184	24	
915-0185	M	5		185		
915-0186	M	5		186		
915-0187	M	5		187		
915-0189	M	5		189		4
915-0191	M	1	ROAD KILL - 264	191		
915-0192	M	1		192	1	1
915-0193	M	4		193		
915-0194	M	3		194		
915-0195	M	1		195		
915-0197	M	5		197		
915-0198	M	6-7		198	2	
915-0199	M	3		199		
915-0200	M	3		200		
915-0202	M	9-10		202		
915-0403	M	6-7		403	3	

915-0405	M	5		405		
915-0406	M	3		406		
915-0471	M	1		471		
915-0482	F	6-7		482		
915-0523	F	3		523		
915-0541	F	1		541		
915-0543	F	9		531		
1054-0203	M	?		203		
1054-0204	M	5		204		
1054-0205	M	2		205	1	
1054-0207	F	3		207	5	
1054-0208	F	13		208		
AR03-129	F	6-7		170		
AR03-143	F	17		201		
AR03-170	M	10-11		110		
AR03-238	F	11-12		142		
AR03-242	F	9		183		
AR03-316	M	16-18		182		
AR03-490	M	4-5		407		
AR03-510	M	8		138		
AR04-023	F	18-20	ROADKILL – 264 HYDE	517		
AR04-049	M	17		167	2	
AR04-056	M	9-10		115		
AR04-171	M	9		104		
AR04-186	F	20-22		531		
AR04-192	M	19	HARVEST – DARE LANDFILL	154		
AR04-212	F	20		188		
AR04-288	F	12		160		
AR04-492	F	7		131		
AR04-497	F	4		114		
AR04-534	F	19		404		
AR04-592	M	9	HARVEST – DARE LANDFILL	103/190		
AR04-687	M	7		108	2	
915-1026	M				1	
915-1035	M				2	
915-1063	M				3	
915-1066	F				2	
915-1088	M				1	
915-1091	M				1	
915-1103	M				1	

915-1184	F				1	
915-1190	M				1	
915-1264	M				1	
915-1358	M					1
915-1368	M					6
915-1449	M					2
915-1517	M					7
915-1547	M					1
AR03-524	M				1	
AR04-503	M					1
1054-1600	M				1	
1054-1709	M				1	
1054-1718	F				1	
1054-1720	M				3	
1054-1794	M				1	
1054-1803	F				4	
1054-1808	M				1	
1054-1810	M				1	
1054-1824	M					1
1054-1848	M				6	
1054-1897	M				2	
1054-1898	F					1
1054-1899	F					1
1054-1929	F				5	
1054-1968	F					5
1054-1982	F				1	
1054-1987	F				1	
1054-2060	M					2
1054-2118	F					1
1054-2159	M				1	
1054-2214	F					3
1054-2262	F					1
1054-2276	M					2
1054-2296	M				2	
1054-2327	F				2	
1054-2358	M					11
1054-2426	M					1

APPENDIX II:
OVERPASS DESIGN AND FENCING LITERATURE REVIEW

To insure maximum use of underpasses by black bears the design of those underpasses and associated fencing must be considered. This brief literature review of both underpass design and fencing options focused on use by black bears is meant to facilitate the selection of an appropriate underpass design.

Crossing Structure design:

Black bears use a wide range of road crossing structures from large, open overpasses and open span bridges to relatively small and long (6.9ft wide x 4.9ft high, 98.4ft length) structures such as metal and box culverts (Clevenger and Waltho 2005, Krawchuk et al. 2005, Ruedinger and DiGiorgio 2007, and McCollister and Van manen 2010). When given the option, black bears seem to exhibit a preference for more confined crossing structures, yet in Virginia, during a 12 month project, Donaldson (2005) documented no bear crossings across a wide range of structural types and sizes (from large bridge spans with 10ft grassy strips on each side to box culverts only 6ft x 6ft and 68ft long). The 6x6 box culvert was placed in an area known to have a high bear density and also contained established trails and road crossings as well as multiple records of bear-vehicle collisions, one resulting in the death of the driver. At a second box culvert (9.8ft wide x 11.8ft high x 189ft long) Donaldson recorded bears approaching and facing into the entrance on multiple occasions, but never crossing. Therefore, defining a specific “best” size or type of crossing structure specifically for black bears is very difficult, especially in homogeneous habitat lacking major topographical features like that of Alligator River NWR. For this project the likely best approach would be a large open underpass that is preferred by ungulates and wolves and located in areas frequently used by bears currently crossing the road.

Fencing:

Previous studies have shown that fencing and barriers used along with crossing structures limit animal access to roadways while directing animals to road crossing structures (Feldhamer et al. 1986, Jackson and Griffin 2000, and Dodd et al. 2004). But in a study of bobcat use of underpasses in Texas, fencing did not result in an overall increase in the use of culverts (Cain et al. 2003). Conversely, Jaeger and Fahrig (2004) found that when used in conjunction with crossing structures, fencing aided in population persistence in every situation. Jones et al. (2010) found that underpasses and fencing installed along US 64 in North Carolina likely resulted in the reduction of white-tailed deer/vehicular collisions. However, they also suggest that it did not appear to reduce the number of incidents with black bears and may have inadvertently increased the bear/vehicular incidents at non-fenced section of the road. This does not suggest that fencing should not be used in conjunction with crossing structures, but instead indicates that further

refinement of how the fencing is installed needs to occur. Jones et al. (2010) suggested an improvement on their 9.8 ft. tall by 2,625 ft long (both directions from underpass) fence design by adding barb wire outriggers to the top of the fence and burying the fence in the ground to alleviate wildlife crossing over or under the fence. They also suggest that if the fences were contiguous from one underpass to another then road mortalities would be greatly reduced. For fencing to be most effective through time a system and schedule for vegetation control, maintenance and repair is imperative.