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The Behavioral Ecology and Population Characteristics of Striped Skunks Inhabiting Piper Plover Nesting Beaches on the Island of Martha's Vineyard, Massachusetts

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Department of Environmental Studies

DISSERTATION COMMITTEE PAGE

The undersigned have examined the dissertation entitled:

THE BEHAVIORAL ECOLOGY AND POPULATION CHARACTERISTICS OF STRIPED SKUNKS INHABITING PIPING PLOVER NESTING BEACHES ON THE ISLAND OF MARTHA'S VINEYARD, MASSACHUSETTS

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THE BEHAVIORAL ECOLOGY AND POPULATION CHARACTERISTICS OF STRIPED SKUNKS INHABITING PIPING PLOVER NESTING BEACHES ON THE ISLAND OF MARTHA'S VINEYARD, MASSACHUSETTS

by

Luanne Johnson

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

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(Environmental Studies)

at

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Dedication

This dissertation is dedicated to some very special people I wish were here to celebrate with me:

Darwin Albert Johnson (2/15/1934 – 3/18/2014), who always supported my love of wildlife, even when it took me far away to Alaska, Hawaii, and the east coast. He taught me the value of loving what you do for a living. I miss you every day, dad.

Zachary Frank Flowers (2/14/1992 – 1/18/2014), whose smile and contagious giggle taught me that a nephew's love is a very special kind of love. You were beautiful in so many ways, Zachary, and I miss you every day too.

Scott Merrill Melvin, PhD (12/14/1953 – 7/11/2014), my committee member, friend, and mentor, helped me develop this research project. I could not have started or completed this work without his guidance, encouragement, and thoughtful criticism. He made me a better shorebird biologist and scientist.

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Melissa Laser, PhD (10/30/69 – 4/27/2010) was a member of my PhD cohort, a friend, confidant, and an inspiration to many. She is always on my shoulder, reminding me to aim high and keep fighting the good fight for endangered species.

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Stephen DeStefano, USGS Cooperative Fish & Wildlife Research Unit Leader at the University of Massachusetts, Amherst was my primary advisor for this research and exhibited extraordinary patience and kindness through several life events that halted my progress. His encouragement, non-judgement, and faith in my abilities allowed me to pick myself up and dust myself off to forge ahead. Steve’s depth and breadth of wildlife research experience and broad view of my research within the context of urban/suburban wildlife work provided me with valuable insight. From mammalogy guidance to IACUC certification to statistical support and editing, he was vital to this work and my professional development. I am indebted to Dave Wattles, Steve’s post-doc, for his statistical guidance on RSFs and use vs. availability analysis. His patience, enthusiasm for my research, and sense of humor helped me in the final stretch.

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Many thanks to the island libraries for hosting my public talks and outreach efforts, and especially Ebba Hierta for getting me started at the Chilmark library. I'm particularly indebted to Cornelia Dean, of Chappaquiddick, who made me famous by featuring my research on the front page of the NY Times Science Times section; to Eric Handler, producer, for featuring me and my research on FETCH, with Ruff Ruffman on PBS, and John Rubin Productions for highlighting my research in "Is that skunk?" on PBS's Nature.

On Martha's Vineyard, I am grateful to the Edey Foundation, an anonymous foundation, and individual donors (anonymous, Nancy Cox, Daryl and Richard Knight, Chris Perleberg, and many others) whose grants and gifts allowed me to follow these 51 skunks and learn about their habits. The Chappaquiddick Island community and ferry drivers welcomed me warmly, and I am grateful to them for their interest in and enthusiasm for my research. At Dogfish Bar and near Long Point, Chip and Barbara Chipman, the Horans, Razdows, Alex Taylor and Shawn, the Callaghys, Tempelsmans, Leonards, Weiss family, the Moore clan of Middle Point and Warren and Meagan Adams at Oyster pond all welcomed this project. Your smiles and good conversation enriched my life and field experience. I was fortunate to have some incredible field assistants who were all dedicated and enthusiastic, which made the sleep deprivation, ticks, poison ivy, and sometimes smelly work, fun! Thank you to: Jim Pepper, Kelsey Harrity, Elliott Garber, Laura Davis, Richard Stanton, Jr., Liz Baldwin, Matt Walter, and David Bouck for helping me capture skunks, track them, and collect this data.

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My obsession with wildlife likely came through my mother's DNA, Betty (Elizabeth) J. Johnson, whose family lived in the Saskatchewan prairies where we visited every summer of my childhood. Thank you for a lifetime of love and opportunity, Mom. My thoughtful and loving sister, Caroline Flowers, and her husband, Frank, and my nephew, Lance, have always encouraged my wildlife pursuits with regular phone calls and care packages wherever I might be.

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Abstract

We studied coastal striped skunks (*Mephitis mephitis*) on the island of Martha's Vineyard, Massachusetts, USA, where beaches are seasonally urban habitats (SUH). From 2004 – 2008, we captured and marked 138 skunks and fitted 51 adults with VHF radio-collars to gather information on the behavior and population characteristics of this known egg predator on piping plover (*Charadrius melodus*) nesting beaches. Spring capture rates were highest at Dogfish Bar (DB), a beach with abundant wrack in the intertidal zone in close proximity to low-density housing, where we estimated a density of 8-10 skunks/km^2. Spring capture rates were too low for a density estimate at Norton Point/Wasque (NPW), a beach with sparse wrack and farther from development. Half (50%) of all radio-collared skunks died from human-related causes while disease killed another 29%. At all sites, telemetry locations from females rearing young were closer to beaches than locations from males or females without young (255 ± 16 m vs. 512 ± 14 m vs. 525 ± 29 m, respectively). Male and female skunks moved similar maximum straight-line distances from their daytime retreats, but females traveled farther because they made round-trip movements from natal dens (1,615 ± 79 m vs. 1,149 44 m). Abundant wrack on the beach was associated with a higher frequency of skunk foraging observations near the shoreline than at inland locations. Of 258 beach foraging observations where we identified food/prey skunks consumed, 76% were invertebrates in the intertidal zone and 24% were anthropogenic food in backshore and backdune areas. Based on habitat use vs. availability analysis, the relative probability of a skunk using any habitat for a daytime retreat or winter den increased as distance to nesting beach decreased. During the plover nesting season, skunks used shrub habitat for daytime retreats more than twice as much as it was available. Switchgrass (*Panicum virgatum*) patches, while limited in availability, had the highest probability of selection for a daytime retreat. During winter denning, skunks used shrub habitat equal to its availability while they used human habitat more than twice as much as it was available on the landscape. On beaches that are seasonally urban habitats (SUH), research investigating the influence of anthropogenic food subsidies on the activity and density of generalist predator species during the summer could provide valuable data for management efforts and public outreach aimed at reducing predation on rare and threatened beach species. Reducing anthropogenic shelter and food subsidies will reduce overall carrying capacity for coastal skunk populations. At beaches where exclusion fencing is not an option for protecting eggs of rare and threatened species, spring trapping could be effective in reducing skunk densities for most of the nesting season.

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CHAPTER 1

Coastal Striped Skunk Population Characteristics on the Island of Martha's Vineyard, Massachusetts, USA.

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Abstract

We studied coastal striped skunks (*Mephitis mephitis*) on the island of Martha's Vineyard, Massachusetts, USA to gather information on the population characteristics of this mesopredator on Atlantic coast beaches with nesting piping plovers (*Charadrius melodus*). From 2004 – 2008, we captured and marked 138 skunks and fitted 51 adults with VHF radio-collars. Capture rates ranged from 1 – 7 individuals/100 trap nights (TN) in the spring and 4 – 21 individuals/100 TN in the fall. Spring capture rates were highest at Dogfish Bar (DB), a beach with abundant wrack in the intertidal zone in close proximity to low-density housing, where we estimated a spring density of 8-10 skunks/km^2. All adult skunks were residents at this site, and most were initially captured in April/May (100% of males and 67% of females). Spring capture rates were too low for a density estimate at Norton Point/Wasque (NPW), a beach with sparse wrack and farther from development. We initially captured 80% of adult males in April/May but only 1 adult female. Most adult females (88%) were captured in June/July, which coincided with the arrival of anthropogenic food on the beach. While all adult females captured at NPW were residents, 50% of males were non-residents. Half (50%) of all radio-collared skunks died from human-related causes while disease killed another 29%. Female site fidelity was high at both sites, with 40% recurring in subsequent years. While male recurrence at DB was high at 36%, no males recurred at NPW. Similarly, no juveniles recurred in subsequent years at the NPW, but 26% of juveniles recurred at DB. The Martha's Vineyard skunk population does not exhibit any distinguishing characteristics from mainland striped skunk populations at this time. Skunks captured exhibited all stripe patterns known for the species, but narrow (45%) and short-striped (37%) patterns were most abundant. Adult skunks weighed a mean of 1.47 ± 0.05 kg between April and July and 2.08 ± 0.09 kg between August and November. At beaches where exclusion

fencing is not an option for protecting eggs of rare and threatened birds, spring trapping could be effective in reducing skunk densities for most of the nesting season because our data indicates that female territories would remain vacant until late summer. Future research tracking the temporal and spatial variation in wrack line fauna availability on beaches with sparse vs. dense wrack lines will increase our understanding of the factors influencing interactions between piping plovers and predators that share foraging habitat with them, such as skunks and crows. On beaches that are seasonally urban habitats (SUH), research using experimental designs to investigate the influence of predictable anthropogenic food subsidies (PAFS) on the activity and density of generalist predator species during the summer could provide valuable data for management efforts and public outreach aimed at reducing predation on rare and threatened beach species.

Introduction

Striped skunks (*Mephitis mephitis*) occupy a broad range of natural habitats in North America, from arid regions of the southwest (Hansen et al. 2004; Doty and Dowler 2006) to boreal forests in Minnesota (Fuller and Kuehn 1985). They also inhabit human-altered landscapes such as agricultural areas, golf courses, and suburban/urban habitats (Dean 1965; Rosatte et al. 1991; Gehrt 2005). While skunks play a beneficial role in ecosystems and agricultural areas as an insect and rodent predator (Kelker 1937; Wade-Smith and Verts 1982), they are also known as a public health risk due to their potential as a rabies vector (Rosatte and Gunson 1984; Greenwood et al. 1997), a nuisance species for homeowners (DeStefano and DeGraaf 2003), and for their impacts as egg predators of ground-nesting birds (Hecht and Nickerson 1999; Lariviere and Messier 2001; Meckstroth and Miles 2005).

Atlantic and Pacific coast beaches have thus far been overlooked in studies of striped skunks, yet the resources available in these habitats have the potential to support high densities of the species. As a habitat and diet generalist with high fecundity potential (Wade-Smith and Verts 1982; Rosatte and Lariviere 2003), skunks may occur at densities of > 20/km^2 in areas with substantial food and shelter resources (Dean 1965; Ferris and Andrews 1967; Verts 1967; Goldsmith 1981; Broadfoot et al. 2001). Some sandy shore ecosystems provide an abundance of invertebrate food and carrion in the intertidal and wrack line zones that other mesocarnivores are known to exploit (Brown and McLachlan 1990; Polis and Hurd 1995; Moore 2002) and which may promote elevated densities of those species (Rose and Polis 1998).

We studied striped skunks captured at piping plover (*Charadrius melodus*) nesting beaches on the island of Martha's Vineyard, Massachusetts to increase our understanding of their biology and behavior in Atlantic coast beach habitat, and to contribute information on an island population of striped skunks for comparison to similarly described continental populations. Our objectives were to (1) estimate densities at nesting beaches, (2) document emigration and dispersal distances, (3) document sources of mortality, (4) determine site fidelity via radio-telemetry and annual recurrence rates in traps, and (5) report physical characteristics, specifically weights, measurements, and pelage patterns of this island population.

Striped skunks were native to Martha's Vineyard when Europeans arrived, based on archeological records from Native American kitchen middens and interviews with island residents (Keith 1969). Skunks were also documented in the historical record by James Freeman (Freeman 1815) in his description of Dukes County. Some believe the original skunk population was a sub-species because the island skunks were described as larger than mainland skunks with mostly black pelts, but no specimens are available from that time period (Keith 1969). The original population of skunks was likely extirpated by 1910, as there were no reliable reports of skunks between then and the 1960s. By the mid-1960s, reports of skunks were increasing around the island, and the population increase was attributed to the release of pet skunks that were popular at the time. Only two other native mammalian carnivores are found on Martha's Vineyard: the raccoon (*Procyon lotor*) and river otter (*Lontra canadensis*) (Keith 1969).

Methods

Study areas

We studied coastal striped skunks at three piping plover nesting beaches on Martha's Vineyard (MV), Massachusetts, USA, 41 21 N, 070 31 W, a 260 km^2 island located 13 km south of the mainland (Fig 1.1). Annual temperature and precipitation average 9.4° C (range-21.7 to

37.2) and 118 cm (range 66 to 127), respectively. The winter climate (December – February) is milder than the mainland, with an average temperature of 0˚ C (range – 4 to 6) and average snowfall of 91.9 cm (range 19 – 27) (www.weatherbase.com, accessed 11/8/2012). The year-round human population is approximately 15,000, however, over 100,000 summer residents and tourists inhabit the Island between mid-June and the end of August. This annual summer pulse of human activity also brings predictable anthropogenic food subsidies (PAFS) (Oro et al. 2013) to the beaches.

The study took place during 2004-2008. We initially selected 2 coastal study areas, Dogfish Bar (DB) and Norton Point/Wasque (NPW), separated by 37 km (Fig 1.1). However, low spring capture success and dispersals from the NPW site in 2005 and 2006 necessitated a third study area. In fall of 2006, we added Long Point Wildlife Refuge (LP), located between the two sites on the south shore of the island (Fig 1.1).

Habitat description

American beach grass (*Ammophila breviligulata*) and beach pea (*Lathyrus japonicus*) were the primary dune vegetation at all sites. Some foredune and most backdune areas had patches of beach rose (*Rosa rugosa*), beach plum (*Prunus maritime*), bayberry (*Myrica pennsylvanica*), and poison ivy (*Toxicodendron radicans*). At DB (Fig 1.2), dense patches of switch grass (*Panicum virgatum*) grew in the transition zone from backdune to wetland. A dirt road separated the backdune from a freshwater wetland area with buttonbush (*Cephalanthus occidentalis*), sweet gale (*Myrica gale*), high-bush blueberry (*Vaccinium corymbosum*), sweet pepperbush (*Clethra alnifolia*), giant reed (*Phragmites australis*), and swamp candle (*Lysimachia terrestris*). Open shrubland habitat dominated by scrub oak (*Quercus ilicifolia*) and beach plum on old dunes grew inland of backdune and wetlands in most areas. Early successional forests contained areas of white, black, and red oak (*Quercus alba*, *Q. velutina*, *Q. rubra*), sassafras (*Sassafras albidum*), shadbush (*Amelanchier canadensis*), and black cherry (*Prunus serotina*), with black huckleberry (*Gaylussacia baccata*) in the understory in most inland areas. Upland forests on moraine soils were primarily American beech (*Fagus grandifolia*), with black tupelo (*Nyssa sylvatica*) in wet soils. Privately owned summer homes and adjacent beach lots on a 1-km long section of beach comprised much of the core DB study area, but protected natural areas bordered it to the east and west. The beach at this site is a premier saltwater fishing location with only limited public access on a small, state-owned parcel.

At NPW (Fig 1.3), a barrier beach sheltered mud flats and salt marsh at Katama Bay and salt marsh at Poucha Pond to the east. On 16 April 2007, a storm created a breach in Norton Point barrier beach isolating Chappaquiddick as an island for the first time since the early 1970s. The break in the beach remained open through the end of our study. Coastal heathlands and grasslands with scrub oak, black huckleberry, lowbush blueberry (*Vaccinium angustifolium*), bearberry (*Arctostaphylus uva-ursi*), bayberry, little bluestem (*Schizachyriam scoparium*), Pennsylvania sedge (*Carex pensylvanica*), poison ivy, and golden heather (*Hudsonia ericoides*) grew behind the beach at Wasque. Patches of pitch pine (*Pinus rigida*) and oak (*Quercus* spp.) forests surrounded the heathlands and much of the inland land cover on Chappaquiddick was of this vegetation type. The NPW site comprises sections of beach owned by Dukes County, the state of Massachusetts, or The Trustees of Reservations (TTOR), a private land-trust. TTOR collectively manages all of NPW. Wasque reservation lies adjacent to a residential area of summer and year-round homes, and the area is a premier saltwater fishing location. NPW is a public beach in the summer months, with both pedestrian and off-road vehicle use for picnicking, swimming, fishing, and shell fishing.

At LP (Fig 1.4), coastal heathlands and grasslands similar to NPW were adjacent to the beach. A large (35 ha) freshwater pond extends from the beach inland >1 km in the center of the refuge, Tisbury Great Pond (320 ha) borders the western edge of the refuge, and undeveloped land lies to the east. Mixed oak and pitch pine forest, with a huckleberry understory, comprised much of the habitat inland of the coastal heath on the refuge. The refuge extends >2 km inland from the beach, which isolated this beach from housing developments. The refuge is owned and managed by TTOR and several hundred people visit the refuge beach on most summer days to swim, fish, and picnic.

Capture and handling

We trapped skunks in Safeguard live traps (76 x 28 x 31 cm, single-door, Safeguard Products Inc., New Holland, PA; mention of trade names does not constitute endorsement by the federal government) with dried grass bedding in the back and cardboard covering the rear and sides of each trap. A 1 m tall metal stake, run through the cardboard and trap, prevented trap roll-over. Traps were baited with a combination of cat food, canned tuna, salmon, or sardines (Bailey 1971; Greenwood et al. 1985). In addition, we placed a peanut butter (Stout and Sonenshine 1974) and jelly cracker, bread with barbeque sauce, or a piece of sweet pastry on the trigger pan. We ceased trapping during foul weather (wind >30 mph, heavy rain, or temps below 0^{o} C). Traps were set at sunset and checked before or at sunrise. We removed bait from empty traps and wired all traps shut during the day to prevent capture of non-target species.

In 2004, we trapped opportunistically at DB during late May – October to capture skunks to test capture and marking methods, gather pilot radio telemetry data, and to mark adults and juveniles in the fall. In subsequent years (2005 – 2007) intensive trapping in April and May focused primarily on capturing skunks for telemetry and a mark-recapture density estimate at

DB. In June and July, we trapped opportunistically to capture any females missed in April and May, and we employed spot-light searches and hand nets on the beach at night to capture unmarked skunks. Late summer and fall (August – November) objectives focused on marking juveniles at the site and capturing new adults in the area. We trapped in the spring of 2008 to remove radio collars and gather survival and recurrence data.

Limited numbers of traps and staff prevented us from trapping at multiple locations simultaneously, but we did attempt to equalize our trapping effort at DB and NPW 2005-2007. The trapping area at each site differed in size and configuration due to differences in development at or near the sites (See Figs 1.2 – 1.4), but we focused most of our effort at all sites within 400 m of the beach. At DB we trapped 33 ha (Fig 1.2), placing traps along the edges of driveways to private homes and on footpaths between homes and the beach where skunk tracks were concentrated. Ease of trapping and consistent use of these paths by skunks allowed for replication of the trapping pattern and effort each year and season for comparison at that site. At NPW we trapped an 80 ha area as there were fewer footpaths to the beach to direct skunk travel and skunk activity was more diffuse (Fig 1.3). We trapped along all footpaths to the beach, the edges of over-sand vehicle routes, and the visitor parking areas. We also trapped along the edges of dirt roads leading to the reservation and the nearest houses, which were 1 km from the beach. At LP we trapped a 20 ha area of the refuge (Fig 1.4). We placed traps near the house and barn on the refuge, on the bathing beach, the visitor parking area, and at the intersections of trails and beach footpaths.

Captured skunks were anesthetized in the trap with a mixture of ketamine hydrochloride (8-10 mg/kg) and acepromazine (1 mg per kg) via jab stick. Upon initial capture, we determined the sex of each individual and aged them as either adults or juveniles (summer and early fall only) based on size, weight, physical appearance, and tooth wear (Jones 1948). Females were palpated for pregnancy and checked for lactation between April and September. Short (≤1 mm) teats identified yearling females in the spring (Petrides 1950; Verts 1967; Bjorge et al. 1981). Upon lactation, all females were aged as adults as teats lengthened and changed in appearance after females nursed kits. Morphometric data (total length, tail length, right rear foot length) and type of stripe pattern were also recorded beginning in 2007.

Skunks were placed under shrubs or in areas of bunch grass after handling and were monitored during their recovery. During cold or wet weather we wrapped skunks in fleece blankets to maintain core temperature post-handling. We completed processing of trapped within 3 hours after sunrise. All trapping and handling of animals was in accordance with University of Massachusetts at Amherst Institutional Animal Care Protocol #24-02-07 and an annual letter permit from the Massachusetts Division of Fisheries and Wildlife.

Marking

In 2004, a standard size, numbered plastic colored ear tag (Roto-tag ®, www.enasco.com, Fort Akinson, WI) placed in one ear of each captured skunk provided a means of visual identification, but skunks did not retain these. In 2005, we began injecting a 12mm, 125 kHz, Passive Integrated Transponder (PIT) tag (Biomark Inc., www.biomark.com, Boise, ID) under the skin between the shoulder blades of each skunk at initial capture as a permanent means of identification. A numbered Monel tag (size #1, www.nationalband.com, Newport, KY) in one ear allowed for visual identification of previously captured skunks.

We fitted a sub-sample of adults at each site with 40g VHF radio-collars equipped with a mortality switch set at 12 hours and a battery life of at least 370 days (model M1930 series, Advanced Telemetry Systems, Isanti, MN). Radio collars never exceeded 5% of the body weight of any skunk. We attempted to collar an equal number of males and females at each site. A unique combination of colored reflective tape on the antenna of each radio-collar provided a means of identifying individuals visually. Skunks first collared in the spring were re-captured in the late summer or early fall to loosen their collars and provide space for fall weight gain. Those not re-captured in traps were anesthetized directly with the jab-stick while sleeping in a lay, or captured with a net while active at night. When radio-collared skunks died, we sent suitable carcasses to the Connecticut Veterinary Medical Diagnostic Lab at the University of Connecticut and to the wildlife clinic at Tufts School of Veterinary Medicine in Massachusetts for necropsy. We conducted gross necropsies of skunk carcasses not suitable for shipping and did not necropsy skunks killed by vehicles.

Radio-telemetry

We used the homing method (White and Garrott 1990) and a handheld receiver and 6-element yagi-antenna (R-1000, RA-165; Communications Specialists, Inc., Orange, CA) to track radio-collared skunks. During and between trapping sessions, we tracked 3 – 5 days per week, at various times of day (morning, mid-day, and late afternoon), to assess daytime resting patterns and fidelity to the study sites. When we could locate them, radio-collared skunks were located at least 7 times per week in the summer, 1 - 3 times per week in the fall and spring, and weekly in the winter and early spring. We determined site fidelity for all skunks monitored via radio-telemetry for ≥2 weeks during the spring and summer months. Any skunk that travelled more than 1 km away from its capture location and was not relocated within 500 m of its capture location at least once per week was considered a non-resident. Resident skunks sometimes traveled more than 1 km from their capture location, but they were relocated within 500 m of their capture location at least once per week.

Density estimate

We used a modified Lincoln-Peterson index (Chapman 1951), with variance estimated using the Seber (1970) method, to calculate a density estimate. We assumed a closed population during the trapping period (April – early May). Radio-collars on a sub-sample of the population provided information on emigration, mortality, and location data to estimate an effective trapping area for the density estimate. We used Home Range Tools extension (Hooge and Eichenlaub 2000) in ArcGIS version 9.31 (2009) to create a 95% minimum convex polygon of all skunk locations during the mark-recapture period, which removed 5% of the furthest locations using a fixed mean. We then used a 75% core of the combined skunk locations to delineate the effective trapping area, assuming we had captured 100% of the skunks using that area.

Statistical analyses

All statistical analyses were conducted in program SPSS 12.0 (2003), except for chi-square analyses, which were conducted with JMP 4.04 (2001) statistical software. Values are given as mean ± SE unless otherwise noted. For analysis of capture data, we split the field season in to 2 biological periods: the early season (April – 3rd week of July inclusive) covered the kit-rearing period for females and allowed time to include females not captured in April or May, while the late season (4th week of July – 2nd week of November inclusive) covered the period when juvenile skunks were active at the sites and adult movements expanded into winter home ranges. Skunks captured by net were not included in any capture rate calculations, unless they were captured in a trap later. We calculated mean weights of adults in the early and late season from all captures, as well as mean body, tail, and right rear foot lengths. Data were tested for homogeneous variance with Levene's test (Levene 1960), and we proceeded with analysis of variance or Mann-Whitney U tests in comparing data for sexes and seasons. To assess annual weight changes in individuals, we calculated mean weight change in grams between early and late season (weight gain) and between late season and the following spring (weight loss).

For comparison of capture rates and sex ratios between study areas and seasons, we used data from 2005 – 2007 when DB and NPW were both active study areas, and data from 2007 at LP, as this was the only full season of trapping. We used a Likelihood-ratio chi-squared test to compare number of male vs. female captures by year and season and to compare site fidelity between sexes and sites, where sample sizes allowed. We split the early season capture period into April/May vs. June/July to assess differences in captures between study areas as most adults were captured during the early season. LP was not included in this analysis due to low sample sizes. We calculated percent recurrence rates for male and female adult and juvenile skunks by dividing the number of individuals of each sex recaptured in a subsequent year at the site by the total number of adults or juveniles of each sex captured at the site. Skunks captured and marked in 2004 at DB were not included in recurrence calculations, as they did not retain the ear tags used in 2004. We did not calculate recurrence rates for LP adults because 2007 was the only full year of trapping.

Results

Density Estimate

In April - May of 2005 and 2006 we captured and marked 9 and 10 skunks, respectively, during the initial 7 – 10 day trapping session at Dogfish Bar. Radio-collars were attached to 6 skunks in 2005 and 9 skunks in 2006. We recaptured 7 individuals in both years during the second trapping session, after a 7 – 10 day interval. However, in 2005, we also captured 2 new skunks in the second session. Using skunk daytime radio-telemetry locations during and between trapping sessions, we calculated an effective trapping area of 1.2 km^2 (Fig 1.2). We estimated densities of 9.8 ± 0.6 SE and 8.5 ± 0.4 SE skunks per km^2 in 2005 and 2006, respectively. Daytime telemetry locations in 2005 documented one incidence of emigration violating the closure assumption. This young male skunk remained >1 km away for much of May and June, and returned to the trapping area in July. He was recaptured at the site in October of that year and in subsequent years. At Norton Point/Wasque in 2005 - 2007, low capture rates, emigration, and mortality between trapping sessions made a Lincoln-Petersen calculation invalid.

Capture success and sex ratios

We made 345 captures of 136 individuals in 2,293 trap nights between spring of 2004 and spring of 2008 at Dogfish Bar, Norton Point/Wasque, and Long Point; 66 were adults and 70 were juveniles (<8 months) (Table 1.1). We captured two adult females by hand net, and one was captured in a trap later. Over half of skunks, 63% (85/136), were captured at the DB site.

Our overall capture rate in this coastal location was 5.9 skunks/100 TN (136 skunks/2,293 TN). Capture rates by site and season are reported in Table 1.2. From 2005 – 2007 the mean early season capture rate at DB was more than twice that of NPW (6.6 ± 0.2 vs. 2.1 ± 0.9 individual skunks/100 trap nights (TN), $t = 4.838$, d.f. = 4, $P = 0.008$), despite more effort at NPW. In 2007, early season capture rates at DB and LP were similar (6.6 and 5.8 individual skunks/100 TN, respectively) (Table 1.2). Late season capture rates were higher than early season rates at all sites. During late season trapping in 2005 – 2007, juveniles represented 49%, 58%, and 54% of all captures, respectively. The majority of juvenile skunks (35/59) were captured at the DB site, and these 35 juveniles represented 56% of the skunk captures during late season trapping at DB from 2005 – 2007 (range = 50 – 62%). Late season capture rates were consistently high at DB where we captured 21, 18, and 18 skunks/100 TN during 2005, 2006, and 2007, respectively. Capture rates dropped at NPW from 17 to 14 to 4 individual skunks/100

TN over the same period. The mean capture rates did not differ (*t* = 1.77, d.f. = 4, P = 0.152). At LP in 2007, the late season capture rate of 16 skunks/100 TN was similar to DB but with limited trapping effort (Table 1.2).

In the early season, there was no difference in the ratio of adult female vs. male skunks captured in traps at DB during 2005 – 2007 (X^2 = 1.96, p = 0.37), at NPW during 2005 and 2006 (X^2 = 0.052, p = 0.859), or LP in 2007, when we captured equal numbers of each sex (Table 3). In the late season at DB, we captured more adult males than females each year (X^2 = 3.26, p = 0.071). Numbers of adult skunks captured at NPW and LP in the late season were too low to report meaningful sex ratios.

Across all years and sites, the number of individual juvenile females captured in the late season equaled or exceeded the number of individual juvenile males (Table 1.3). From 2005 – 2007 at DB, we captured more juvenile females (n = 21) than males (n = 14), however, the ratio was not skewed (X^2 = 0.97, p = 0.617). Numbers of juvenile skunks captured at NPW and LP in the late season were too low to report meaningful sex ratios.

Trapping data from April through July suggests that adult male and female skunks differed in their activity at NPW during the spring and summer months but activity of the sexes were similar at DB. Of the entire sample of adult skunks captured between April and July 2005 - 2007 at NPW (n = 18), the first capture of most male skunks (80% [8/10]) occurred in April or May, but most females (87% [7/8]) were captured in June or July (Figure 5). Total trap nights for April/May at NPW were 527 vs. 349 in June/July. By contrast, 100% of males (17/17) and most females (67% [12/18]) were initially captured in April or May at DB. Total trap nights for April/May at DFB were 425, vs. 115 in June/July when we captured an additional 6 females but no new males. Too few skunks were captured at LP to compare with the other sites.

Recurrence rates

Adult female skunks captured in traps at DB and NPW recurred in traps in a subsequent year at similar rates (41% [7/17] and 38% [3/8], respectively). At DB, 4 females recurred in the year following their initial capture, 1 female recurred in 2 subsequent years, and another adult female recurred during 3 subsequent years of trapping. At NPW, 2 adult females recurred in the year following their initial capture, and 1 female recurred in 2 subsequent years.

Recurrence of adult males differed by site. Of 22 male skunks captured in traps at DB, 8 (36%) recurred in traps in the subsequent year, and 3 of these males recurred in 2 successive years. At NPW, however, none of the 10 males captured recurred in a subsequent year.

Recurrence of juveniles also differed by site. Of 35 juveniles captured and marked at DB between 2005 and 2007, 6/21 (29%) of females and 3/15 (20%) of males recurred as adults in traps the following spring. Of 17 juveniles captured at NPW, none recurred in traps as adults. Of 7 juveniles captured at LP, 1 (14%) was recaptured as an adult the following year.

Site Fidelity

We attached radio-collars to 51 adult skunks between 2004 and 2007 (Appendix 1.1). We were able to determine site fidelity for 82% (42/51) of radio-collared skunks during the intensive monitoring period (May – September). Of these, 88% (37/42) were residents. Females at all sites (n = 17) were residents (DB = 9, NPW = 5, LP = 3), and males at DB (n = 13) and at LP (n = 5) were also resident skunks. By contrast, 57% (4/7) of NPW males were non-residents (X^2 = 10.46, p = 0.001, DF = 1).

Using telemetry, we documented emigration of 4 adult male skunks at the NPW site during May and June. Three males left the study area within 21 days of capture and moved 1 – 3 km inland, where they remained for the duration of their monitoring. One individual occupied hayfields, old fields, and adjacent woodlots until we removed his collar in late August. The other two males occupied lightly developed residential areas on Chappaquiddick. The fourth male left the study area within 48 hours of capture and occupied a residential area almost 8 km from NPW in the town of Edgartown.

A metal ear tag provided information on one dispersal. We recovered a road-killed yearling female in July of 2007 who dispersed on Chappaquiddick island 5.7 km (straight-line distance) from NPW where she was captured as a juvenile in August 2006.

Causes of Mortality

Of the 47 radio-collared skunks monitored > 1 month, 24 died (12 females, 12 males), and we determined cause of death for 21 skunks. Human-related activities killed 13/24 (54%) skunks, including nuisance animal removal (8), vehicles (3), domestic dog (1), and 1 instance where an adult male died from internal bleeding under a house. Diseases, or parasite infections, killed 7/24 (29%) of the radio-collared sample. An unknown carnivore killed a female at DB near her den containing kits approximately 5 weeks old. Bite wounds on the neck and back were punctures indicative of a carnivore. The kits were not seen after she died. While we did not document any natural predation in this study, a few island residents reported red-tailed hawks (*Buteo jamaicensis*), Cooper's hawks (*Accipiter cooperii*), and great-horned owls (*Bubo virginianus*) preying upon adult and juvenile skunks at or near their homes.

Disease was a significant mortality factor at Dogfish Bar in 2005 when 4/9 (44%) of radio-collared skunks died in the spring and early summer. These skunks exhibited limited movements in the week before their deaths and carcasses recovered were thin and hosting >100 ticks (*Dermacentor variabilis*); at least 1/3 having full blood meals. This suggests that the skunks could not maintain their grooming activities. Necropsies on 2 of these skunks showed that a yearling male died with lungworm pneumonia (*Metastrongyle* spp.) and a heavy infestation of gastric *Physaloptera* spp., and a yearling female, carrying 6 young, died of an intussusception of the jejunum from large numbers of round worms (*Eimeria* spp.). The following spring (2006), a yearling male died with a heavy infestation of ticks and *Physaloptera* spp. in the stomach. These 3 skunks tested negative for rabies, post mortem.

At Long Point in 2007, a yearling male died in June after exhibiting limited movements and locomotion consistent with neurological impairment similar to what was seen at DB in 2005. The carcass was not fresh enough to send for necropsy. A yearling female died without exhibiting signs of illness in the 36 hours prior. Spots on her liver and fluid in her lungs suggested tularemia, which is present in the tick population in the area (Berrada and Telford 2010).

Pelage patterns, weights, and measurements

We recorded pelage patterns of 127 skunks (65 females, 62 males) captured during the study and documented all known patterns at similar ratios in males and females in our sample. Narrow and short-striped skunks were the most common pelage types at 45% (57/127) and 37% (47/127) of the sample, respectively. “Star” pelts were the rarest at 3% (4/127), and broad-striped skunks comprised the remaining 15% (19/127) of our sample.

Adult skunks captured during the entire field season (Apr – Nov) weighed 1.72 ± 0.05 kg ($n = 125$, range = 0.8 – 3.75). In the early season (Apr – Jul) adults weighed 1.47 ± 0.05 kg ($n = 75$, range = 0.8 – 2.5), and in the late season (Aug – Nov) adults weighed 2.08 ± 0.09 kg ($n = 50$, range = 1.2 – 3.8) (Table 1.4). Adult males weighed significantly more than females in both the early and late seasons (Early season, $Z = -3.770$, $p < 0.01$ and Late season, $Z = -1.972$, $p = 0.049$), and both sexes weighed significantly less in the early season than in the late season

(Females, Z = -4.372, $p < 0.01$, Males, Z = -4.016, $p < 0.01$). We captured an exceptionally heavy pregnant female in April of 2007 at LP, who weighed 2.5 kg. All other females captured in the early season weighed < 2.0 kg.

Male skunks were significantly larger than females in total length (t = -2.840, $P < 0.01$, DF = 36), body length (t = -5.241, $p < .01$, DF= 34) and length of right rear foot (t = -6.375, $p < .01$, DF = 34). Tail lengths in males and females were similar (Table 1.4).

Radio-collared skunks in this study used multiple (≥2) winter dens, and exhibited periods of torpor from December through mid-March. Changes in den location and tracks in the snow indicated both males and females were active when temperatures rose above freezing. We documented seasonal weight changes for 18 adult skunks (7 females and 11 males). Mean winter weight loss between October/November and the following spring for 7 males weighing a mean of 2,130 ± 26 g was - 597 ± 15 g (range = 280 – 1300). Weight loss for 2 females weighing 2,600 g was - 1045 ± 25 g (range = 1020 – 1070). Mean weight gain between spring and the following fall for 10 males weighing 1556 ± 109 g was 967 ± 11 g (range = 540 – 1800), and weight gain for 7 females weighing 1,380 ± 123 g was 521 ± 68 g (range = 330 – 780) (Appendix 1.2).

Discussion

Food resources influence the distribution, productivity, and survival of most species, which influence species abundance (Gotelli 2001). This is the first study, to our knowledge, to estimate densities or report capture rates of striped skunks in beach habitat where they have access to intertidal invertebrates and carrion linked to higher densities or increased activity of mesocarnivores reported from other regions (Rose and Polis 1998; Brown and McLachlan 2002; Moore 2002). Rose and Polis (1998) studied coyote (*Canis latrans*) populations in remote Baja

California, Mexico and found that tracks and sign of coyotes near the coast were 2 – 13 times higher than inland desert sites due to the more diverse and abundant foods from the ocean. We only studied coastal skunks, but capture rates from a concurrent study investigating tick-borne illnesses on Martha's Vineyard (2005-2007) did indicate more skunk activity along the coast than inland locations (S. Telford, unpublished data). Near-shore capture rates of 2.5 striped skunks per 100 trap nights were similar to our early season capture rates at NPW (Table 1.2). In contrast, the capture rate at inland sites, with adjacent oak and pine habitats, was only 0.52 skunks/100 trap nights (S. Telford, unpublished data). Few researchers have published capture rates for striped skunks, but our overall rate of 5.9 individuals/100 TN was much higher than rates of 1.3 skunks/100 TN in metropolitan Toronto reported by Rosatte et al.(1991) and 0.86/100 TN in mesquite brush land of Texas reported by Doty and Dowler (2006). However, our rates were much lower than rates of 11.9 skunks/100TN and 14.4 skunks/100TN from a Cades Cove Campground study in Great Smokey Mountains National Park (Goldsmith 1981) where skunks had access to considerable anthropogenic food subsidies.

Our spring density estimate of 8 – 10 skunks/km^2 at Dogfish Bar was in the middle range of other estimates from North America that reported densities of 1 – 44 skunks/ km^2 (Table 1.5). The highest density estimates for striped skunks were in or near habitats with anthropogenic food and shelter subsidies (Dean 1965; Ferris and Andrews 1967; Goldsmith 1981; Rosatte et al. 1991; Broadfoot et al. 2001). Researchers have documented high densities of coyotes, raccoons, and common ravens (*Corvus corax*) in developed areas with human subsidies (Fedriani et al. 2001; Prange et al. 2003; Boarman et al. 2006; Rosatte et al. 2010), higher reproductive success for female raccoons that regularly fed at dumpsters (Prange et al. 2003), and increased activity of generalist mammals and birds in habitat treated with supplemental food (Delap and Knight

2004). In addition to the natural food associated with daily tidal cycles on beaches, predictable anthropogenic food subsidies (PAFS) (Oro et al. 2013) become available during the summer months when the beaches at our study sites became 'seasonally urban habitats' (SUH) much like other beaches in the Northeastern United States. Human densities and activity increased substantially in June and remained high through August, and many people left food refuse behind at the end of the day that skunks consumed at night. Skunks in our study also visited homes with bird feeders, compost piles, and pet food outside. These supplemental resources, along with an abundance of natural food in dense wrack lines at Dogfish Bar, likely contributed to the higher density estimate and capture rates on Martha's Vineyard than reported for some mainland North American skunk populations.

The beaches at our study areas differed in morphology and in their proximity to development, and we believe these two factors contributed to differences in spring capture rates among the sites (Table 1.2). Wave height and beach slope are two main factors influencing deposition of organic materials on beaches, which influences faunal assemblages from wrack line invertebrates up to the birds and mammals that consume them (McLachlan 1990; Moore 2002; Colombini et al. 2003; Orr et al. 2005). On the Atlantic coast, sheltered, low-energy beaches have more invertebrate biomass than high-energy beaches (U.S. Army Corps of Engineers 2005). The beach at DB was a low-energy beach, in close proximity to anthropogenic food and shelter (Fig 1.2) while NPW and LP were high-energy beaches more isolated from anthropogenic food and shelter (Fig 1.3). We believe low early season capture rates at NPW (Table 1.2), lower site fidelity of males (43% NPW vs. 100% at DB), and delayed capture of females at NPW (Fig 1.5) reflected the limited available food resources for skunks in April and May at this site. The intertidal and wrack line resources at DB, paired with its proximity to anthropogenic food and shelter, provided optimal skunk habitat on and near the beach, which, in turn, contributed to consistently higher capture rates than our other sites.

Late season capture rates (Table 1.2) indicated increased skunk activity at all sites, which was largely due to the presence of newly independent juveniles. While DB maintained high capture rates, differences between NPW and DB late season capture rates were not as extreme as early season. Preferred insect food of skunks, such as beetles and grasshoppers (Kelker 1937; Greenwood 1981), become abundant in the dune grass areas of beaches (Kluft-Steinback 1999) in the summer months. The influx of hundreds of people, and the food subsidies they bring to the beaches at NPW and LP in July and August likely contributed to an equalizing effect on available resources between sites. The low capture rates at NPW in 2007 coincided with a breach in the barrier beach at NPW that separated Chappaquiddick from Martha's Vineyard. We believe skunks were regularly traveling to and from NPW via this barrier beach in prior years.

Recurrence rates, emigration, dispersal, and mortality

Our recurrence rates for females at Dogfish Bar (41%) and Norton Point Wasque (38%) were similar to other studies where 33 – 50% of the female population recurred at a site from year to year (Bjorge et al. 1981; Sargeant et al. 1982; Greenwood et al. 1985). Sargeant et al. (1982) found that female skunks remained in areas where they first settled as adults, and researchers have found high retention rates of marked females during the spring and summer (Bjorge 1977; Sargeant et al. 1982; Greenwood et al. 1985; Lariviere et al. 2006), when most females are rearing young (Verts 1967; Bjorge et al. 1981; Fuller and Kuehn 1985; Lariviere and Messier 1998a). None of the 16 adult females captured and radio-tagged at DB and NPW between April and July left the study area during monitoring.

In contrast, males captured at a site in the spring or early summer were likely either transient males seeking breeding opportunities or resident males (Verts 1967; Bjorge et al. 1981). Previous studies have found that male skunks often travel significant distances (3 – 120 km) in the months of March – June (Sargeant et al. 1982; Greenwood et al. 1985; Hansen et al. 2004), and we saw evidence of this at NPW. Four radio-tagged males (50%, 4/8) emigrated 2 – 8 km from our study area at NPW during May and June and all moved to residential or farm areas. At DB, however, no males emigrated from the site. The male recurrence rate at DB of 36% was higher than has been reported in other studies from North America (Bjorge et al. 1981; Sargeant et al. 1982; Greenwood et al. 1985; Hansen et al. 2004). The high quality resources at DB may support a dense population of skunks with little incentive to emigrate.

Causes of mortality

The human-related mortality rates for radio-collared skunks in this study are similar to mortality documented in other studies of the species. Vehicles on roads, farm equipment, drowning, and shooting of skunks as nuisance animals caused the majority of skunk mortalities in previous studies (Verts 1967; Sargeant et al. 1982; Hansen et al. 2004). Two licensed public animal control agents operate on Martha’s Vineyard, and they lethally removed between 450 – 750 skunks per year from 2005 to 2009 (M. Huguenin, Massachusetts Division of Fisheries and Wildlife, personal communication); human tolerance for skunks on the Martha’s Vineyard may be lower than in other areas because most people believe skunks are non-native. While distemper and tularemia are present on the island and may periodically depress the skunk populations, the island is free of rabies, which acts as a limiting factor in other skunk populations (Rosatte et al. 1991; Greenwood et al. 1997).

Several authors have suggested winter length and severity can be a significant mortality factor for striped skunks in northern regions, particularly young males that do not den communally (Sunquist 1974; Bjorge et al. 1981; Fuller and Kuehn 1985). Skunks on Martha's Vineyard may have lower winter mortality due to a milder climate, and this would contribute to higher recurrence rates. In most winters on the island, temperatures average 1° C and snowfall 9 cm (National Climatic Data Center, www.ncdc.noaa.gov, accessed 15 November 2010). However, winter of 2005 had unusually heavy snowfall that lasted for several weeks. We believe the loss of 44% of radio-collared skunks to disease in the spring of 2005 at DB was the result of poor body condition from the harsh winter (Gehrt 2005; Gehrt et al. 2010). Studies in other regions of North America documented winter weight loss in striped skunks ranging from 14 – 58% (Hamilton 1937; Allen 1939; Verts 1967; Sunquist 1974). Our male winter weight loss of 28% was less than all other studies, except Hamilton's (1937) who reported 14% weight loss in males. Our female weight loss of 40% was mid-range, but we believe this value was atypically high. Our female sample size was only 2 animals from the severe winter of 2005, and we believe weight loss would be less for most females in a temperate coastal habitat.

Weights, measurements, and pelage patterns

The current population of skunks inhabiting Martha's Vineyard does not exhibit any physical characteristics that would distinguish them from mainland striped skunk populations in eastern North America. Body lengths and weights of our coastal dwelling skunks were similar to those reported for the species in Michigan, Ohio, and Virginia (Allen 1939; Bailey 1971; Stout and Sonenshine 1974), and they were smaller and lighter than reported for the species in the spring and summer in Texas, Illinois, Minnesota, and Canada (Verts 1967; Fuller et al. 1985; Rosatte et al. 1991; Hansen et al. 2004) (Table 1.6).

While the original Martha's Vineyard skunk population was described as predominantly "star" pelt variety (Keith 1969), our sample indicates narrow (45%) and short-stripe (37%) patterns are dominant in today's population. The pelage characteristics of our sample were similar to those reported by Jones (1948) and Verts (1967), where narrow or short-striped patterns characterized the majority of observed skunks. Hunter (2008) studied the behavioral responses of wild carnivores to taxidermied skunks in California. She found that coyotes avoided skunk models and grey foxes approached them extremely hesitantly, suggesting that wild canids recognize and respond to the aposematic coloration of striped skunks with avoidance behavior. Therefore, a maximally conspicuous wide stripe pattern may provide an advantage for skunks co-occurring with larger carnivores. In a Minnesota study where skunks co-occur with wolves (Fuller et al. 1985), 79% of skunks exhibited a wide-striped pattern. It is possible that wolf predation, over time, exerted some selective pressure, resulting in the high degree of contrasting coloration in this Minnesota population. By comparison, the contemporary Vineyard skunk population may not experience enough predation pressure from canids for a high degree of pelage contrast to be favorable over cryptic coloration. We encourage other researchers studying striped skunks to report pelage patterns and provide information on co-occurring carnivores in order to further our understanding of aposematism in the species.

Future Research

This study places striped skunks within the maritime mammal (Moore 2002) community and invites further study of their ecological role as predators and scavengers in sandy shore ecosystems. Skunks occurred at higher densities and had higher recurrence rates at our resource-rich beach (dense wrack line) than at our resource-poor beach (sparse wrack line), but we did not collect any data on invertebrate food availability during the study. Future research tracking the temporal and spatial variation in wrack line fauna on beaches with sparse vs. dense wrack lines will provide valuable information on the factors influencing interactions between piping plovers and predators that share foraging habitat with them, such as skunks and crows.

A 'resource pulse' refers to the temporary availability of dramatically higher than normal levels of resources, which are depleted over time (Ostfeld and Keesing 2000; Yang 2004). The pulse of anthropogenic food that emerges annually in July and August on temperate beaches can have high caloric value and is somewhat unpredictable in nature due to the vagaries of New England weather. As nest predators, skunks can have catastrophic impacts on imperiled shorebird and seabird species (Hecht and Nickerson 1999; Meckstroth and Miles 2005). Research using experimental designs to investigate the influence of PAFS on the activity and density of generalist predator species on beaches that are seasonally urban habitats could provide valuable data for management efforts and public outreach aimed at reducing predation on rare and threatened beach species. These investigations may also contribute to ecological research on the 'top down' and 'bottom up' effects of pulsed resources in natural systems (Yang et al. 2010).

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Tables and Figures

Table 1.1 Age and sex of skunks captured and marked at 3 sites on Martha's Vineyard, Massachusetts during the entire study period from May 2004 – May 2008. Juveniles were captured and marked August – November.

Site	Adult Females	Adult Males	Juvenile Females	Juvenile Males	Total Individuals
Dogfish Bar	16	22	28	19	85
Norton Pt/ Wasque	8	11	9	7	35
Long Point[1]	5	4	5	2	16
Total	29	37	42	28	136

[1] Includes one adult female captured by hand net.

Table 1.2. Early (Apr – Jul) vs. late (Aug – Nov) season skunk trapping results at Dogfish Bar (DB), Norton Point/Wasque (NPW) and Long Point (LP) on the island of Martha's Vineyard, Massachusetts. Capture rate is individuals per 100 trap nights.

		April - July				August – November				
Site	Year	Trap Nights	New Captures	Recaptures	Capture Rate	Trap Nights	New Captures	Recaptures	Juvenile Captures	Capture Rate
DB	2005	228	12	2	6.1	94	6	4	10	21.3
DB	2006	143	3	7	7.0	115	6	3	12	18.3
DB	2007	153	1	9	6.5	119	2	6	13	17.6
NPW	2005	301	8	nd	2.7	70	2	3	7	17.1
NPW	2006	285	7	2	3.2	71	1	2	7	14.1
NPW	2007	360	1	0	0.3	53	0	1	1	3.8
LP	2007	103[1]	5	1	5.8	56	1	3	5	16.1

[1] Over half of trap nights were in late June and July.

Table 1.3. Numbers of male and female skunks captured during early (Apr – Jul) and late (Aug – Nov) season trapping at Dogfish Bar (DB), Norton Point/Wasque (NPW), and Long Point (LP) on the island of Martha's Vineyard, Massachusetts.

	April-July		August-November			
	Adult Females	Adult Males	Adult Females	Adult Males	Juvenile Females	Juvenile Males
DB 2005	9	5	2	8	6	4
DB 2006	4	6	3	6	6	6
DB 2007	4	6	2	6	9	4
Mean ± SE	5.7 ± 1.3	5.7 ± 0.3	2.3 ± 0.3	6.7 ± 0.7	7.0 ± 1.0	4.7 ± 0.7
NPW 2005	4	4	5	0	5	2
NPW 2006	4	5	1	2	4	4
Mean ± SE	4 ± 0	4.5 ± 0.5	3 ± 2	1 ± 1	4.5 ± 0.5	3 ± 1
LP 2007	3	3	1	3	4	1

Table 1.4. Weights (kg) and measurements (cm) of adult skunks by season on Martha's Vineyard, Massachusetts, 2004-2008.

	Females		Males		All Adults	
Measurement	n	Mean ± SE (range)	n	Mean ± SE (range)	n	Mean ± SE (range)
Early Season Weight	37	1.31 ± 0.05 (0 .8 - 2.5)	38	1.63 ± 0.07 (0.9 - 2.5)	75	1.47 ± 0.05 (0.9 - 2.5)
Late Season Weight	18	1.83 ± 0.10 (1.2 – 2.6)	32	2.23 ± 0.12 (1.3 – 3.8)	50	2.08 ± 0.09 (1.2 – 3.8)
Total Length	16	58.3 ± 0.9	21	61.1 ± 0.7	37	59.8 ± 0.6
Body Length	16	34.0 ± 0.6	20	38.1 ± 0.5	36	36.0 ± 0.5
Tail Length	16	21.9 ± 0.4	21	21.4 ± 0.5	37	21.3 ± 0.4
Rt. Rear Foot Length	15	6.3 ± 0.07	22	6.9 ± 0.8	37	6.7 ± 0.9

Table 1.5. Comparison of density estimates for striped skunks in North America.

Study	Location	Density Estimate Skunks/km^2	Habitat	Method
Rosatte et al. 1991	S. Ontario, Canada	1- 36	Forest-park - Fields	Mark-recapture
Goldsmith, 1981	GSMNP, Tennessee	20	Campground	Mark-recapture
Broadfoot et al. 2001	S. Ontario, Canada	6 – 13	Urban/Suburban	Mark-recapture
Johnson 2016	Martha's Vineyard, MA	8 – 10	Sandy Shore/Beaches	Mark-recapture
Bailey 1971	Northern Ohio	4 – 8	Marshland	Mark-recapture
Gehrt 2004	Chicago, IL	2 – 6	Urban parks	Mark-recapture
Hansen et al. 2004	Northern Texas	0.10 – 1	Cropland and Residential	Mark-recapture
Dean 1965	Orono, ME	22 – 44	University Campus	Total captures
Ferris & Andrews 1967	Southern Illinois	13 – 26	Farmland	Total captures
Lynch 1972	Manitoba, Canada	21	Farmland	Total captures
Verts 1967	Northern Illinois	4 – 14	Farmland	Total captures
Stout & Sonenshine 1974	Richmond, Virginia	5 – 11	Farmland	Total captures
Allen & Shapton 1942	S. Central Michigan	5	Farmland	Total captures
Scott & Selko 1939	Northwestern Iowa	0.4 – 1.4	Farmland	Total captures

Table 1.6. Means ± SE weights (kg) and body lengths (cm) of adult striped skunks in spring/summer from studies in North America.

		Weight		Body Length	
Study	Location	Female	Male	Female	Male
Johnson 2016	Martha's Vineyard, MA	1.31 ± 0.05	1.63 ± 0.07	34.0 ± 0.6	38.1 ± 0.5
Stout & Sonenshine 1974	Richmond, VA	1.38 ± 0.18	1.49 ± 0.05	No data	
Allen 1939[1]	Southern Michigan	1.41 ± 0.12	1.67 ± 0.09	32.7 ± 0.62	34.9 ± 0.56
Bailey 1971	Northwestern Ohio	No data		34.5 ± nd	37.3 ± nd
Hansen et al. 2004	Northern Texas	1.58 ± 0.11	2.14 ± 0.12	No data	
Verts 1967	Northern Illinois	1.89 ± nd	2.47 ± nd	37.8 ± 3.2	40.7 ± 3.1
Fuller et al. 1985[1]	Northeastern Minnesota	1.90 ± nd	2.72 ± nd	41.1 ± nd	43.0 ± nd
Rosatte et al. 1991[2]	S. Ontario, Canada	2.1 ± 0.38	3.3 ± 0.15	36.5 ± nd	40.9 ± nd

[1] Weight = average of spring weight for 1 and ≥1.5 age class. Body length = average of total length – tail length for both age classes.

[2] Body length calculated as (total length – tail length) from reported data

Figure 1.1. The island of Martha's Vineyard, Massachusetts, in relationship to mainland Massachusetts, with three study areas identified: Dogfish Bar (DB), Long Point (LP), and Norton Point/Wasque (NPW).

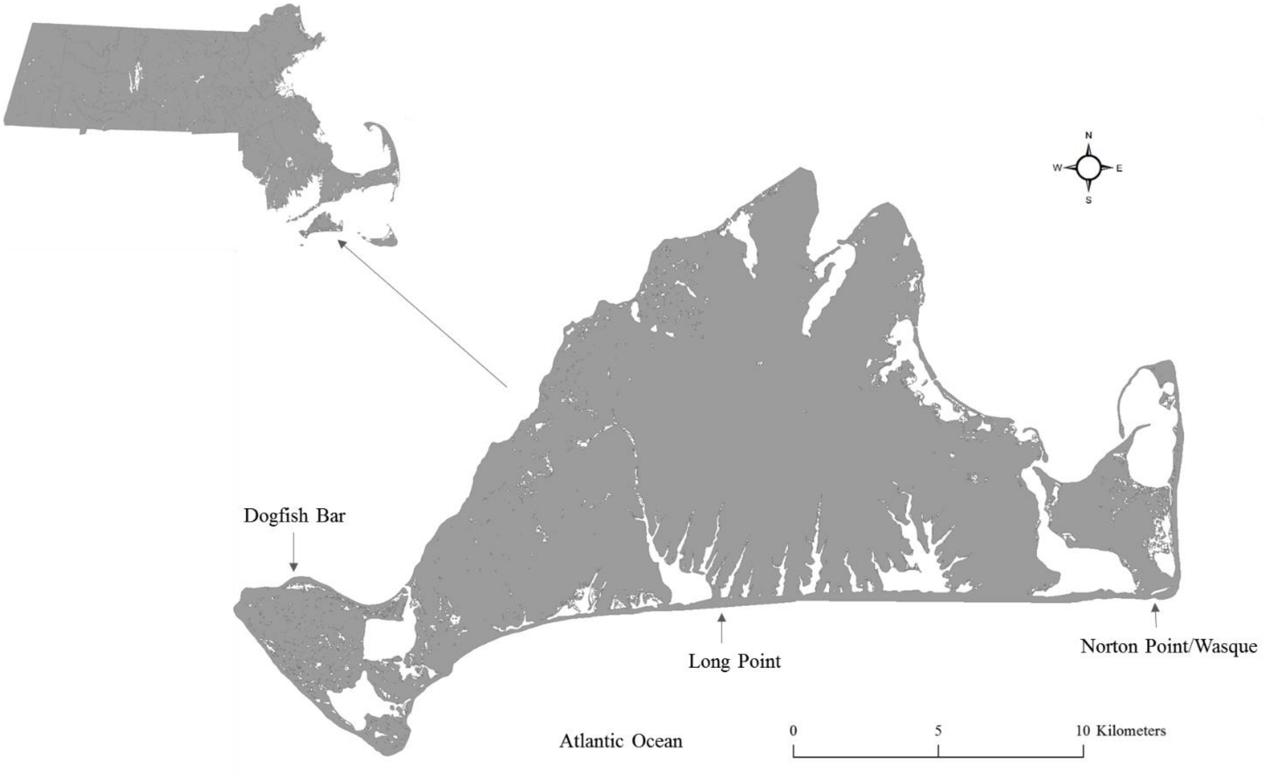


Figure 1.2. The Dogfish Bar Study Area on Martha's Vineyard, Massachusetts.

Figure 1.3. The Norton Point/Wasque Study Area on Martha's Vineyard, Massachusetts.

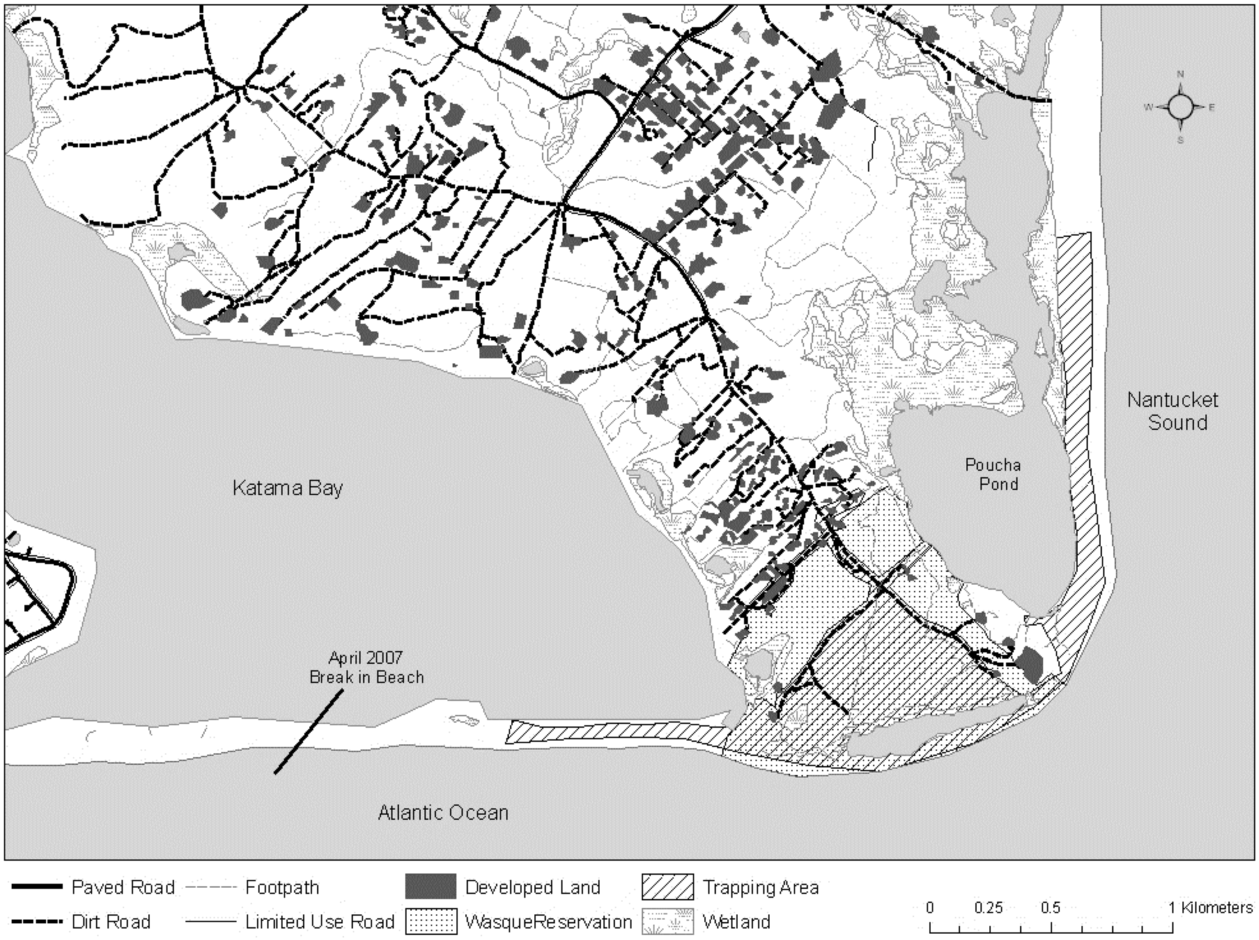


Figure 1.4. The Long Point Study Area on Martha's Vineyard, Massachusetts.

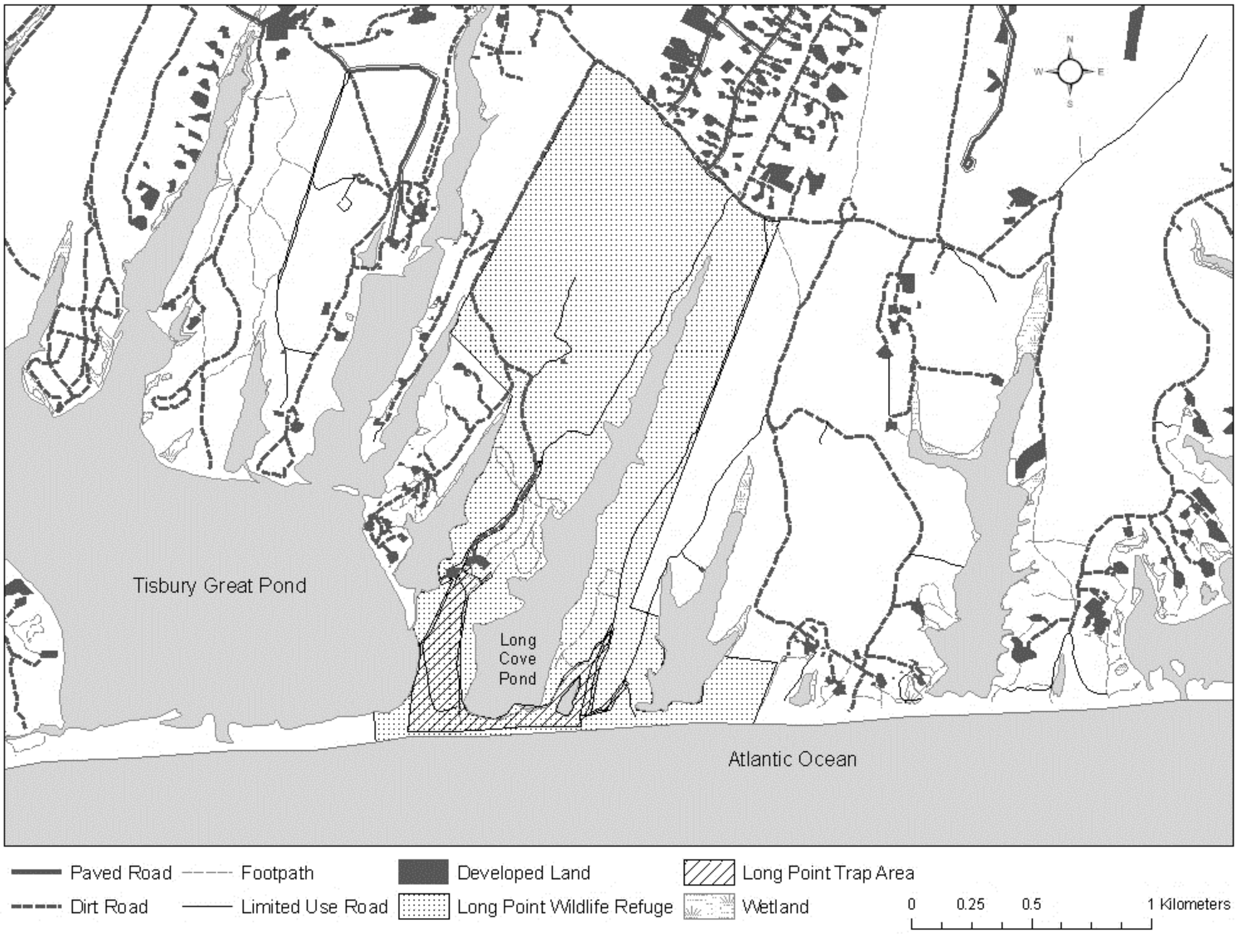
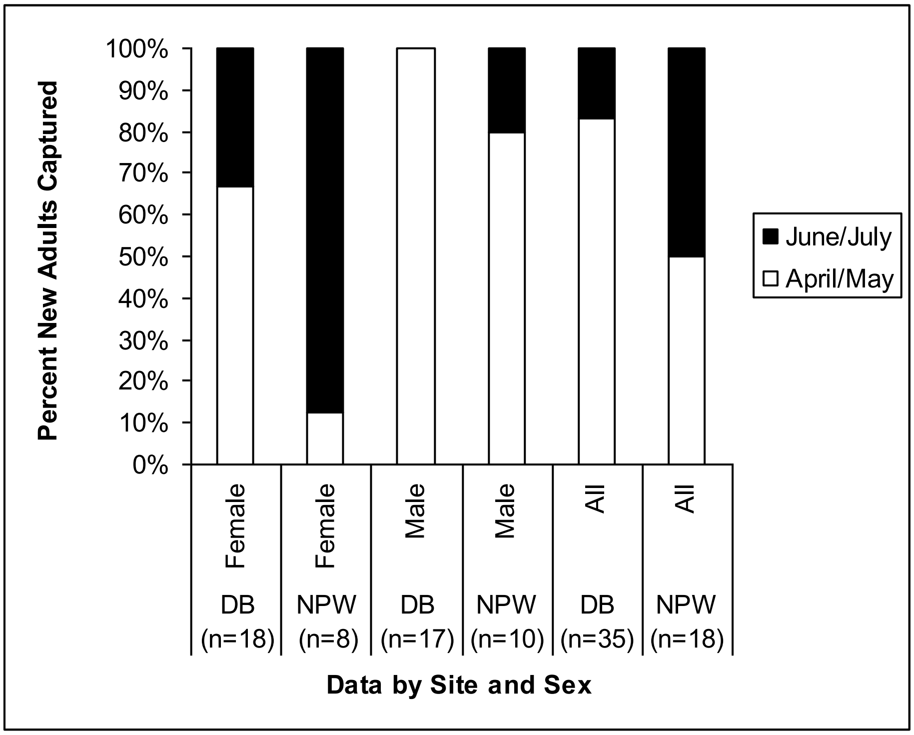


Figure 1.5. Percentage of new adults (female, male, and all adults) captured in the spring (April/May) vs. summer (June/July) at Dogfish Bar (DB) and Norton Point/Wasque (NPW). Data from April through July 2005 – 2007 combined.



Appendix 1.1. Tracking history and fates of 51 radio-collared skunks, sorted from largest to smallest number of telemetry locations. Weight is at time of collaring. Type of tracking indicates whether the skunk was wearing an active radio collar continuously (C) or discontinuously (D).

Skunk ID	Site	Sex	Age	Wt. (kg)	Wt. month	# Data Points	Date 1st Collared	Type of Tracking	Last Point	Days Elapsed	Fate	Explanation
10	DB	F	≥1	1.40	4	322	8/10/2004	D	2/24/2008	659	UNKN	Mort. Signal in den
30	DB	M	≥1	1.15	4	320	5/5/2005	D	3/23/2008	796	UNKN	Mort. Signal. in den
45	DB	F	1	1.20	4	262	4/17/2006	C	4/19/2008	733	SURV	Pulled collar
02	DB	M	≥1	2.30	5	166	5/28/2004	C	2/20/2005	268	UNKN	Lost signal
79	NPW	F	≥1	1.10	6	154	6/23/2006	D	5/18/2008	526	SURV	Slipped collar
36	NPW	F	≥1	1.45	6	152	6/28/2005	D	3/14/2007	351	DIED	Rat poison
51	DB	M	≥1	1.65	4	146	4/14/2006	C	6/25/2007	403	DIED	Vehicle Trauma
72	NPW	M	≥1	1.53	3	134	3/31/2006	C	3/10/2007	344	UNKN	Lost signal
73	DB	M	≥1	1.43	4	130	4/11/2006	C	6/6/2007	421	SURV	Pulled collar[a.b]
97	DB	F	1	1.40	4	121	5/30/2007	C	5/21/2008	357	DIED	Vehicle Trauma
90	DB	M	1	1.50	4	116	4/24/2007	C	12/29/2007	249	SURV	Slipped Collar
54	DB	M	≥2	1.55	4	116	4/11/2006	D	3/30/2008	551	UNKN	Lost signal

112	DB	M	≥1	1.40	4	112	4/27/2007	C	5/6/2008	375	SURV	Pulled collar, end
23	DB	F	≥1	1.18	4	106	4/17/2005	C	9/1/2005	137	UNKN	Lost signal
81	DB	F	≥1	1.10	7	109	7/8/2006	D	6/14/2007	341	UNK	Lost Signal[c]
117	LP	M	≥1	1.30	6	94	7/8/2007	C	6/8/2008	336	SURV	Pulled collar, end
50	DB	M	≥3	1.80	4	83	4/24/2007	C	10/1/2007	160	DIED	Vehicle Trauma
114	NPW	M	≥1	1.63	5	78	5/9/2007	C	1/17/2008	253	UNK	Lost Signal
25	DB	M	≥1	1.20	4	75	4/18/2005	C	8/1/2005	105	DIED	Unk. Trauma
77	NPW	M	≥2	2.15	5	75	5/21/2006	C	10/2/2006	134	UNK	Lost Signal
74	DB	M	≥1	1.13	4	68	4/11/2006	C	3/18/2007	341	DIED	Unk. Trauma
40	NPW	F	≥1	1.53	7	66	7/27/2005	D	8/31/2006	145	DIED	Nuisance removal
109	LP	M	≥2	2.20	4	64	4/23/2007	C	9/24/2007	135	SURV	Lost Signal
116	LP	M	≥1	1.85	7	63	7/1/2007	C	10/26/2007	117	SURV	Slipped Collar
34	DB	F	≥1	1.23	4	62	6/20/2005	D	6/2/2006	129	DIED	Dog Trauma
108	DB	F	1	1.15	4	47	4/24/2007	C	6/19/2007	56	DIED	Carnivore Trauma
37	NPW	M	≥2	2.10	7	44	7/6/2005	C	12/12/2005	159	DISP	Pulled collar
110	LP	M	1	1.30	6	43	11/14/2006	C	6/11/2007	209	DIED	Disease
118	LP	F	≥1	1.20	7	42	7/10/2007	C	9/4/2007	56	UNK	Lost Signal
18	LP	F	≥1	1.30	9	41	9/6/2004	C	2/20/2005	167	SURV	Slipped collar

38	NPW	F	≥1	1.70	7	34	7/13/2005	C	11/08/2005	118	SURV	Pulled collar[a]
120	LP	F	≥1	1.25	7	31	7/25/2007	C	9/21/2007	59	UNK	Lost Signal
21	DB	F	1	0.83	4	29	4/17/2005	C	5/28/2005	41	DIED	Disease
94	DB	F	1	1.15	7	29	7/27/2007	C	11/11/2007	107	DIED	Unk. Trauma
32	NPW	M	≥1	1.70	5	27	5/21/2005	C	8/11/2005	82	DISP	Pulled collar[d]
01	DB	M	≥1	1.90	5	27	5/28/2004	C	6/29/2004	32	UNKN	Slipped collar
24	DB	M	≥1	0.93	4	20	4/18/2005	C	5/22/2005	34	DIED	Disease
35	NPW	M	≥2	2.15	6	19	6/28/2005	C	12/18/2005	107	DISP	Lost signal
115	LP	F	≥1	1.28	7	16	7/1/2007	C	7/28/2007	21	DIED	Disease
33	DB	F	≥1	1.08	6	15	6/3/2005	C	6/13/2005	10	DIED	Disease
22	DB	M	≥1	1.00	4	12	4/17/2005	C	5/11/2005	24	DIED	Disease
82	NPW	F	≥1	1.40	7	12	7/12/2006	C	7/24/2006	12	DIED	Unk. Trauma
113	LP	F	≥2	2.50	4	11	4/25/2007	C	5/29/2007	34	UNKN	Slipped collar
143	LP	M	≥1	1.80	5	11	5/3/2008	C	6/10/2008	38	SURV	Pulled collar
43	DB	M	1	1.40	4	10	4/11/2006	C	5/12/2006	31	DIED	Disease
124	LP	F	≥1	1.70	9	10	9/22/2007	C	11/17/2007	56	DIED	Nuisance Removal
28	NPW	F	≥1	1.60	4	8	4/27/2005	C	5/11/2005	14	DIED	Vehicle trauma
78	NPW	M	≥2	2.48	5	5	5/23/2006	C	5/27/2006	4	UNKN	Lost signal

29	NPW	M	≥2	2.10	4	3	4/27/2005	C	4/30/2005	3	UNKN	Slipped collar
71	NPW	M	≥2	2.15	3	3	3/31/2006	C	4/5/2006	5	DIED	Nuisance Removal
76	NPW	M	≥2	2.03	5	3	5/21/2006	C	8/20/2006	91[e]	DIED	Nuisance Removal

[a] Pulled failing collar.

[b] Skunk lethally removed (nuisance animal) on 2/27/2008 from residence within his home range.

[c] Collar failed. Skunk lethally removed (nuisance animal) on 5/20/2008 from residence within her home range.

[d] Lost the signal on 5/22/2005. Despite regular effort, I did not locate him again until 7/5/2005 in a hayfield on farm inland from the beach. I tracked him in that area for 36 days before removing his collar.

[e] Lost the signal on 5/22/2006. Despite regular effort, I did not find him again until 8/20/2006 when I picked up a mortality signal in a residential area over 6 km from where he was captured.

Appendix 1.2 Seasonal weight changes for adult skunks at Martha's Vineyard, Massachusetts

Skunk ID	Sex	Date	Weight (kg)	Date	Weight (kg)	% Change
36	F	6/28/05	1.45	11/06/05	2.60	+ 79
36	F	11/06/05	2.60	06/27/06	1.58	-39
38	F	7/13/05	1.70	11/8/05	2.48	+46
40	F	7/27/05	1.93	11/08/05	2.60	+35
40	F	11/08/05	2.60	7/15/06	1.53	-41
39	F	7/15/05	1.18	10/20/05	1.72	+46
45	F	4/17/06	1.20	9/23/06	1.53	+27
79	F	6/23/06	1.10	10/12/06	1.60	+45
81	F	7/8/06	1.10	9/23/06	2.00	+82
30	M	5/5/05	0.95	10/20/05	1.68	+76
30	M	10/20/05	1.68	4/20/06	1.33	-21
30	M	4/20/06	1.33	9/13/06	1.70	+28
30	M	9/13/06	1.70	5/29/07	1.25	-26
30	M	5/29/07	1.25	10/17/07	1.60	+28
50	M	4/24/07	1.80	10/1/07	3.60	+100
51	M	10/22/05	2.65	4/14/06	1.65	-38
54	M	10/22/05	1.83	4/11/06	1.55	-15
54	M	4/11/06	1.55	9/27/06	2.30	+48

72	M	4/1/06	1.53	10/19/06	2.40	+57
73	M	6/6/07	1.60	9/30/07	2.40	+50
90	M	4/24/07	1.50	10/22/07	2.43	+62
107	M	10/10/06	1.80	4/29/07	1.45	-19
109	M	11/12/06	3.50	4/23/07	2.20	-37
109	M	4/23/07	2.20	9/22/07	3.40	+55
117	M	9/24/07	1.75	6/8/08	1.30	-26
116	M	7/1/07	1.85	10/22/07	2.50	+35

CHAPTER 2

Resource Use and Movements of Striped Skunks (*Mephitis mephitis*) Inhabiting Piping Plover Nesting Beaches on the Island of Martha's Vineyard, Massachusetts

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Abstract

We conducted a VHF radio telemetry study of coastal striped skunks (*Mephitis mephitis*) to inform integrated predator management aimed at reducing egg predation on federally threatened Atlantic coast piping plovers (*Charadrius melodus*). From 2004 – 2008, we captured and radio-tagged 51 skunks (29 M, 22 F) at 3 beaches on the island of Martha's Vineyard, MA, USA to gather information on their movements, foraging behavior, and resource use during the plover nesting and skunk winter denning seasons. At all sites, telemetry locations from females rearing young were closer to beaches than locations from males or females without young (255 ± 16 m vs. 512 ± 14 m vs. 525 ± 29 m, respectively). Male and female skunks moved similar maximum straight-line (SL) distances from their daytime retreats while foraging along beaches at night, but females traveled farther because they made round-trip movements from natal dens (1,615 ± 79 m vs. 1,149 44 m, Mood's median test, $X^2 = 17.20$, DF = 1, $P < 0.001$). Abundant wrack on the beach was associated with a higher frequency of skunk foraging observations near the shoreline than at inland locations (Pearson $X^2 = 56.598$, DF = 1, $P < 0.001$). Of 258 beach foraging observations where we identified food/prey skunks consumed, 76% were invertebrates in the intertidal zone and 24% were anthropogenic food in backshore and backdune areas. We located skunks at 890 daytime retreats during the piping plover nesting season. Of these, 70% were above ground lays, 14% were burrows, 8% were under human structures or objects, and 6% were 'natural'. Almost all natal dens (96%) were burrows, excavated by females in shrub (n = 41) or tree (n = 2) roots. Of 129 winter dens, 70%, were burrows skunks excavated in shrub or tree roots or slopes (hillsides or dunes) and 30% were beneath human structures (foundations and culverts under roads) or objects (fish totes washed into dunes, debris piles, and covered woodpiles). Winter dens at Dogfish Bar and Norton Point/Wasque (108/129) were farther from

nesting beaches than daytime retreats during the spring/summer (638 ± 38 m and 990 ± 111 m vs. 437 ± 17 m and 553 ± 33 m, respectively, Mood's median test, $X^2 = 50.81$, DF = 1, $P < .001$). Based on habitat use vs. availability analysis, the relative probability of a skunk using any habitat type for a daytime retreat or winter den increased as distance to nesting beach decreased ($P < 0.001$). During the nesting season, skunks used shrub habitat for daytime retreats more than twice as much as it was available. However, switchgrass (*Panicum virgatum*) patches had the highest probability of selection for a summer retreat ($P < 0.001$) as they were used ten times more than available when present at a site. During winter denning, skunks used shrub habitat equal to its availability, but they used human habitat more than twice as much as it was available on the landscape ($P < 0.001$). Excluding skunks from anthropogenic structures could decrease overwinter survival by limiting availability of dens with a thermal advantage and increasing competition for natural dens. Removal of human objects in dune areas in the spring would reduce high quality den sites in close proximity to plover nesting areas. At beaches where exclusion fencing is not an option for protecting eggs of rare and threatened species, spring trapping could be effective in reducing skunk densities for most of the nesting season because our data indicates that female territories would remain vacant until late summer. Future research tracking the temporal and spatial variation in wrack line fauna availability on beaches with sparse vs. dense wrack lines will increase understanding of the factors influencing interactions between piping plovers and predators that share foraging habitat with them, such as skunks and crows. On beaches that are seasonally urban habitats (SUH), research investigating the influence of predictable anthropogenic food subsidies (PAFS) on the activity of generalist predator species during the summer months could provide valuable data for management efforts and public outreach aimed at reducing predation on rare and threatened species.

Introduction

Striped skunks (*Mephitis mephitis*) are highly adaptable mesocarnivores that thrive in suburban and agricultural areas where they readily exploit anthropogenic shelter and food subsidies (Wade-Smith and Verts 1982; Gehrt 2004; Weissinger et al. 2009). Their broad diet and habitat needs are typical of 'urban adaptor' species (McKinney 2006), a group that has increased in number and distribution in the last century that also includes raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), and American crow (*Corvus brachyrhynchos*) (Putman 1989; Garrott et al. 1993; Adams 1994; DeStefano and DeGraaf 2003). These nocturnal mammals are one of the primary nest predators of piping plovers (*Charadrius melodus*), least terns (*Sternula antillarum*), and American oystercatchers (*Haematopus palliatus*) on the island of Martha's Vineyard and on other Massachusetts beaches (Rimmer and Deblinger 1990, 1992; Melvin et al. 1992; Swanson 2001, Harris and Reddington 2009).

The federally threatened Atlantic coast piping plover, a habitat specialist, has experienced significant population declines due to development of beach nesting habitat, human disturbance, and high levels of predation on their eggs and chicks by abundant urban adaptors (Patterson et al. 1991; Hecht et al. 1996; Elliott-Smith and Haig 2004). To reduce nest predation, biologists began using predator exclosure fencing around piping plover nests in the late 1980s with great success (Rimmer and Deblinger 1990; Melvin et al. 1992). Within a decade, however, predator exclosures were associated with increased rates of nest abandonment and adult plover mortality (Hecht and Nickerson 1999, Murphy et al. 2003). Because loss of predator exclosures as a management tool would leave many plover populations once again vulnerable to high rates of egg predation, other management options, including targeted predator control, were recommended as part of an adaptive recovery plan for piping plovers and other rare species. However, managers need site specific information on predator species and their behavior to select appropriate management methods (lethal or non-lethal) with the best chance of achieving conservation goals (Hecht and Nickerson 1999; Engeman et al. 2003, 2009).

Many studies have investigated the behavior, movements, and diet of striped skunks in North America due to their role as a rabies reservoir, nuisance wildlife species, and egg predator of ground-nesting birds (Dean 1965; Sargeant et al. 1982; Weller and Pelton 1987; Rosatte et al. 1991; Vickery et al. 1992; Greenwood et al. 1997, 1999; Lariviere and Messier 1998a; Bixler and Gittleman 2000; Gehrt 2005). However, coastal striped skunks inhabit linear landscapes with daily allochthonous inputs from ocean tides, which may influence behavior and movements of these mesocarnivores differently than inland populations (Polis and Hurd 1995; Rose and Polis 1998; Moore 2002; Killengreen et al. 2011).

From spring of 2004 – 2008, we conducted a radio telemetry study of striped skunks captured at piping plover nesting beaches on the island of Martha's Vineyard with a history of high rates of predation (40 – 70%) on unfenced plover and tern nests (Swanson 2001, Baldwin et al. 2006). We studied skunk resource use and movements during the piping plover nesting season and skunk winter denning period in order to determine the landscape scale of the predation problem and recommend integrated predator management methods. Specifically, we focused on skunk habitat selection for and characteristics of daytime retreats during the nesting and winter denning seasons, as well as female natal den characteristics. We tracked skunk movements between these retreats and piping plover nesting beaches and observed active skunks at night to better understand their foraging activity in beach and dune habitats shared with nesting birds

(May –August). Finally, we summarized skunk use of anthropogenic food and shelter subsidies to document their influence on coastal skunk activity.

Methods

Study areas

We studied coastal striped skunks at three piping plover nesting beaches on Martha's Vineyard (MV), Massachusetts, 41 21 N, 070 31 W, a 260 km^2 island located 13 km south of the mainland (Fig 2.1). Annual temperature and precipitation average 9.4° C (range-21.7 to 37.2) and 118 cm (range 66 to 127), respectively. The winter climate (December – February) is milder than the mainland, with an average temperature of 0° C (range – 4 to 6) and average snowfall of 91.9 cm (range 19 – 27) (www.weatherbase.com, accessed 11/8/2012). The year-round human population is approximately 15,000, however, over 100,000 summer residents and tourists inhabit the Island between mid-June and the end of August bringing an annual pulse of human activity and associated predictable anthropogenic food subsidies (PAFS) (Oro et al. 2013) to the beaches.

We selected beaches that differed in habitat configuration to provide skunk habitat use data representing a variety of Atlantic coast piping plover nesting beaches. The study sites were Dogfish Bar (DB) (Fig 2.2) in the town of Aquinnah, Norton Point/Wasque (NPW) (Fig 2.3) in Edgartown, and Long Point Wildlife Refuge (LP) (Fig 2.4) in West Tisbury. Development and human influence varied by site (Table 2.1), with DB being the most suburban and LP being the most isolated from residential areas. At DB, house lots were interspersed within the dune system, whereas LP and NPW's dune systems were undeveloped. Dominant dune vegetation at all sites included American beach grass (*Ammophila breviligulata*), beach pea (*Lathyrus japonicus*), and poison ivy (*Toxicodendron radicans*) in prostrate and shrub form. Other patches of shrubs included beach rose (*Rosa rugosa*), beach plum (*Prunus maritime*), or bayberry (*Morella pennsylvanica*). In open backdune areas at DB and NPW, beach heather (*Hudsonia ericoides*) and poverty grass (*Hudsonia tomentosa*) provided herbaceous cover. Switchgrass (*Panicum virgatum*), a tall bunch grass, grew in dense patches along the edges of wetlands near the beach at DB and LP. Dune habitats at LP and NPW transitioned to maritime shrublands, heathlands, and grasslands of little bluestem (*Schizachyriam scoparium*). Shrub vegetation was black huckleberry (*Gaylussacia baccata*), scrub oak (*Quercus ilicifolia*), bayberry, lowbush blueberry (*Vaccinium angustifolium*), and poison ivy, with patches of Pennsylvania sedge (*Carex pensylvanica*) and bearberry (*Arctostaphylus uva-ursi*). At LP and NPW, vegetation communities inland from the beach and dune were interrupted by large coastal ponds (15 - 320 ha) or estuaries that extended 0.5 to 3 km inland (Figures 2.3 and 2.4). Behind or within backdune areas at DB, a 16 ha buttonbush (*Cephalanthus occidentalis*) and sweet gale (*Myrica gale*) shrub swamp, smaller high-bush blueberry (*Vaccinium corymbosum*) wetlands, and a few ponds stretched from east to west within 0.5 km of the beach. Coastal forests at all sites were assemblages of oaks (*Quercus alba*, *Q. velutina*, *Q. coccinia*), sassafras (*Sassafras albidum*), shadbush (*Amelanchier canadensis*), and black cherry (*Prunus serotina*), with black huckleberry or sweet pepperbush (*Clethra alnifolia*) in the understory. Inland forests at LP and NPW were mixed oak and pitch pine (*Pinus rigida*) on glacial outwash soils whereas the moraine soils at DB supported forests of oak and American beech (*Fagus grandifolia*) interspersed with black tupelo (*Nyssa sylvatica*) wetlands.

Capture, handling, and radio-tagging

We captured skunks during the spring, summer, and fall 2004 – 2007 and spring 2008 using Safeguard live traps (76 x 28 x 31 cm, single-door, Safeguard Products Inc., New Holland, PA; mention of trade names does not constitute endorsement by the federal government) set in beach habitat or along footpaths, low-traffic dirt roads, or driveways within 400m of the beach. We anesthetized skunks in the trap with a mixture of ketamine hydrochloride (8 - 10 mg/kg) and acepromazine (1 mg per kg) via jab stick. We determined their sex and aged them as either adults or juveniles (summer and early fall only) based on size, weight, physical appearance, and tooth wear (Jones 1948). Short (≤1 mm) teats identified yearling females in the spring (Petrides 1950; Verts 1967; Bjorge et al. 1981). We injected a 12 mm, 125 kHz, Passive Integrated Transponder (PIT) tag (Biomark Inc., www.biomark.com, Boise, ID) under the pelt between the shoulder blades of each skunk at initial capture as a permanent means of identification. A numbered Monel tag (size #1, www.nationalband.com) in one ear allowed for visual identification of previously captured skunks.

We fitted a sub-sample of adults with 40g VHF radio-collars equipped with a mortality switch set at 12 hours (model M1930 series, Advanced Telemetry Systems, Isanti, MN). Radio collars never exceeded 5% of body weight. We attempted to collar an equal number of males and females at each site and recaptured skunks to loosen collars as they gained weight in the fall. All trapping, anesthetizing, and handling of animals was in accordance with University of Massachusetts at Amherst Institutional Animal Care Protocol #24-02-07 and the guidelines of the American Society of Mammalogists (Animal Care and Use Committee 1998).

Radio-telemetry and data collection

We tracked skunks on foot using the homing method (White and Garrott 1990) and a handheld receiver with 6-element yagi-antenna (R-1000, RA-165; Communications Specialists, Inc., Orange, CA). We located skunks at daytime rest sites at least three times per week in the bird-nesting season (1 April – 31 August) and once per 7 – 10 days in the winter denning season (November 1 – March 31). We monitored active skunks at least 3 nights per week between late May and late August in most years, tracking skunks in a random order with a goal of 3 observations per night, at least 1 hour apart, as skunks were capable of moving across their entire territory in less than 1 hour. This population of skunks regularly foraged around anglers and other people on the beach at night. Thus, we were able to observe focal skunks at close range (15 - 40 m) with a 1st generation night-vision monocular (Night Storm; ATN Corp., San Francisco, CA) (Lariviere and Messier 1998b).

To collect skunk behavioral and resource use location data, we used handheld computers (Palm m500; Palm, Inc., Santa Clara, CA) running a modified North American Cybertracker® sequence (version 2.79, www.cybertracker.co.za) connected to a global positioning system unit with an average error of ≤ 10 m (GPS, Garmin eTrex Vista, Garmin, Kansas City, KS). To record the location of active skunks, we observed their position, then moved to and recorded the location after the skunk left. When tracking skunks to daytime retreats, we regularly approached to within 2 m without incident. If we could not access the skunk's active or resting location without disturbing it, we estimated the distance (5 – 100 m) to the skunk and took a bearing with the GPS compass. We later adjusted the observer UTM location coordinates to the skunk's position using trigonometry (Table 2.2). When a skunk occupied a larger area of impenetrable habitat (i.e., shrub thickets, dense forest at night) observers triangulated skunk locations, taking bearings within 5 minutes of each other. We used Locate III (Nams 2006) to determine UTM coordinates of triangulated skunk locations.

Upon locating a resting skunk, observers recorded the percent cover of dominant vegetation species within a 1-meter radius and described the retreat site as one of four types: (1) burrow, (2) lay, (3) human, or (4) natural. Burrows were dens dug into the ground in natural areas. Lays were above ground retreats under vegetation. Human retreats were under anthropogenic structures (buildings, foundations, decks, sheds, road culverts) or objects (tent platforms, woodpiles, stonewalls, dump areas, plastic buckets, or fish totes in dune habitats). Natural retreats were those in impenetrable shrub or vine thickets where we could not differentiate between a burrow and lay. Natal dens were occupied by females for >5 days during the kit-rearing season (May 1 – June 30) and later confirmed to have kits, or those found with young kits after locating a newly captured lactating female.

We described the behavior of active skunks as: (1) foraging, (2) traveling, (3) other, or (4) unknown. When possible, we documented food/prey items of foraging skunks. When skunks were active in beach or dune habitat, we placed locations in: (1) intertidal zone (including the wrack line from the most recent tide), (2) backshore, (3) primary dune (Elias et al. 2000), and (4) backdune (sand and dune areas behind the primary dune) to better understand overlapping habitat use with piping plovers.

After collecting detailed information about active and resting locations, observers characterized the general habitat for each skunk location as one of 8 types: (1) beach, (2) dune, (3) forest, (4) grass, (5) human, (6) marsh, (7) shrub, or (8) switchgrass. Beach habitat was bare or sparsely vegetated and included the intertidal zone and backshore areas. The primary dune and backdune comprised dune habitat, with dune grass covering the majority of the habitat. Human habitat included homes and adjacent lawns, other built structures, public parks, parking areas and roads. Coastal oak, pitch pine, oak-pine, and mixed deciduous forest were all classified as forest. Grass habitat included grasslands, hayfields, and old-field areas dominated by grasses and forbs while salt and freshwater marshes comprised marsh habitat. Shrub included maritime shrubland, scrub oak thickets, and shrub swamps. We separated switchgrass from other grass habitats because skunks used dense patches of this taller bunch grass for daytime retreats.

Skunk movements

To determine the landscape area contributing to the predation problem at each plover nesting beach, and the length of beach vulnerable to predation by a single skunk, we measured maximum straight-line (SL) distances moved from their capture beach and during nightly foraging activities by skunks that wore radio collars for more than 7 days. We used Home Range Tools 1.1 (Rodgers et al. 2007) in ArcGIS 9.3 (Environmental Systems Research Institute Inc., Redlands, CA) to calculate distances between skunk capture locations and the farthest location from that point as well as the distance between daytime retreats and nocturnal foraging locations on the beach. We tested for differences in skunk movements by sex and site using Mood's Median Test in Minitab 17 (2016)

Coastal skunk resource selection

To create vegetative cover type (habitat) maps for each study area, we viewed all skunk location data in ArcGIS on 2005 color orthoimagery quadrangle maps at a spatial resolution of 1:5,000 (Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, Information Technology Division). In Home Range Tools, we created a 100% minimum convex polygon (MCP) of all skunk locations with a 0.5 km buffer to allow for available habitat beyond outermost skunk locations. We used the buffered MCP to clip each study site from a 2003

Vegetation Communities on Martha's Vineyard GIS layer (The Nature Conservancy (TNC), Massachusetts Chapter Field Office). This vegetation layer used photointerpretation methods of 1993 color aerial photos and ground verification to classify vegetation and land use base on Swain and Kearsley's (2001) natural communities of Massachusetts. We displayed the TNC layer at 50% transparency over the orthoimagery quadrangles, magnified to a scale of 1:1,000, in order to modify and consolidate the 65 terrestrial vegetation habitat polygons into our 8 general habitat types (beach, dune, forest, grass, human, marsh, shrub, and switchgrass). Within dune and grass habitats, we traced the boundaries of shrub patches because many skunk burrows were in shrub roots in these habitats. We expanded the TNC developed habitat polygons to include yard areas around homes as 'human' habitat and added polygons for recently developed home sites. We also created human habitat polygons for outbuildings, abandoned vehicles or boats, slash piles, and old dumps visible within natural habitat types on orthoimagery. We used a handheld GPS unit to map these same resources in forest areas, as well as large patches of switchgrass (>20 plants) within dune, grass, and shrub habitats at DB and LP where they occurred. We tested the accuracy of our skunk habitat layer by joining it to the active and resting skunk locations and verified that the habitat type assigned to the point data in GIS matched the general habitat type characterized by the observer who collected the data in the field. We did not find any errors in habitat assignment.

We calculated available habitat areas separately for the piping plover nesting and winter denning seasons at each site in order to match the available habitat to the areas used by skunks in the sample. In ArcGIS, we pooled all telemetry locations from skunks in the data set of interest and buffered them by the mean distance moved between daytime rest sites in that season (471 m nesting season, 288 m winter), then dissolved the boundaries between buffered locations, and calculated the area (km^2) of each habitat type within the resulting polygon. Using Hawths Tools 3.27 (Beyer 2004), we generated enough random points to represent availability of vegetative cover types for each site and season (n = 400 – 600 points).

We hypothesized that skunk daytime and winter retreats would be closer to human habitat and corridors than random points due to the subsidies and ease of movement that these resources offered. For each skunk location and random point, we measured distance to nearest human habitat and distance to nearest road or footpath (corridor) in ArcGIS. In the winter season, we excluded beach parking lots and picnic areas from human habitat because they did not offer any subsidies during that season. We also measured the distance to nearest nesting beach, which was a polygon encompassing the bird nesting area at each site, to provide a constant reference distance between skunks and nesting plovers. This distance also provided a constant reference point to areas where skunks were captured.

We modeled third-order selection (Johnson 1980) of natural or human habitat for daytime retreats and winter dens. We calculated resource selection functions (RSF) with a use: availability framework (Manly et al. 2002), assuming the exponential form (Johnson et al. 2006). This framework allowed us to compare how covariates measured at used and available locations influenced habitat use by the equation:

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k + y_{0i})$$

where $w(x)$ is the relative probability of selection of habitat types for daytime retreats or winter dens as a function of the model coefficients (β_n) of habitat type, distance to nesting beach, distance to corridor, and distance to nearest human habitat, and y_{0i} is the random intercept effect of skunk$_i$. The random intercept model accounted for unequal sample sizes and repeated measures on individual skunks (Gillies et al. 2006). We estimated resource selection coefficients

with mixed-effect logistic regression (glmer) using the R-package 'lme4' (Bates et al. 2014), comparing skunk locations (1's) to random locations (0's). Random points for skunks at each site were linked through their identification numbers and based on the available habitat for the sample of skunks at that site in each season. We used Program R 3.0.1 for all resource selection analyses (R Core Team 2013)
and selected the most parsimonious best-fitting model using difference in Akaike information criteria (ΔAIC) values and Akaike weights (*w*) (Burnham and Anderson 2004).

Results

Between May 2004 and 2008, we placed VHF radio collars on 29 male and 22 female skunks (4–24 per year) and collected 3,434 telemetry locations (2–296 per skunk) during the piping plover nesting season, fall, and winter (Tables 2.3 and 2.4). Of these, 2,498 (72%) were GPS locations taken after a skunk walked away from a location, 25% (847) were locations within 100 m of observers that we adjusted using bearing and distance to the skunk from observer, and 3% (89) were triangulated. Due to difficulty retaining collared skunks and lower capture rates at LP and NPW, DB skunks contributed 66% of the data (2,260/3,434 locations) (Table 2.4). Mortality, dispersal, and collar loss limited data to <20 locations on 13 skunks (7 M, 6 F) (Fig. 2.5), but even a few locations contributed valuable information on natal dens, movements, and resources used by coastal skunks. Because our primary focus was on the plover nesting season, when skunks were sharing habitat with beach-nesting birds, 77% of telemetry locations (2,644/3,434) were collected during that season (Table 2.4, Fig. 2.5).

Skunk movements to and from nesting beaches

At all sites, the maximum SL distances skunks moved from nesting beaches where they were captured was greater for males (n = 22) than females (n = 19) (2,259 ± 248 m (mean ± SE) vs. 1,642 ± 148 m), but the difference was not significant at the $P < 0.05$ level (Mood's Median Test, $X^2 = 2.02$, DF = 1, $P = 0.16$) (Table 2.5). Long-distance (>3 km) male movements included exploratory forays by single males at DB and LP as well as movements by non-resident males at NPW that left the beach area shortly after capture and did not return during monitoring (n = 3). Figures 2.6 – 2.8 show active and resting telemetry locations for male and female skunks at each study site by season, including outlier and non-resident skunk locations. Considering resident skunks only, the mean distance from NPW and DB skunk locations to the nesting beach where they were captured was less than for LP skunks (431 ± 9 m and 398 ± 14 m vs. 1,012 ± 49 m respectively, Mood's median test, $X^2 = 57.00$, DF = 2, $P < 0.001$) (Fig. 2.9). During the plover nesting season, telemetry locations from females rearing young were closer to nesting beaches than locations from resident males or females without young at all sites (255 ± 16 m vs. 512 ± 14 m vs. 525 ± 29 m, respectively, Mood's median test, $X^2 = 49.25$, DF = 2, $P < 0.001$) (Fig. 2.10 and Figs. 2.6 - 2.8). At DB and NPW, winter dens were farther from nesting beaches than daytime retreats during the nesting season (638 ± 38 m and 990 ± 111 m vs. 437 ± 17 m and 553 ± 33 m, respectively, Mood median test, $X^2 = 50.81$, DF = 1, $P < .001$) (Fig. 2.11). We did not include LP in the comparison because there were only 21 winter dens at that site, but LP male winter dens (n = 16) also fit this pattern (Fig. 2.11).

During nighttime tracking, male and female skunks foraging on beaches moved similar maximum SL distances, ranging from 395–2,502 m (n = 21), sometimes moving considerable distances in two hours. For example, a DB male traveled 1,214 m along the beach in 72 minutes, and a DB female traveled 1,004 m in 89 minutes. When comparing cumulative 24-hour movements, however, females (n = 20) traveled farther than males (n = 18) covering a mean distance of 1,615 ± 79 m while males traveled 1,149 ± 44 m (Mood median test, $X^2 = 17.20$, DF = 1, $P < 0.001$). LP females contributed significantly to this difference (Fig. 2.12). One LP female was tracked to a natal den 2.4 km east, and she made round-trip movements of >5 km on several nights to forage on or near the public beach where she was captured. We tracked another LP female to a natal den 1.6 km inland, but she lost her collar her a week after she was captured. Females at NPW and DB also traveled >4 km in 24 hours, but not as frequently.

Coastal Skunk Foraging Activity

During the piping plover nesting season, we collected 1,269 telemetry locations for 38 active skunks (21 DB, 7 LP, 10 NPW), and 72% of these locations (912/1269) were from DB. We located active skunks at DB in beach or dune areas more frequently than inland habitats while LP and NPW skunks were active inland more frequently than in beach or dune areas (Fig. 2.13, Pearson $X^2 = 81.673$, DF = 2, $P < 0.001$). At DB, where wrack was dense on the beach 44% (158/363) of beach foraging observations were in the intertidal zone (ITZ). By contrast, at NPW and LP, where wrack was typically sparse and scattered, only 11% of NPW (6/53) and 5% (1/19) LP foraging observations were in the intertidal zone. At these sites, skunks were observed foraging in the backshore or dune habitats more frequently (Fig. 2.14). We were able to determine prey items or food consumed during 258 foraging observations in beach and dune habitat. Beach invertebrates comprised 76% (196/258) of these observations and the remaining 24% (62/258) were anthropogenic food. Beach invertebrates skunks consumed in the intertidal zone and backshore included amphipods in the family Talitridae, krill (order Euphausiacea), and mole crabs (*Emerita talpoida*). On many nights during the summer months, Talitrid amphipods or krill were so plentiful in the wrack at DB that we could pick them up by the handful. Of the anthropogenic foraging observations in beach habitats, 73% (49/62) were of skunks consuming picnic food scraps and fish remains from shore fishing in the backshore microhabitat. The remaining observations were of skunks consuming picnic food scraps dumped in backdune parking lots or loose trash near trash cans at beach houses.

In addition to these observations, we listened for and observed interactions between piping plovers and foraging skunks. On 18 occasions, we observed plovers and skunks within 10m of each other at the DB site. On one occasion, a female skunk appear to pounce at a plover and chase it for 3 meters before giving up and returning to foraging in the wrack line. We did not see any evidence of skunks responding to plover calls when the plovers were vocal and moving chicks. These observations were limited in number, and through a night-vision scope, so we do not rule out the possibility that we missed a depredation event when plovers and skunks were both foraging in the ITZ or on the upper beach. However, we observed skunks consuming least tern eggs and possibly chasing tern chicks in a small colony at DB on three separate occasions in late June/early July. Two observations were of the same female visiting the colony twice in a night, and the other was a male skunk in a different year.

Daytime retreats during the plover nesting season (April 1 – August 31)

We tracked 49 skunks (28 M, 21 F) to 890 unique daytime retreats on 1,297 occasions during the nesting season. Males used more retreats in a season (n = 614, range 1 – 35) than females, who were rearing kits May – July (n = 300, range 1 – 21). At all sites, most retreats were aboveground lays under vegetation (644/890) (Table 2.6), primarily used by males. However, females also used lays after our just before their young became independent. Burrows were 14% of daytime retreats (122/890), and 45 burrows were female natal dens. Only 8% of retreats were human objects (48/890) or structures (27/890) during this season. Some retreats were in dense vegetation where we were unable to determine if they were burrows or lays (n = 49) (Table 2.6). The distance from skunk retreats to a corridor (footpath or dirt road) was 34 ± 1 m at DB (n = 587, range 1-157 m), 51 ± 5m at LP (n = 128, range 1-444 m), and 38 ± 2 m at NPW (n = 228, 1-131 m). Distance to nearest corridor from male and female retreats was similar (38 ± 1 m vs. 35 ± 2 m).

Male skunks, and females without young, typically switched retreats daily, returning to the same location infrequently (47 re-uses of retreats). Of the 890 retreats, 66% were under shrubs in coastal shrublands or dune habitats (449 lays, 92 burrows, 42 natural), 15% were in forests (104 lays, 23 burrows, 7 natural), and 11% were in grass habitats (91 lays, 5 burrows) that included switchgrass (61) and dune grass (28). The remaining 8% were under house foundations, decks, or outbuildings (27), woodpiles (10), stonewalls (9), boats (8), tent platforms (7), metal refuse piles (6), brush piles (5), and plastic buckets or fish totes in dunes (2).

Natal dens

We followed 14 female skunks (9 DB, 2 LP, 3 NPW) to 45 natal dens while they were rearing young, Of the 45 dens, 27 were at DB, 3 at LP, and 15 at NPW (Figs. 2.6 – 2.8). Female skunks primarily excavated burrows under shrubs (41/45 natal dens), but one female at DB excavated burrows under tree roots, and two other females at DB used human objects late in kit rearing. Of the 41 shrub dens, 41% (17) were in dune habitats at DB (13) and NPW (4). Shrub species hosting > 5 natal dens were bayberry (*Morella pennsylvanica*), beach rose (*Rosa rugosa*), huckleberry (*Gaylussacia baccata*), scrub oak (*Quercus ilicifolia*), and poison ivy (*Toxicodendron radicans*). Of four females monitored during multiple seasons, three re-used natal dens under shrubs the following season. Mean distance from female natal dens to nesting beaches was 340 ± 40 m (median 279 m, range 0–1,042 m), and 64% (29/45) were within 500 m of the nesting beach. Only two natal dens (at DB and LP) were >1 km from the nesting beach. Nine females monitored from parturition (mid-May) through kit independence (late July–early August) used 4-6 natal dens, moving young 100 – 1,050 m between dens.

Winter dens (November 1 – March 31)

Radio-collar failure and mortality reduced the number of skunks available for winter tracking to 26 (11 F, 15 M), which we tracked to 134 retreats on 418 occasions (220 M, 198 F) (Table 2.7). On 4 days in November and 1day in February, we located skunks resting in aboveground lays when daytime temperatures were > 8° C and skies were clear. Of 129 unique winter dens, 69% (90) were burrows that skunks excavated in shrub roots, slopes (hillsides or dunes), or in tree roots. The remaining 30% (39) were under structures (home foundations, barns, sheds), in dry culverts under roads, or under objects (fish totes in dunes, tarped woodpiles, stonewalls, debris piles, and overturned boats). As with daytime retreats during the nesting season, most winter dens (90/129) were < 50 m from a corridor. At DB, mean distance from winter dens to nearest corridor was 39 ± 3 m (n = 116, range 1 - 156 m), at LP it was 73 ± 20 m (n = 21, range 10-425 m), and at NPW it was 42 ± 5 m (n = 35, 14 - 131 m).

Radio-tagged males used 77 winter dens (range = 2-11), females used 39 (range = 1-12), and 13 dens were used by tagged skunks of both sexes. Because radio-tagged skunks sometimes shared dens simultaneously, or used the same den on different days, we documented 171 winter den selections (100 M, 71 F) for the 129 dens. While human structures or objects were 38% of female den selections (27/71), they were only 25% of male selections (25/100) (X^2 = 3.33, DF = 1, P =0.07). When we compared all telemetry locations (n = 414, 216 M, 197 F), females used anthropogenic dens more frequently than males, with 47% of female locations in anthropogenic dens (92/197) vs. 23% (50/216) for males ($X^2 = 25.33$, DF = 1, $P < 0.001$).

Skunk habitat selection during the plover nesting and winter denning seasons

For use vs. availability resource selection analysis (RSF) of skunk retreat locations during the plover nesting season, we used retreat data from 24 resident skunks at DB, 9 at LP, and 13 at NPW (Figs. 2.16-2.18). For the winter denning RSF analysis, we used data from 13 resident skunks at DB, 5 at LP, and 7 at NPW (Figs. 2.19-2.21). At DB, the estimated available habitat area and percent composition was similar between the plover nesting and winter denning seasons. At LP and NPW, where we tracked fewer skunks through both seasons, available habitat differed in area and percent composition between the two seasons because the sample of skunks differed (Table 2.8).

During the plover nesting season, skunks at all sites used shrubs for daytime retreats more than other cover types (Table 2.9). RSF analysis showed that switchgrass patches, if present, had the highest relative probability of selection for a daytime retreat, followed by shrub habitat that was used more than twice as much as it was available at all sites (Tables 2.10-2.12). Skunks used human habitat similar to its availability during this season and human was the reference habitat (intercept) for the analysis. For all sites, including distance to nesting beach improved the model, with the relative probability of a skunk using a retreat in any habitat type increasing as distance to plover nesting beach decreased ($P < 0.001$) (Table 2.13). At DB the best model included the random effect of individual skunk and fixed effects of distance to nesting beach and distance to corridor, with the probability of a skunk selecting any cover type increasing as distance to a corridor decreased ($P < 0.001$) (Tables 2.10, 2.13). At LP, the best model included distance to nesting beach and human habitat as fixed effects, and individual skunk as a random effect. The relationship for distance to human habitat was positive, where relative probability of selection for a retreat site increased as distance to human habitat increased ($P = 0.10$) (Tables 2.11, 2.13). At NPW, the best model included the distance to nesting beach and individual skunk as a random effect (Tables 2.12, 2.13).

Skunks used forest, human (road culverts, house foundations, and human objects), and shrub habitats for winter denning (Table 2.14). However, given its availability on the landscape, human habitat had the highest probability of use, being used 3 times as much as it was available (Table 2.15). Shrub habitat was used equal to its availability and was the reference habitat (intercept) for RSF, while forest and dune habitats were used less than their availability. Similar to daytime retreat selection during the nesting season, the relative probability of skunks using a site for winter denning increased as distance to nesting beach decreased ($P < 0.001$). Including this effect produced the best model for winter den selection whether human object dens were designated as human or as the natural habitat type where they occurred (Table 2.16).

Discussion

To our knowledge, this is the first study to document resource use and movements of striped skunks on Atlantic coast beaches where they share habitat with federally threatened piping plovers and other beach-nesting birds. On the island of Martha’s Vineyard, predation rates on unexclosed piping plover nests range from 40 – 100%, and skunks are frequently identified as egg predators (Swanson 2001, 2005, and Harris et al. 2008). However, little was known about skunk foraging activity on beaches prior to this study. We did not anticipate the importance of wrack lines and beach invertebrates as a food source for skunks. Piping plovers also rely on beach invertebrates in wrack lines as primary prey during the nesting season (Elliott-Smith and

Haig 2004), which places skunks and plovers in direct competition for food. Beach morphology influences wrack/seaweed deposition, which provides habitat for the invertebrates that birds and mammals consume (Moore 2002; Colombini et al. 2003; Orr et al. 2005). As wave height and beach slope increase, diversity of sandy shore systems decreases (McLachlan 1990). Sheltered, low-energy beaches like DB have greater wrack deposition and more invertebrate biomass than high-energy beaches like LP and NPW (U.S. Army Corps of Engineers 2005). DB, with its dense wrack line, has 3 – 4 nesting pairs of plovers/km of beach while LP and NPW, with scattered and sparse wrack lines, have 1 – 2 pairs/km (Swanson 2001, Baldwin et al. 2006). DB skunks consumed wrack line invertebrates as they walked along the intertidal zone, while skunks at LP and NPW foraged for invertebrates in the backshore, dune, and inland areas. In these habitats, skunks were consuming Coleoptera and Lepidoptera similar to the striped skunk diet reported by Greenwood et al. (1999) in North Dakota grasslands and wetlands.

Annually, our Atlantic coast beach study sites become what we describe as ‘seasonally urban habitats’ (SUHs) in the warm summer months. During the day, backshore habitat was teeming with humans in beach chairs or on blankets picnicking and relaxing. From the data we collected, we know that nocturnal skunks travel to the beach and exploit food waste people leave behind. These subsidies are Predictable Anthropogenic Food Subsidies (PAFS) (Oro et al. 2013), which wildlife track and exploit with regularity in a variety of habitats and settings (Orams 2002; Marzluff and Neatherlin 2006; Oro et al. 2013). The fact that PAFS primarily occur in the backshore area of the beach, between the ITZ and dune, is particularly problematic because that zone of the beach is where plovers and terns typically lay their eggs. By placing PAFS in backshore habitat, humans attract foraging skunks to areas where they may encounter and depredate nests while searching for PAFS.

Our telemetry data showed that female skunks rearing young pose the most risk to beach-nesting birds because their activity was concentrated closer to the beach than male skunks or females without young and they regularly ranged >1 km from their natal den along beaches during nightly foraging. Lariviere and Messier (1998c) identified female skunks as the predator of concern for duck nests in the Canadian prairie because their home ranges overlap and they can reach high densities, they forage more intensively within their home range than males, and they forage intensively near their natal den. Similarly, we documented 2 – 5 females with active natal dens foraging along the nesting beach we studied, and more than half of natal dens were within 500 m of the nesting beach.

Skunks at all of our study sites exploited anthropogenic food in the backshore zone of the beach as well as at parking lots and homes in backdune areas. While anthropogenic food comprised only 24% (62/258) of our skunk foraging observations in beach habitats, human food waste and fish scraps are probably higher in calories than natural invertebrate food, or anthropogenic food may have been preferred for another reason, because we observed skunks fighting over these subsidies, rolling in them, and returning to areas where they consumed subsidies the following night. One female at LP traveled 2.4 km SL distance from her natal den to forage on the LP recreational beach at least 3 nights during a 10-day monitoring period. A recent experimental study in Australia found that even small and temporary food subsidies, such as a fish carcass, could elevate scavenger activity and increase nest predation in the area (Rees et al. 2013).

Most winter dens we located were natural burrows in shrub and forest habitats, but the RSF use vs. availability analysis revealed that human habitat had the highest probability of use. It is possible that skunks selected dens in human structures because they were close to winter food subsidies such as bird feeders or scallop discard piles that skunks could access during mild winter weather. Other studies have documented skunks and island foxes denning near human subsidies (Weller and Pelton 1987; Weissinger et al. 2009; Resnik and Andelt 2012). Skunks used dry culverts under a paved road at the DB site every winter and multiple structure foundations at DB and NPW, which may have provided a thermal advantage during winter torpor. Of the human objects skunks used as daytime retreats or winter dens, plastic fish totes that washed ashore, and eventually into the dunes, provided considerable thermal advantage because skunks would burrow under them and add grass bedding. Black or dark in color, the totes would collect heat on sunny days, even in cold weather. A female at LP spend several weeks of the winter under one of these tubs behind the primary dune.

Management Implications and Future Research

Reducing food and shelter subsidies for skunks and other predators near plover nesting beaches will act to reduce overall carrying capacity and may meet with the most long-term success in reducing abundant generalist predator populations (Frey and Conover 2007). Excluding skunks from anthropogenic structures could decrease overwinter survival by limiting availability of dens with a thermal advantage and increasing competition for natural dens. Removal of human objects in dune areas in the spring would reduce high quality den sites in close proximity to plover nesting areas. For beach managers and bird advocates, outreach efforts within 1.5 km of nesting beaches could emphasize excluding skunks from winter dens in human structures, removing all human objects washed ashore in dune areas in the spring, and reducing PAFS such as bird seed, pet food outside, compost piles, and shellfish discard piles.

In areas where exclusion fencing is not an option for protecting eggs of rare and threatened birds, early spring trapping would remove skunks before female parturition when they become less active and available for capture. Because adult females are typically residents where they are captured in the spring (Sargeant et al. 1982 and this study), their removal would provide a benefit for beach-nesting birds until juvenile females colonize the site the following fall.

Future research using GPS enabled radio-collars at beaches with dense and sparse wrack lines would provide fine-scale (15-minute intervals) movement data on skunks in microhabitats shared with nesting birds. GPS collars would function very well in beach habitat free from vegetative cover that limits satellite reception in other ecosystems. Tracking the temporal and spatial variation in wrack line fauna availability on beaches with sparse vs. dense wrack lines will increase understanding of the factors influencing interactions between piping plovers and predators that share foraging habitat with them, such as skunks and crows. On beaches that are seasonally urban habitats (SUH), research investigating the influence of predictable anthropogenic food subsidies (PAFS) on the activity of generalist predator species during the summer months could provide valuable data for management efforts and public outreach aimed at reducing predation on rare and threatened species.

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Table 2.1 Summary of human influence within 1 km of study sites (Dogfish Bar (DB), Long Point (LP), and Norton Point/Wasque (NPW)) on the Island of Martha's Vineyard, Massachusetts.

Site	Public Beach	Houses within 1 km of Nesting Beach	Number of Footpaths per km of Beach	Human Beach Activity
DB	No	122	16	fishing, swimming, picnics
LP[1]	Yes	46	4	fishing, swimming, picnics
NPW[2]	Yes	68	1	fishing, swimming, picnics

[1] Public access is from a 130-car parking lot. [2] Public access is primarily by off-road vehicle, but also pedestrians from a 60-car parking lot and a 10-car lot.

Table 2.2 Example calculations to obtain UTM coordinates of skunk location from observer coordinates, bearing, and distance to skunk, for adjusted skunk locations within 100 m of observer.

Observer UTM Easting	Observer UTM Northing	Bearing (degrees)	Distance (meters)	Delta Easting *cos(bearing)*distance*	Delta Northing *sin(bearing)*distance*	Skunk UTM Easting	Skunk UTM Northing
255822	788931	330	12	-11.894386	-1.5885796	255810	788929

Table 2.3. The number of female (F) and male (M) striped skunks monitored with VHF radio telemetry each year during the plover nesting and winter denning seasons on Martha's Vineyard, MA 2004-2008.

Season	Site	2004-2005		2005-2006		2006-2007		2007-2008		2008	
		F	M	F	M	F	M	F	M	F	M
Nesting	DB	1	2	5	4	4	6	6	7	2	1
	LP	0	0	0	0	0	2	5	4	0	2
	NPW	0	0	4	4	4	5	1	1	1	0
Winter	DB	1	1	0	0	2	5	4	4	0	0
	LP	1	0	0	0	0	2	1	1	0	0
	NPW	0	0	2	2	2	2	5	6	0	0
# of individuals		2	2	9	8	8	14	12	12	3	3

Table 2.4 Summary of coastal striped skunk VHF radio telemetry data 2004 - 2008 for plover nesting and winter denning seasons on Martha's Vineyard, MA.

Site	Total Telemetry Points	Skunks Tracked Nesting Season	Nesting Season Telemetry Points	Skunks Tracked Fall/Winter	Fall/Winter Telemetry Points
DB	2,260	24	1,799	13	461
	F	10	802	5	195
	M	14	997	8	266
LP	396	9	294	6	102
	F	4	89	2	46
	M	5	205	4	56
NPW	778	16	551	9	227
	F	6	273	4	135
	M	10	278	5	92
TOTAL	3,434	49	2,644	28	790

Table 2.5. The maximum straight-line (SL) distances (meters ± SE) moved by female and male coastal striped skunks tracked for more than 7 days during the piping plover nesting season 2004 – 2008 on Martha's Vineyard, MA.

	Maximum SL distance moved[1]	Maximum SL beach foraging distance[2]
Females	1,642 ± 148	1,615 ± 79
Range	845 – 3,039	312 – 5,229
No. of Females	19	11
Males	2,259 ± 248	1,149 ± 173
Range	1,027 – 6,224	418 – 2,887
No. of Males	22	10

[1] Maximum SL distance moved = farthest SL distance moved from a daytime retreat in 1 or more days.

[2] Maximum SL beach foraging distance = farthest SL distance moved away from a daytime retreat in a night of foraging.

Table 2.6. Striped skunk daytime retreat data summary for females (F) and males (M) April to August (piping plover nesting season) 2004 – 2008 at Dogfish Bar (DB), Long Point (LP), and Norton Point/Wasque (NPW) study sites on Martha's Vineyard, MA.

Site	Sex	No. of Skunks	Telemetry Locations	No. of Unique Locations	No. of Retreats By Sex	Percent Burrows	Percent Lays	Percent Human Objects	Percent Human Structures	Percent Natural
DB		24	870	553		14	71	7	4	4
	F	10	406		187	28	52	5	6	9
	M	14	464		381	7	81	7	4	1
LP		9	146	126		10	83	4	2	1
	F	4	36		23	19[1]	76	0	0	5
	M	5	110		103	9	84	5	2	0
NPW		16	281	211		19	72	4	4	1
	F	6	132		90	32	59	4	1	3
	M	10	149		130	10	81	4	5	0
All Sites		49	1,297	890	914	15	73	6	4	3

[1] Due to mid-late season captures, 70% of daytime retreats were post kit weaning, when females primarily used lays.

Table 2.7. Striped skunk winter denning data summary for females (F) and males (M) November - March 2004 – 2008 at Dogfish Bar (DB), Long Point (LP), and Norton Point/Wasque (NPW) study sites on Martha's Vineyard, MA.

Site	Sex	No. of Skunks	Telemetry Locations	No. of Unique Locations	No. of Dens By Sex	Percent Burrows	Percent Human Objects	Percent Human Structures	Percent Lays
DB		13	253	86		62	23	14	1
	F	5	113		46	54	35	11	0
	M	8	140		70	69	12	17	1
LP		5	52	22		74	13	11	2
	F	2	14		5	50	36	8	7
	M	3	38		16	82	5	13	0
NPW		8	113	26		68	0	30	2
	F	4	71		20	55	0	45	0
	M	4	42		13	90	0	5	5
All Sites		26	418	134	170	65	15	18	1

Table 2.8. Percent composition of available cover types used by striped skunks at 3 study sites on Martha's Vineyard, MA during the piping plover nesting and skunk winter denning season.

Site	No. of Skunks	Area Km^2	Season	Dune	Forest	Grass	Human	Shrub	Switchgrass
DB	24	8	Nesting	4	43	4	13	35	1
	13	6	Winter	5	39	4	14	35	1
LP	9	9	Nesting	2	72	7	6	13	< 1
	5	5	Winter	4	56	6	5	18	1
NPW	13	5	Nesting	13	53	8	9	17	0
	7	3	Winter	15	29	5	7	20	0

Table 2.9. Percent cover type use by resting coastal striped skunks (n = 46) during the piping plover nesting season (April – August) at Dogfish Bar (DB), Long Point (LP), and Norton Point/Wasque (NPW) study sites on Martha's Vineyard, MA from 2004 – 2008. Numbers in parentheses show percentage if human objects used as rest sites were counted as the natural habitat type.

Site	Sex	No. of Skunks	No. of Retreats	Dune	Forest	Grass	Human	Shrub	Switchgrass
DB		24	570	6	10 (11)	1	12 (9)	62 (64)	10
	F	10	187	6	7 (8)	1	13 (10)	65 (66)	9
	M	14	383	5	11 (13)	1	12 (8)	61 (62)	10
LP		9	124	4	37 (38)	5	6 (4)	46 (47)	2
	F	4	21	0	52	0	0	43	5
	M	5	103	5	34 (35)	6	7 (5)	47 (48)	2
NPW		13	178	1	25	0	6	69	0
	F	6	90	1	18	0	6	76	0
	M	7	88	0	33	2	5	63	0
		46	872	4 (5)	17 (18)	1	10 (7)	61 (62)	7

Table 2.10. Results of resource selection function habitat use vs. availability analysis for coastal skunk daytime retreats at the Dogfish Bar study site, April – August 2004 – 2008, using 571 retreats, and 600 random locations.

	Estimate ± SE	Lower (95%)	Upper (95%)	Relative Selection Probability	Re-Scaled Selection Probability	Percent of Available	Percent of Used
(Intercept) HUMAN*	-0.4965 ± 0.2449	-0.9765	-0.0165			15	12
Dune***	-2.0688 ± 0. 2466	-2.5500	-1.5876	0.1263	0.05	5	6
Forest***	-1.3034 ± 0.1937	-1.6831	-0.9237	0.2716	0.10	39	10
Grassland*	-1.3316 ± 0.6024	-2.5123	-0.1509	0.2641	0.10	5	1
Shrub	-0.2285 ± 0.1561	-0.5345	0.0775	0.7957	0.30	36	62
Switchgrass***	0.9765 ± 0.2584	0.4700	1.4830	2.6551	1.00	1	10
Distance to Nesting Beach***	-0.0028 ± 0.0001	-0.0030	-0.0026	0.9972			
Distance to Human Corridor***	-0.0090 ± 0.0016	-0.0121	-0.0059	0.9910			

Significance Codes: < 0.001 '***', 0.001 '**', 0.01 ‘*’, 0.05 ‘.’, 0.1 ‘ ‘

Table 2.11. Results of resource selection function habitat use vs. availability analysis for coastal skunk daytime retreats at the Long Point study site April – August 2007 - 2008, using 124 retreats and 500 random points.

	Estimate ± SE	Lower (95%)	Upper (95%)	Relative Selection Probability	Re-scaled Selection Probability	Percent of Available	Percent of Used
(Intercept) HUMAN***	-3.1918 ± 0.5251	-4.2210	-2.1626			7	6
Dune grass	-0.7123 ± 0.6570	-2.0000	0.5754	0.4905	0.18	4	4
Forest .	-0.7724 ± 0.4311	-1.6173	0.0726	0.4619	0.17	71	37
Grassland	-0.6909 ± 0.5909	-1.8491	0.4672	0.5011	0.19	6	5
Shrub*	0.9757 ± 0.4335	0.1260	1.8253	2.6530	1.00	12	46
Switchgrass[1]	20.449 ± 3000.0	-5860.0	5900.0	7.60e08		<1	2
Distance to Nesting Beach***	-0.0005 ± 0.0001	-0.0007	-0.0003	0.9995			
Distance to Human Habitat	0.0003 ± 0.0003	-0.0003		1.003			

[1] The extreme values for switchgrass were due to its very limited availability. We did not include it in the re-scaled selection probabilities.

Significance Codes: < 0.001 '***', 0.001 '**', 0.01 ‘*’, 0.05 ‘.’, 0.10 ‘ ‘

Table 2.12. Results of resource selection function habitat use vs. availability analysis for coastal skunk daytime retreats at the Norton Point/Wasque study site April – August 2005 - 2008, using 178 retreats and 254 random points. Switchgrass habitat was not available at this site.

	Estimate ± SE	Lower (95%)	Upper (95%)	Relative Selection Probability	Re-scaled Selection Probability	Percent of Available	Percent of Used
(Intercept) HUMAN**	-1.3950 ± 0.5277	-2.4293	-0.3607			9	5
Dune***	-4.7890 ± 1.0920	-6.9293	-2.6487	0.0083	0.01	9	1
Forest*	-0.7939 ± 0.3955	-1.5691	-0.0187	0.4521	0.35	54	25
Grassland	-14.610 ± 419.90	-837.61	808.39	4.52e-07	0.00	8	0
Shrub	0.2425 ± 0.3920	-0.5258	1.0108	1.2744	1.00	20	69
Distance to Nesting Beach***	-0.0027 ± 0.0003	-0.0032	-0.0021	0.9973			

Significance Codes: < 0.001 '***', 0.001 '**', 0.01 ‘*’, 0.005 ‘.’, 0.10 ‘ ‘

Table 2.13. Model selection results for habitat use vs. availability analysis of coastal skunk daytime retreats April – August 2004 – 2008 at Dogfish Bar (DB), Long Point (LP), and Norton Point/Wasque (NPW). Models are listed with factors, followed by Akaike information criterion (AIC), degrees of freedom (df), delta AIC (dAIC) and weights.

		AIC	df	dAIC	weight
DB5	Skunk ID + Distance to Nesting Beach + Distance to Corridor	3365.7	9	0	1
DB4	Skunk ID + Distance to Nesting Beach	3399.6	8	33.8	< 0.001
DB3	Skunk ID + Distance to Corridor	4125.8	8	760.1	< 0.001
DB2	Skunk ID + Distance to Human Habitat	4192.3	8	826.5	< 0.001
DB1	Skunk ID	4192.8	7	827.0	< 0.001
LP4	Skunk ID + Distance to Nesting Beach	1014.4	8	0	0.572
LP6	Skunk ID + Distance to Nesting Beach + Distance to Human Habitat	1015.0	9	0.6	0.428
LP2	Skunk ID + Distance to Human Habitat	1031.0	8	16.5	< 0.001
LP1	Skunk ID	1033.2	7	18.8	< 0.001
LP3	Skunk ID + Distance to Corridor	1033.3	8	18.8	< 0.001
NPW4	Skunk ID + Distance to Nesting Beach	1017.0	7	0	1
NPW1	Skunk ID	1127.2	6	135.7	< 0.001
NPW3	Skunk ID + Distance to Corridor	1128.5	7	136.2	< 0.001
NPW2	Skunk ID + Distance to Human Habitat	1128.5	7	137.0	< 0.001

Table 2.14. Percent cover type use by coastal striped skunks (n = 25) during the winter denning season (November 1 – March 31) on Martha's Vineyard, MA from 2004 – 2008. Numbers in parentheses show percent use if human objects used as dens were counted as the natural habitat type where they occurred.

Site	Sex	No. of Skunks	No. of Rest Sites	Dune	Forest	Grass	Human	Shrub
DB		13	116	4 (5)	30	0	34 (31)	32 (34)
	F	5	46	2	39	0	37 (33)	22 (26)
	M	8	70	7	24	0	31 (30)	39
LP		5	19	0 (5)	26	11 (16)	37 (21)	26 (32)
	F	2	5	0 (20)	20	0 (20)	60 (20)	20
	M	3	14	0	29	14	29 (21)	29 (36)
NPW		7	31	0	35	3	26	35
	F	4	20	0	30	0	35	35
	M	3	11	0	45	9	9	36
		25	166	3 (4)	31	2	33 (29)	32 (34)

Table 2.15. Results of resource selection function habitat use verse availability analysis for coastal skunk (n=25) winter denning using 166 den selections and 1,200 random points.

	Estimate ± SE	Lower (95%)	Upper (95%)	Relative Selection Probability	Re-scaled Selection Probability	Percent of Available	Percent of Used
(Intercept) SHRUB***	-2.9640 ± 0.2948	-3.5418	-2.3862			33	32
Dune***	-1.9040 ± 0.4828	-2.8503	-0.9577	0.1490	0.03	8	3
Forest	0.3695 ± 0.2154	-0.0527	0.7917	1.4470	0.25	43	31
Grass	-0.8899 ± 0.6181	-2.1014	0.3216	0.4107	0.07	6	2
Human***	1.7500 ± 0.2125	1.3335	2.1665	5.7546	1.00	11	33
Switchgrass	-11.700 ± 233.40	-469.164	445.764	0.0000	0.00	1	0
Distance to Nesting Beach***	-0.0019 ± 0.0002	-0.0023	-0.0015				

Significance Codes: < 0.001 '***', 0.001 '**', 0.01 ‘*’, 0.05 ‘.’, 0.10 ‘ ‘

Table 2.16. Model selection results for habitat use vs. availability analysis for skunk winter denning (November 1 – March 31). Models are listed with factors, followed by Akaike information criterion (AIC), degrees of freedom (df), delta AIC (dAIC) and weights.

	AIC	df	dAIC	Weight
M4 Skunk ID + Distance to Nesting Beach	1515.7	8	0	1
M1 Skunk ID	1640.7	7	125	< 0.001
M2 Skunk ID + Distance to Development	1642.3	8	126.6	< 0.001
M3 Skunk ID + Distance to Human Corridor	1642.7	8	127	< 0.001

Figure 2.1. The island of Martha's Vineyard, Massachusetts, in relationship to mainland Massachusetts, with three study areas identified: Dogfish Bar (DB), Long Point (LP), and Norton Point/Wasque (NPW).

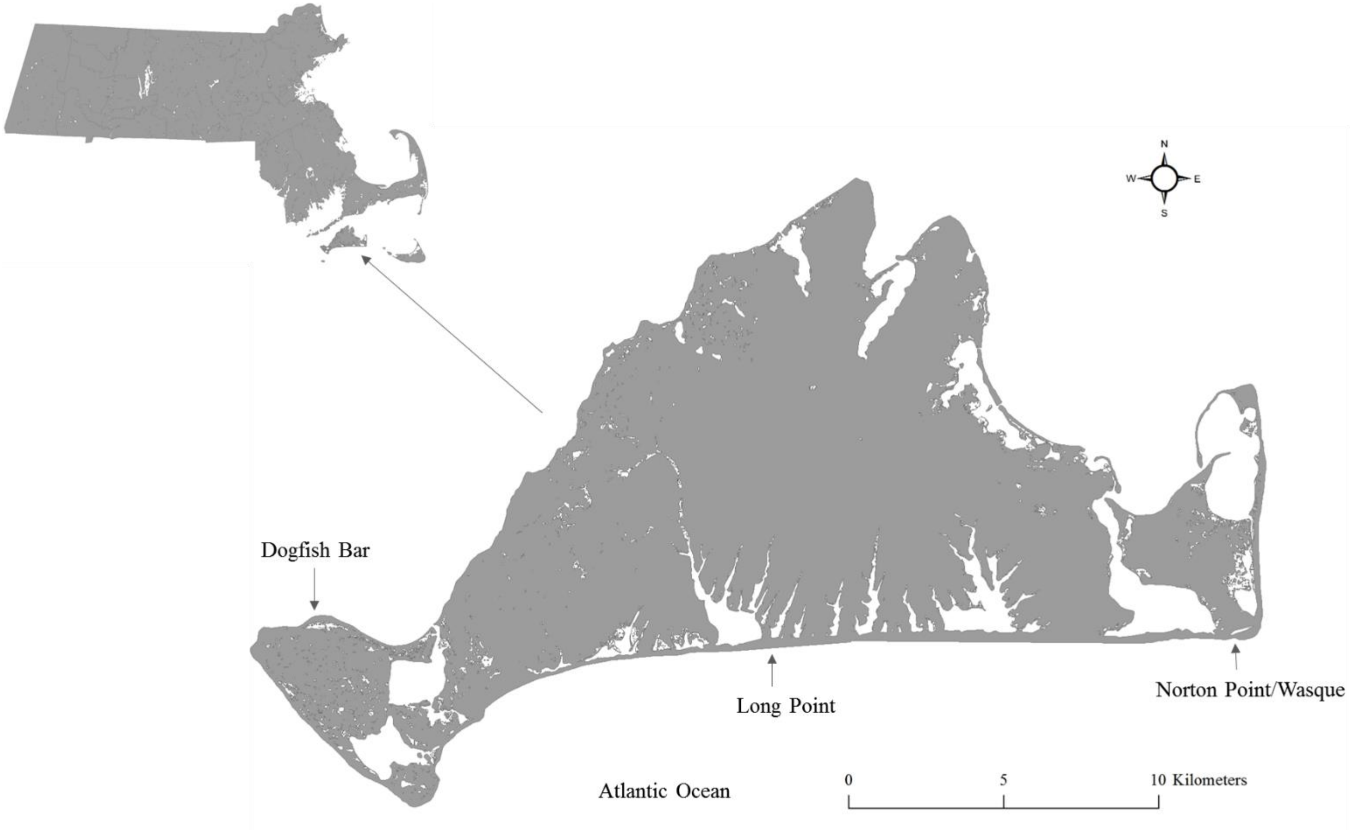


Figure 2.2. Dogfish Bar (DB) site map on Martha’s Vineyard showing cover types and skunk capture area at piping plover nesting beach.

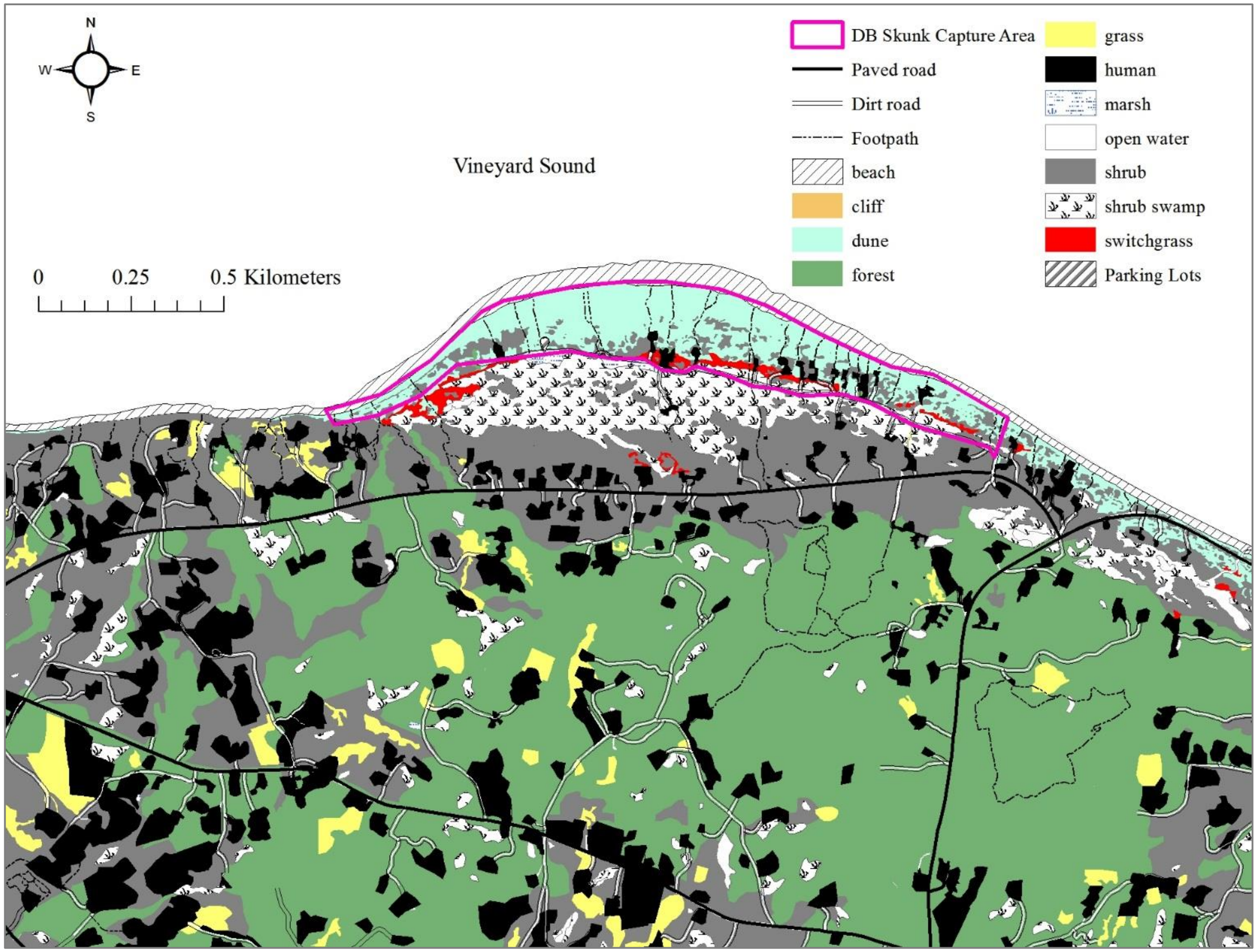


Figure 2.3. Long Point (LP) site map on Martha's Vineyard, showing cover types and skunk capture area near the piping plover nesting beach.

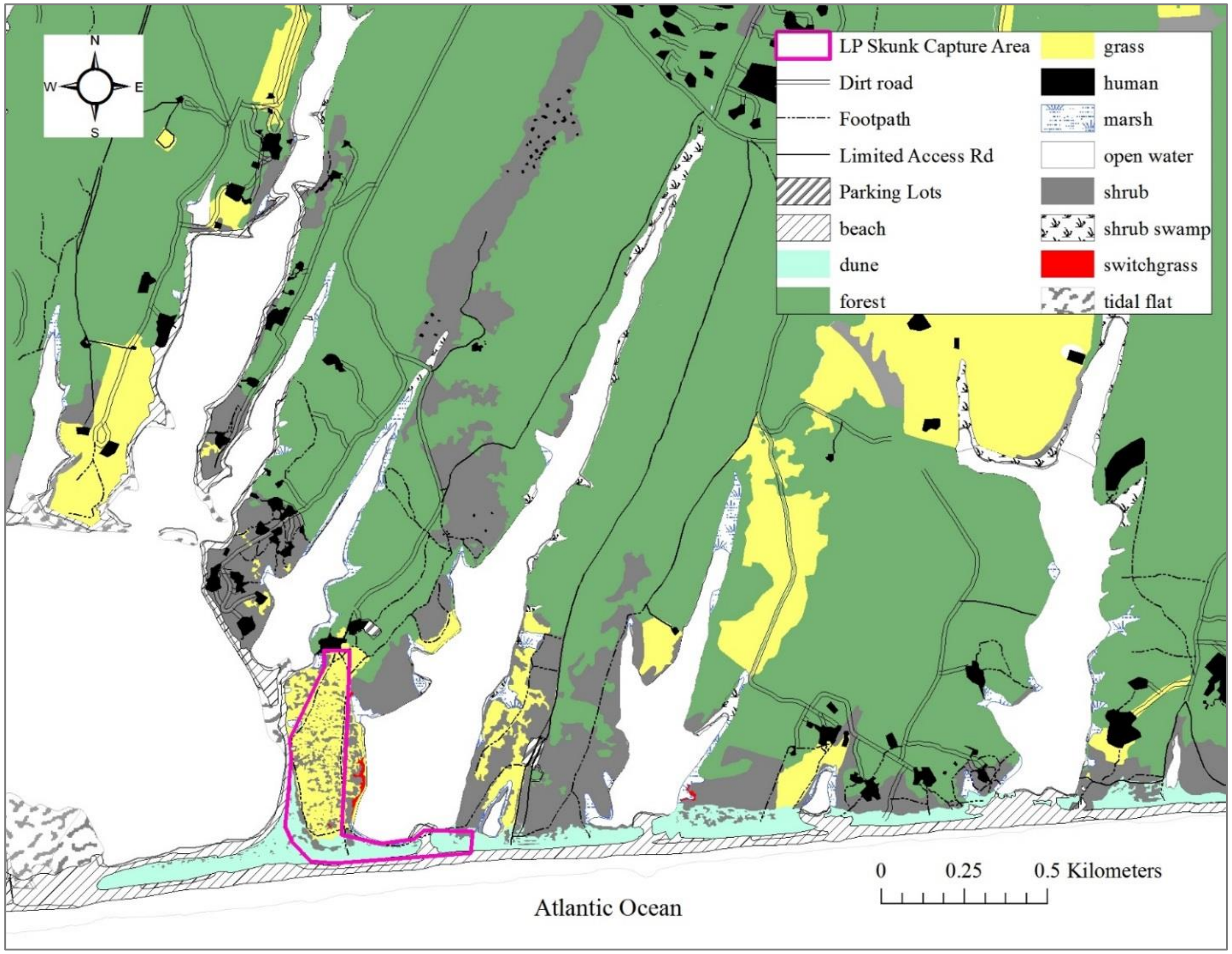


Figure 2.4. Norton Point/Wasque (NPW) site map on Martha's Vineyard, showing cover types and skunk capture areas at and near piping plover nesting beaches.

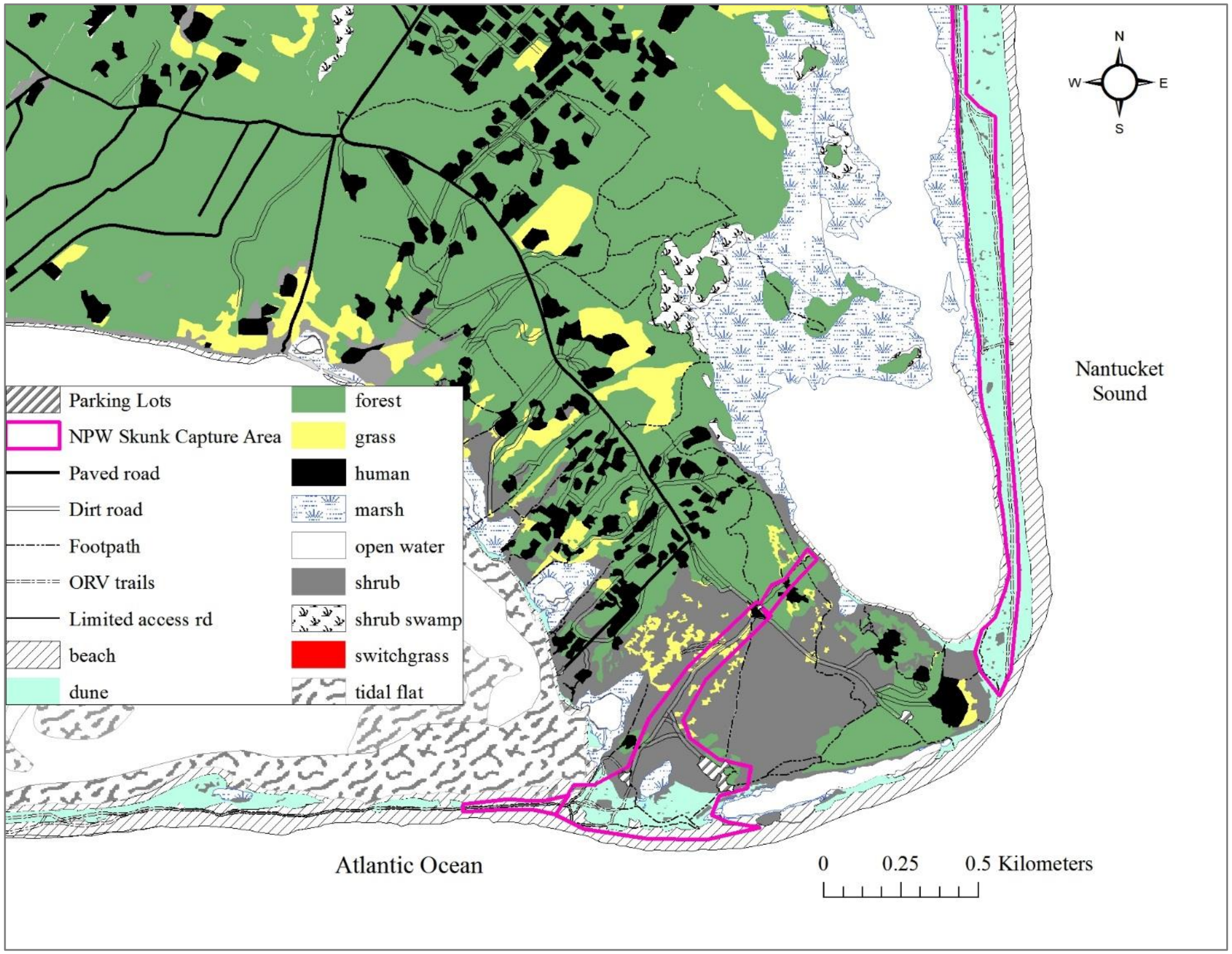


Figure 2.5. The number of VHF telemetry locations for each skunk during the piping plover nesting season, fall and winter on Martha’s Vineyard, MA 2004 – 2008. Nesting season locations for each skunk are shown in grey, fall locations in black and winter locations in white. Skunks are listed by identification number along the x-axis.

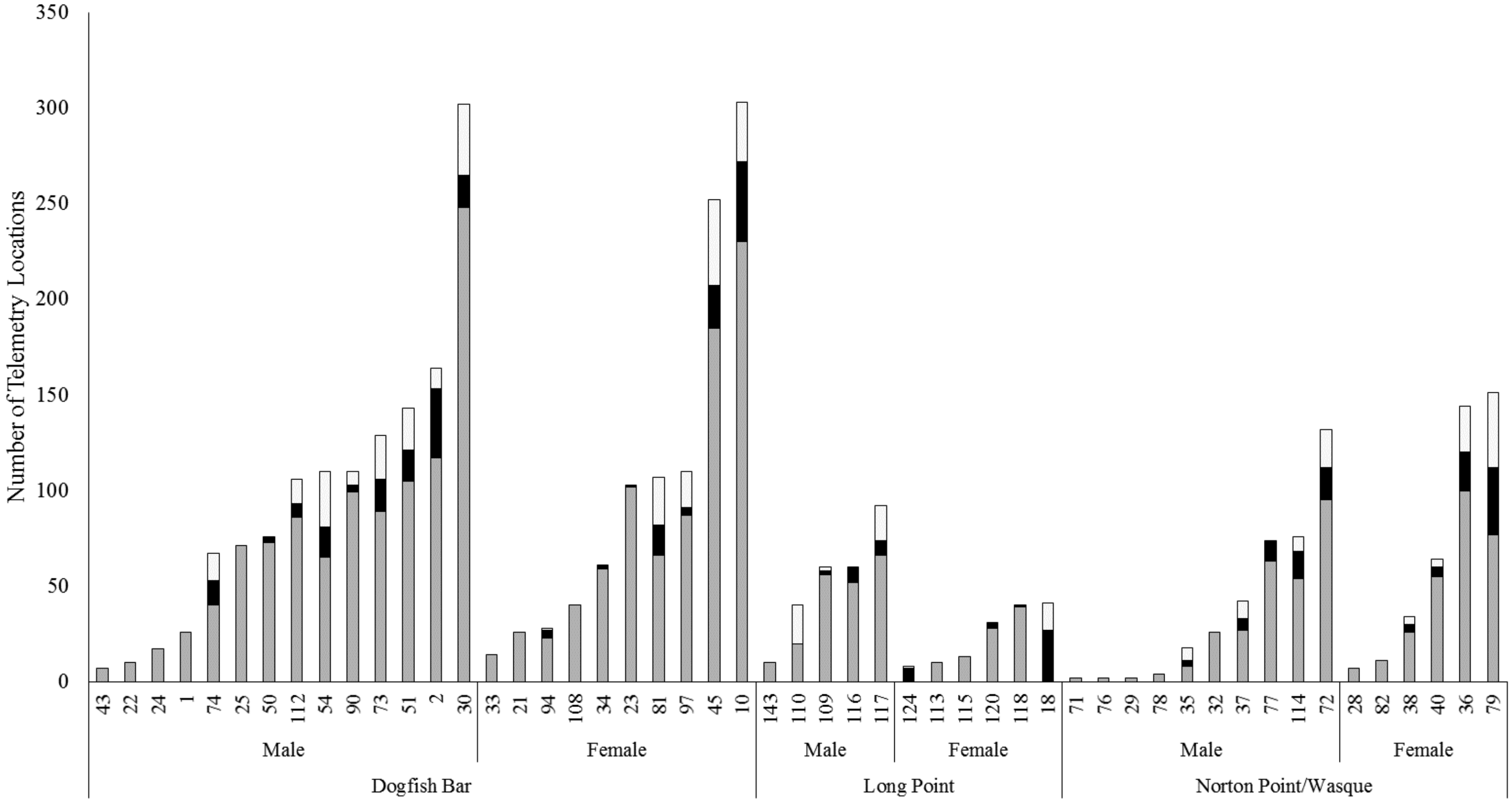


Figure 2.6. The distribution of male and female skunk telemetry locations at Dogfish Bar (DB) August 2004 – May 2008 on Martha's Vineyard, MA. An exploratory movement by a male skunk is circled in yellow in the SW.

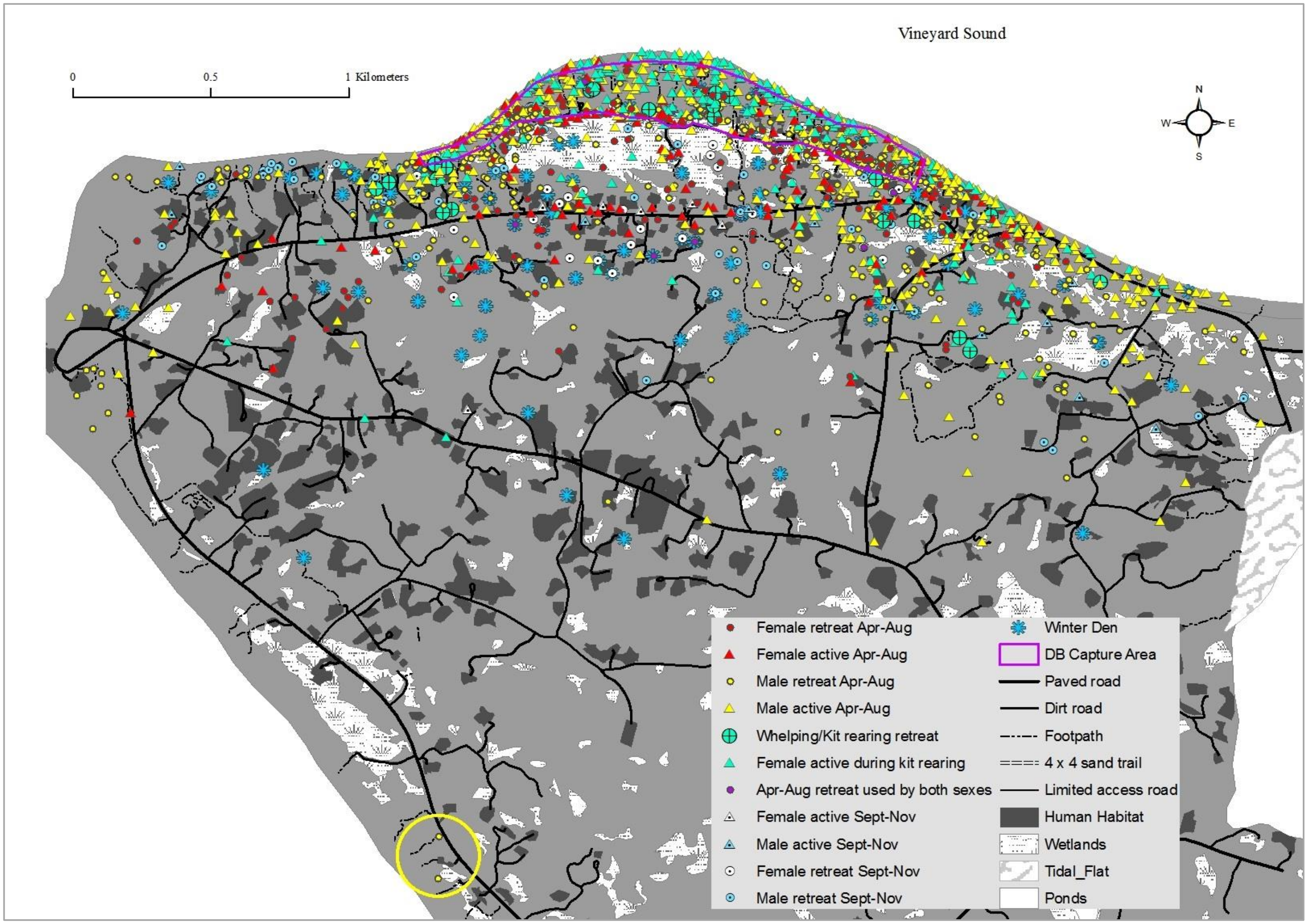


Figure 2.7. The distribution of all male and female skunk telemetry locations at Long Point (LP) September 2004 – June 2008 on Martha’s Vineyard, MA. An exploratory movement by a male skunk is circled in yellow in the NW.

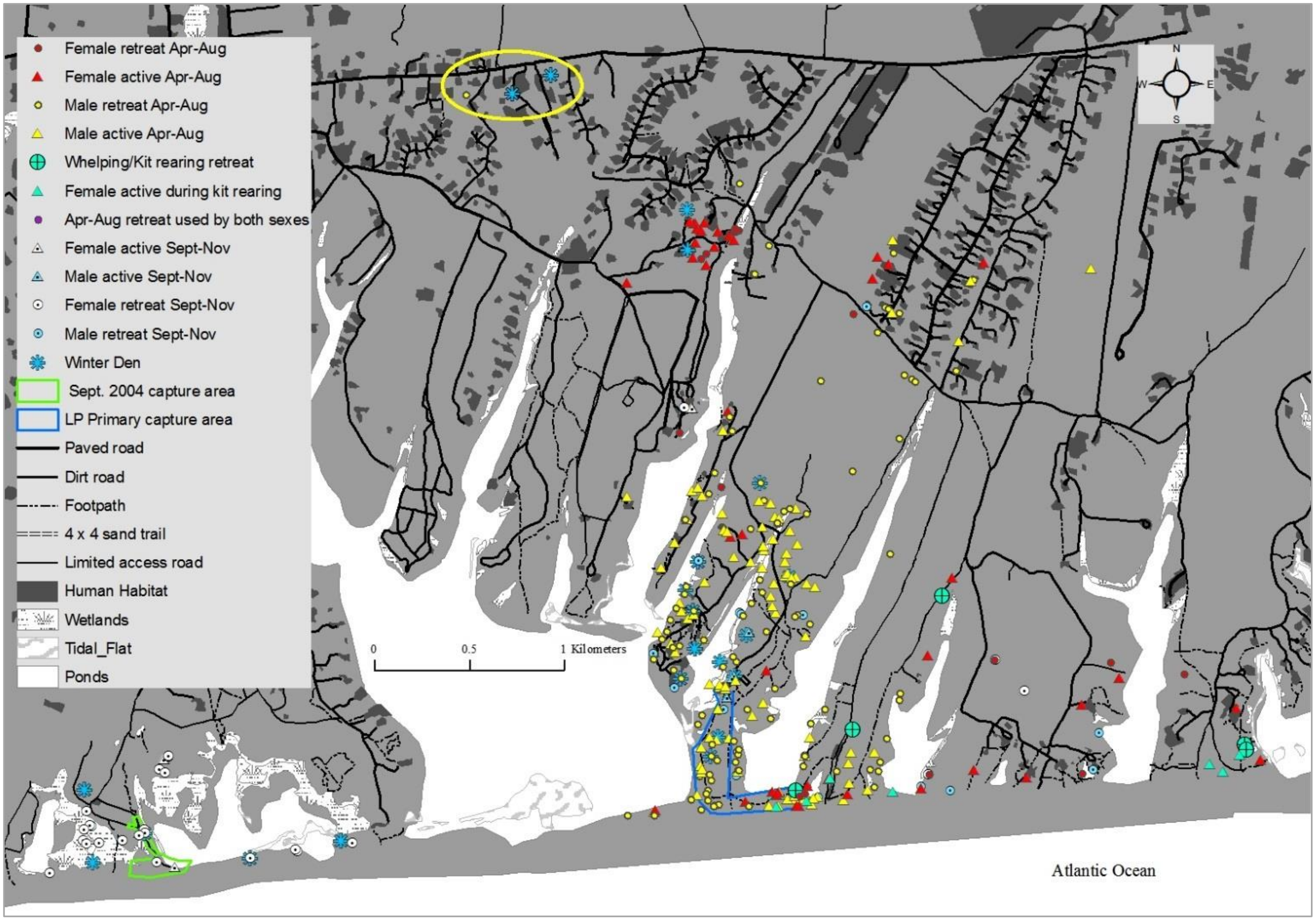


Figure 2.8. The distribution of all male and female skunk telemetry locations at Norton Point/Wasque (NPW) May 2005 – May 2008 on Martha’s Vineyard, MA. A dispersal location from a male skunk is circled in yellow in the NW.

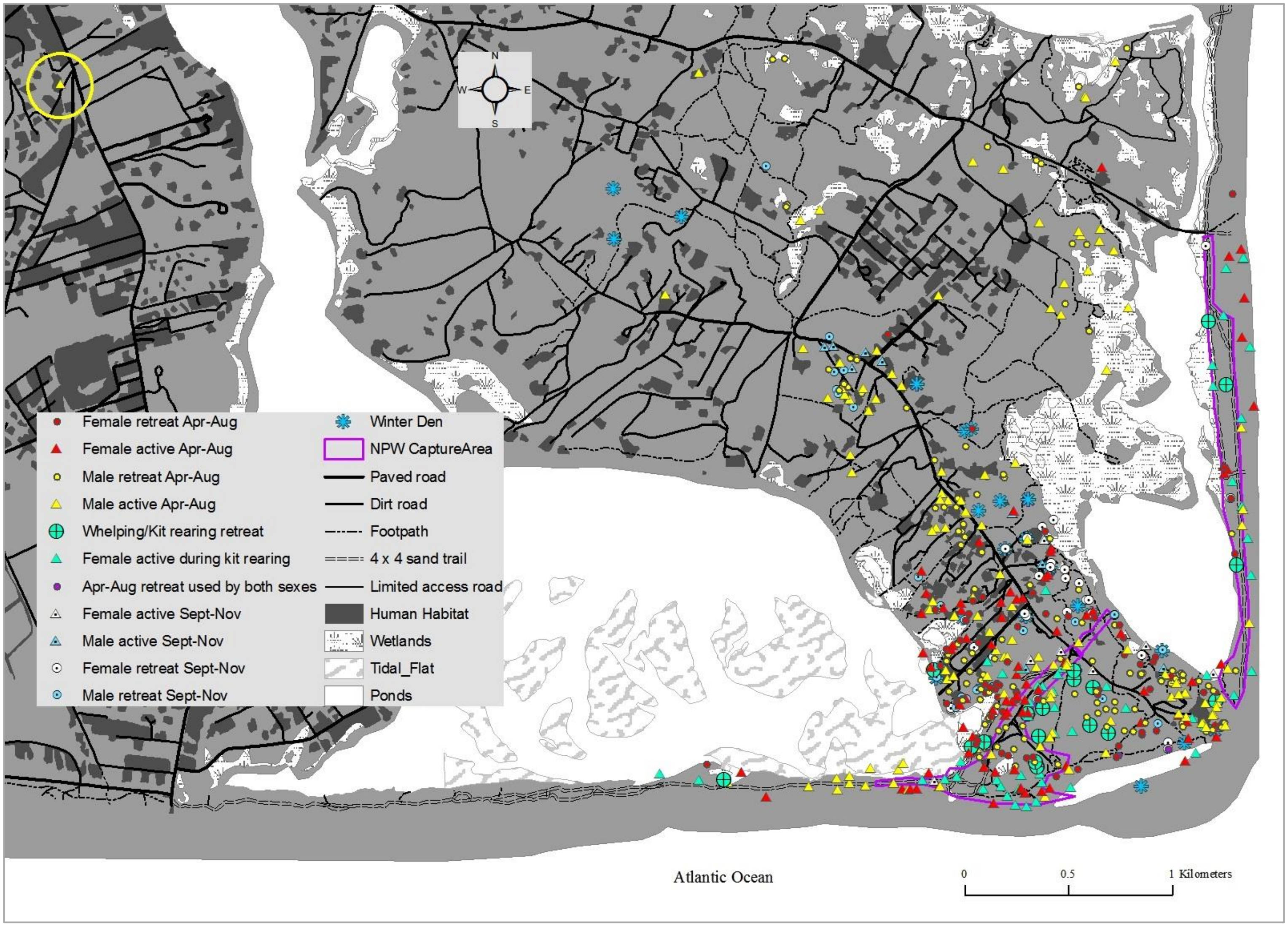
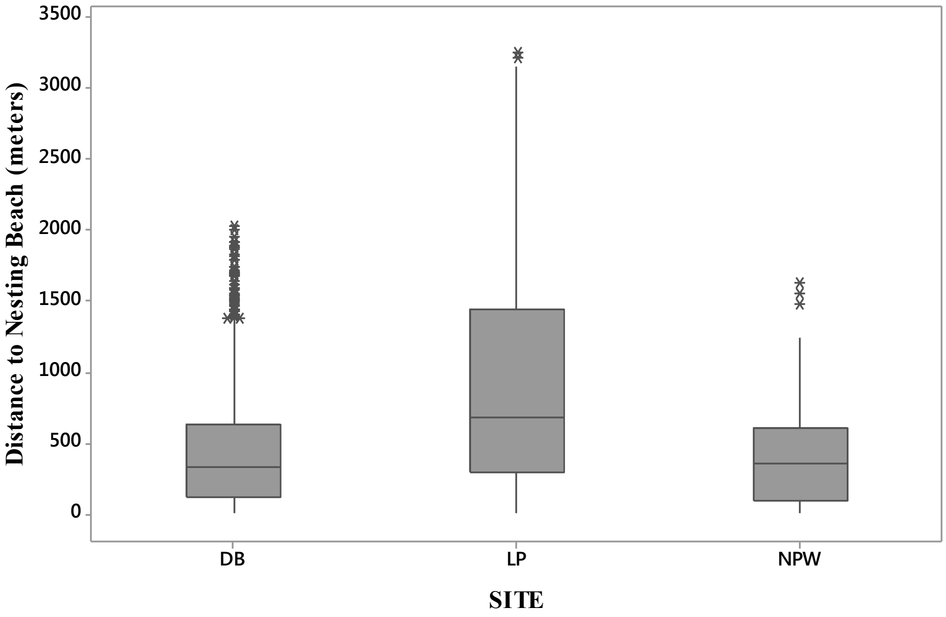


Figure 2.9. Box plots summarizing distance between resident skunk active and resting telemetry locations 2004 – 2008 and nesting beaches at Dogfish Bar (DB, n = 1819), Long Point (LP, n = 355), and Norton Point/Wasque (NPW, n = 528) on Martha's Vineyard, MA. Mood's median test results for differences by site are below the figure.



Mood's median test results showing LP locations were farther from nesting beaches than DB and NPW locations.

Chi-Square = 57.00   DF = 2 $P < 0.001$, Overall median = 367

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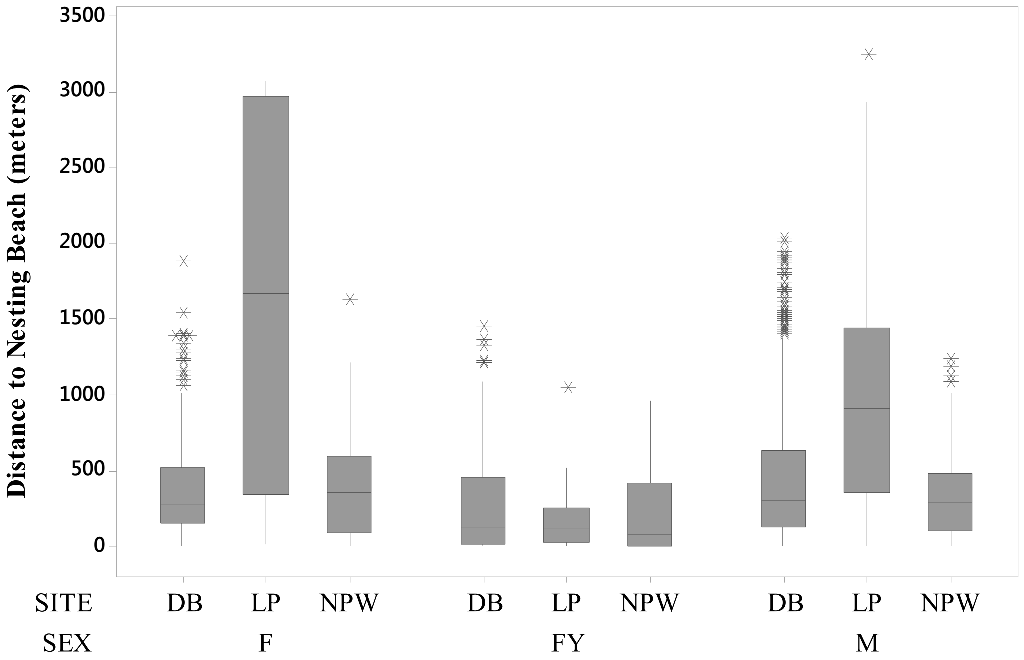
                                       Individual 95.0% CIs
SITE   N≤   N>   Median  Q3-Q1   -+---------+---------+---------+-----
DB     972  847    328     504     (*-)
LP     112  243    675    1152                      (------*-----------)
NPW    267  261    356     511     (-*--)
                                 -+---------+---------+---------+-----
                                320       480       640       800
```

Figure 2.10. Box plots summarizing distance from piping plover nesting beaches to active and resting skunk telemetry locations (n = 2,228) at Dogfish Bar (DB), Long Point, (LP) and Norton Point/Wasque (NPW) April – August, 2004 – 2008 on Martha's Vineyard, MA. F = non-reproductive females, FY = females rearing young, and M = males with Mood's median test results comparing medians for each sex below the figure.

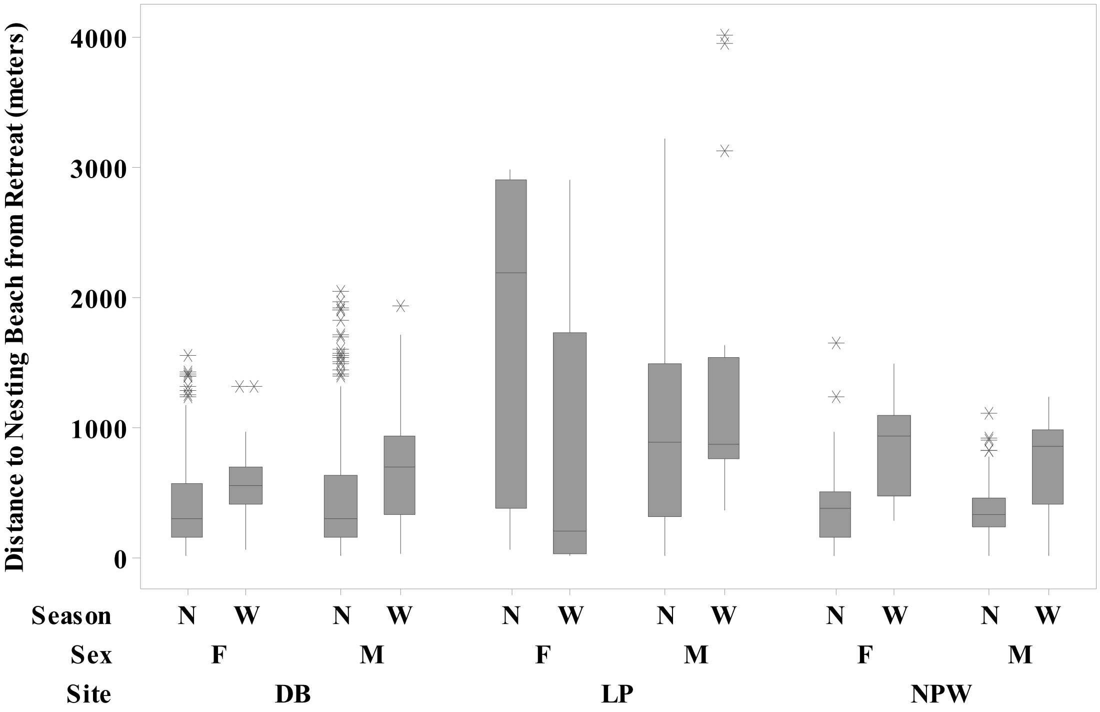


Mood's median test results showing that locations from females with young were closer to nesting beaches than locations from males or females without young.

Chi-Square = 49.25   DF = 2 $P < 0.001$ Overall median = 316

```
                                        Individual 95.0% CIs
SEX   N≤    N>   Median  Q3-Q1   -+---------+---------+---------+-----
F     254   283    334    459                        (---*-----)
FY    246   123    119    431     (--*---)
M     614   708    353    542                            (--*--)
                                 -+---------+---------+---------+-----
                                100       200       300       400
```

Figure 2.11. Box plots summarizing distance to piping plover nesting beaches from skunk retreat locations during the plover nesting (N) and winter denning (W) seasons 2004 - 2008 at Dogfish Bar (DB, N = 570, W = 116), Long Point (LP, N = 124, W = 21), and Norton Point/Wasque (NPW, N = 177, W = 31) on Martha's Vineyard, MA. Results from Mood's median test for difference between seasons for DB and NPW pooled data are below the figure.



Mood's median test results showing skunk winter dens (W) are farther from nesting beaches than retreats during the plover nesting (N) season, using pooled data from DB and NPW.

Chi-Square = 50.81   DF = 1 $P < 0.001$ Overall median = 365

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                                              Individual 95.0% CIs
SEASON  N≤  N>  Median  Q3-Q1  -------+---------+---------+---------
   N    413 334   318    425   (---*)
   W     34 113   680    531                    (-------------*-)
                               -------+---------+---------+---------
                                     360       480       600
```
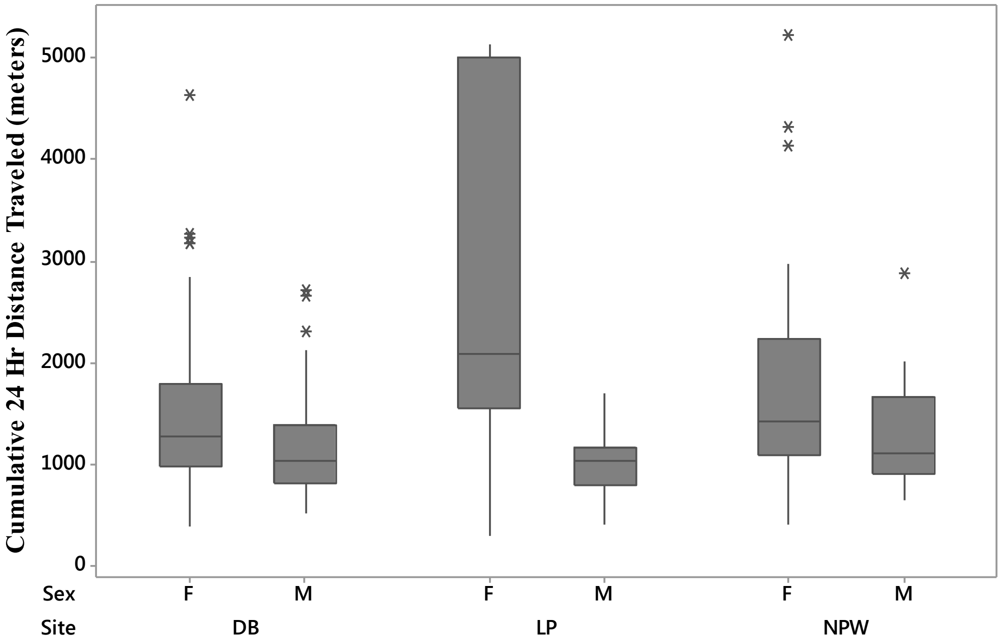

Figure 2.12. Box plots comparing cumulative distances traveled in 24-hours by male (M) and female (F) skunks at Dogfish Bar (DB), Long Point (LP) and Norton Point/Wasque (NPW) during the plover nesting season on Martha's Vineyard, MA 2004 – 2008. Mood's median test results for difference between the sexes are below the figure.



Mood's median test results showing that females traveled farther than males in 24 hours.

Chi-Square = 17.20   DF = 1 $P < 0.001$ Overall median = 1246

```
                                       Individual 95.0% CIs
Sex  N ≤  N >  Median  Q3-Q1   ------+---------+---------+---------+
 F    59   92    1334    922                    (---*--------)
 M    71   38    1060    545   (------*------)
                               ------+---------+---------+---------+
                                   1050      1200      1350      1500
```

Figure 2.13. Percent of active skunk telemetry locations (n = 646) in beach, primary dune, backdune, and inland habitats during the piping plover nesting season 2004 – 2008 at Dogfish Bar (DB), Long Point (LP), and Norton Point/Wasque (NPW) on Martha's Vineyard, MA.

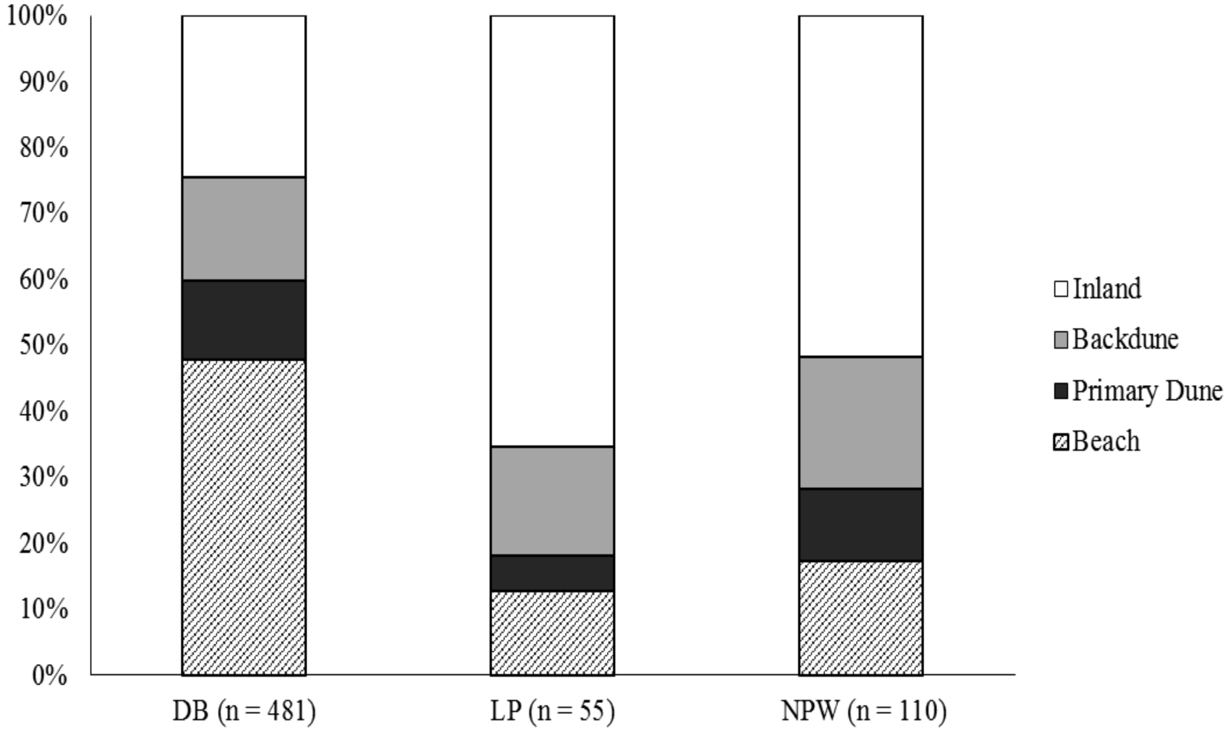


Figure 2.14. The percent of skunk foraging observations (n = 253) in habitats shared with piping plovers during the nesting season 2004 – 2008 at Dogfish Bar (DB), Long Point (LP), and Norton Point/Wasque (NPW) on Martha’s Vineyard, MA.

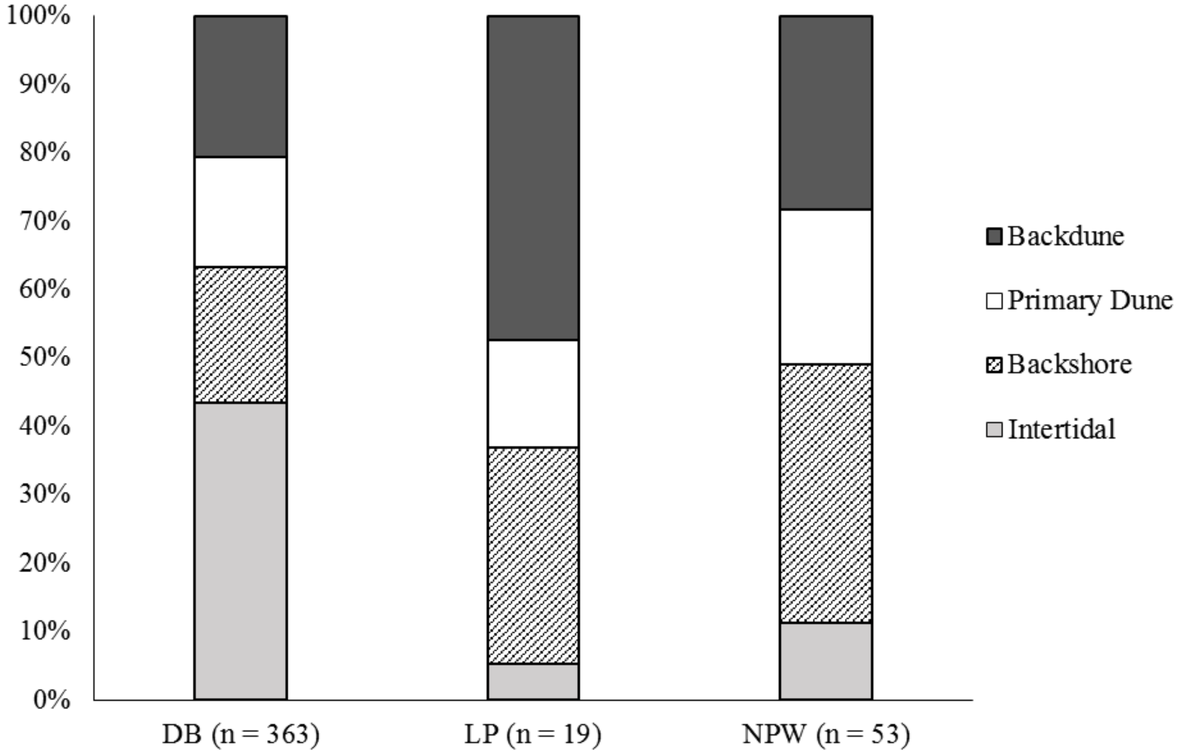


Figure 2.15. The percent of each type of winter den (n=129) used by 14 male and 11 female striped skunks between November 1 and March 31, 2004 – 2008 on the island of Martha's Vineyard.

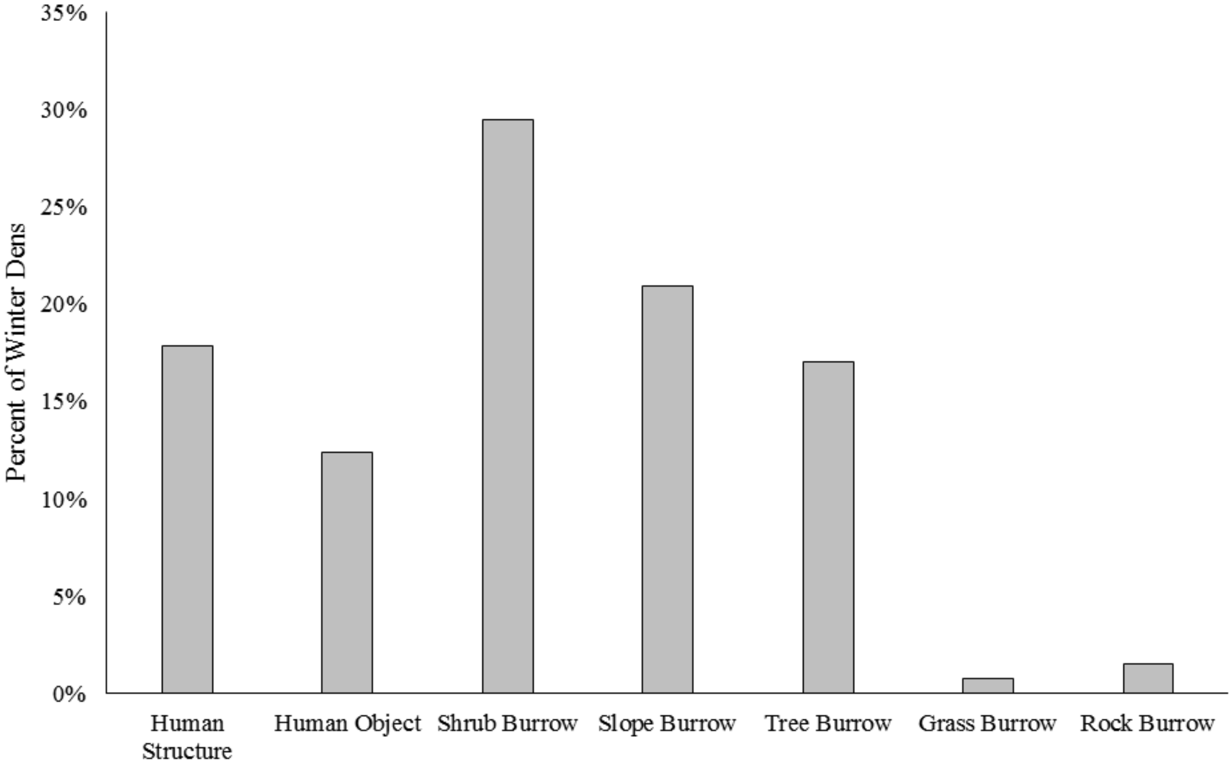


Figure 2.16. The DB study site showing skunk daytime retreats (yellow) and random points (pink) used for resource selection analysis during the plover nesting season within the estimated area of available habitat from resident skunk locations in all seasons.

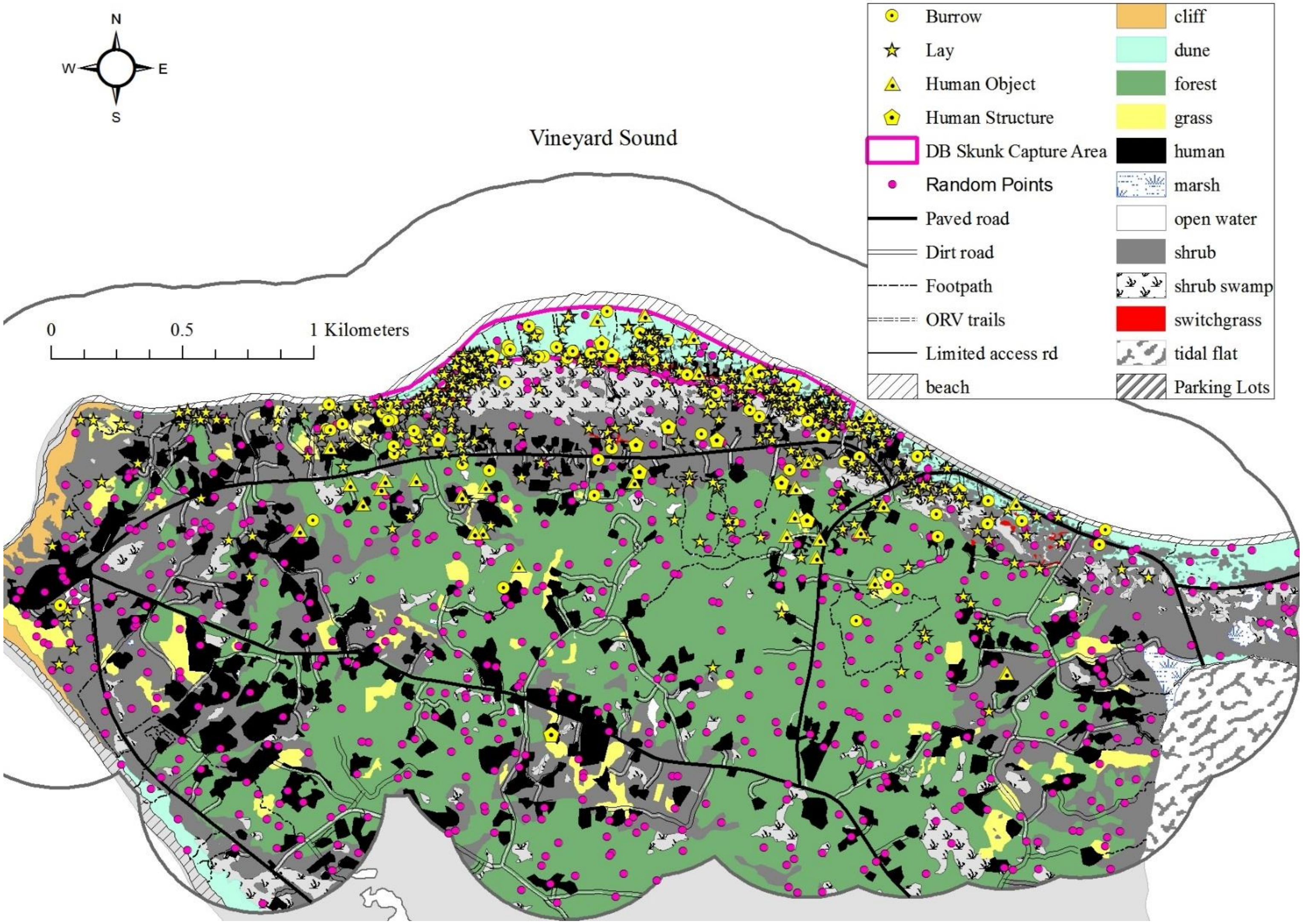


Figure 2.17. The LP study site showing skunk daytime retreats (yellow) and random points (pink) used for resource selection analysis during the plover nesting season within the estimated area of available habitat from resident skunk locations in all seasons.

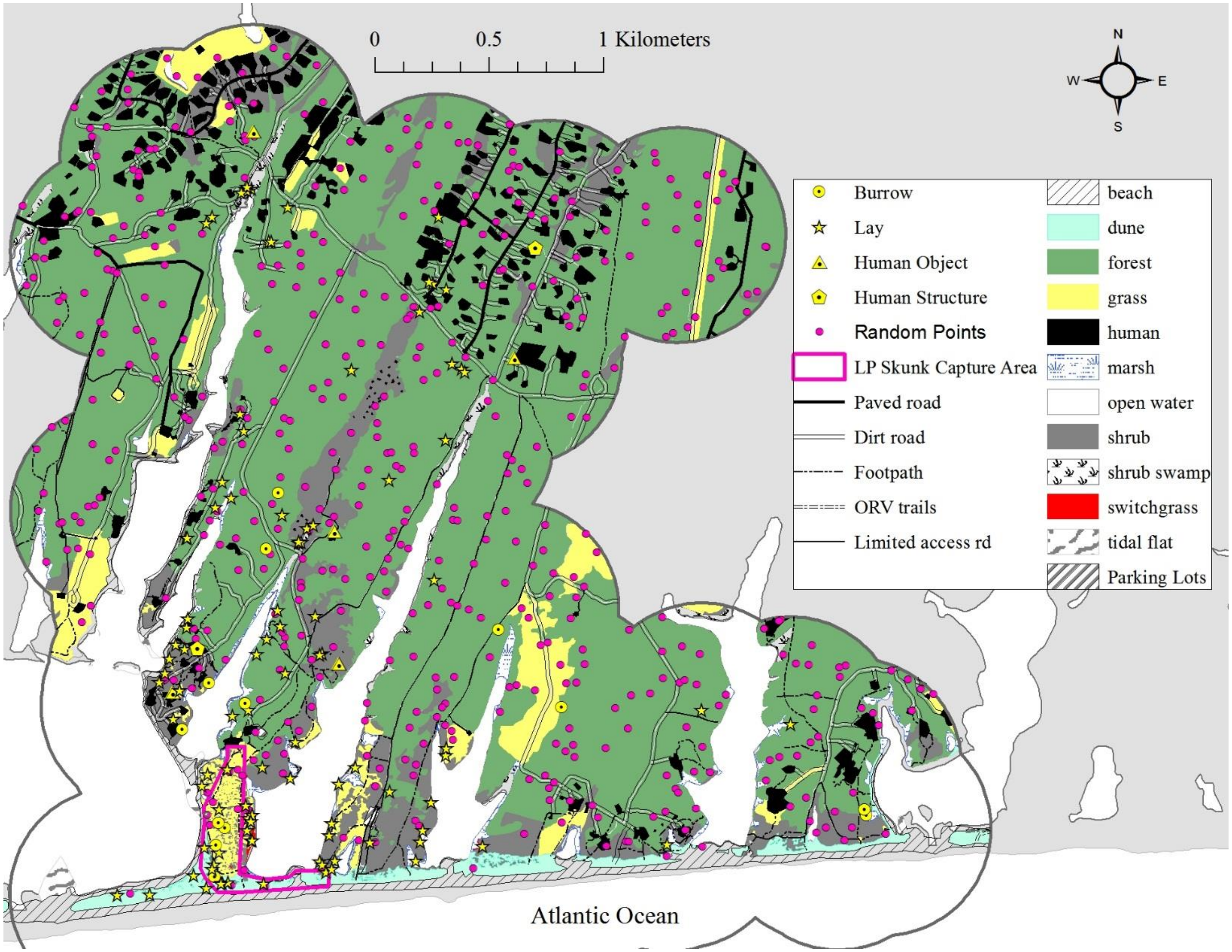


Figure 2.18. The NPW study site showing skunk daytime retreats (yellow) and random points (pink) used for resource selection analysis during the plover nesting season within the estimated area of available habitat from resident skunk locations in all seasons.

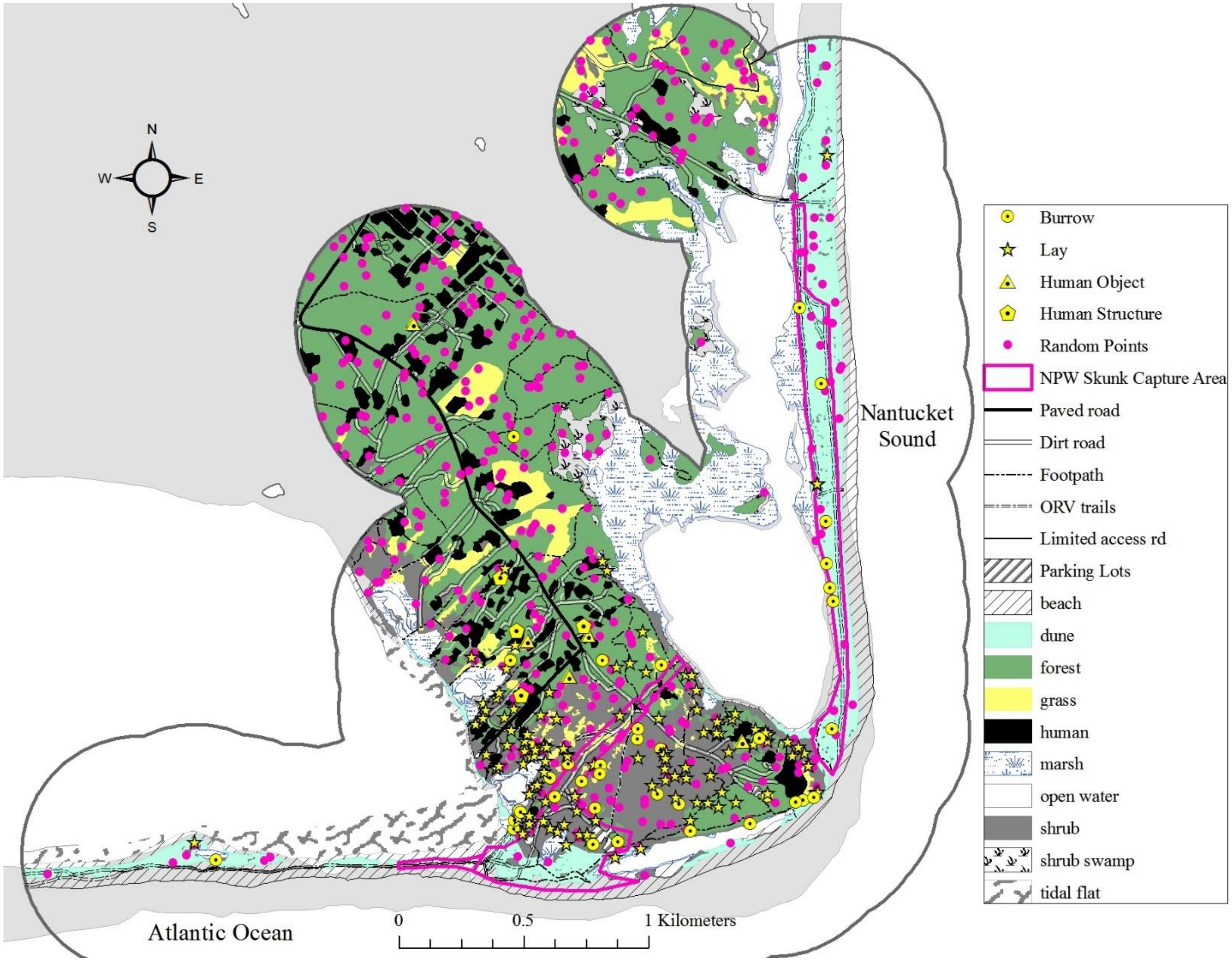


Figure 2.19. The DB study site showing the available habitat area, skunk winter dens (blue) and random points (pink) used for resource selection analysis within the estimated area of available habitat from resident skunk locations in all seasons.

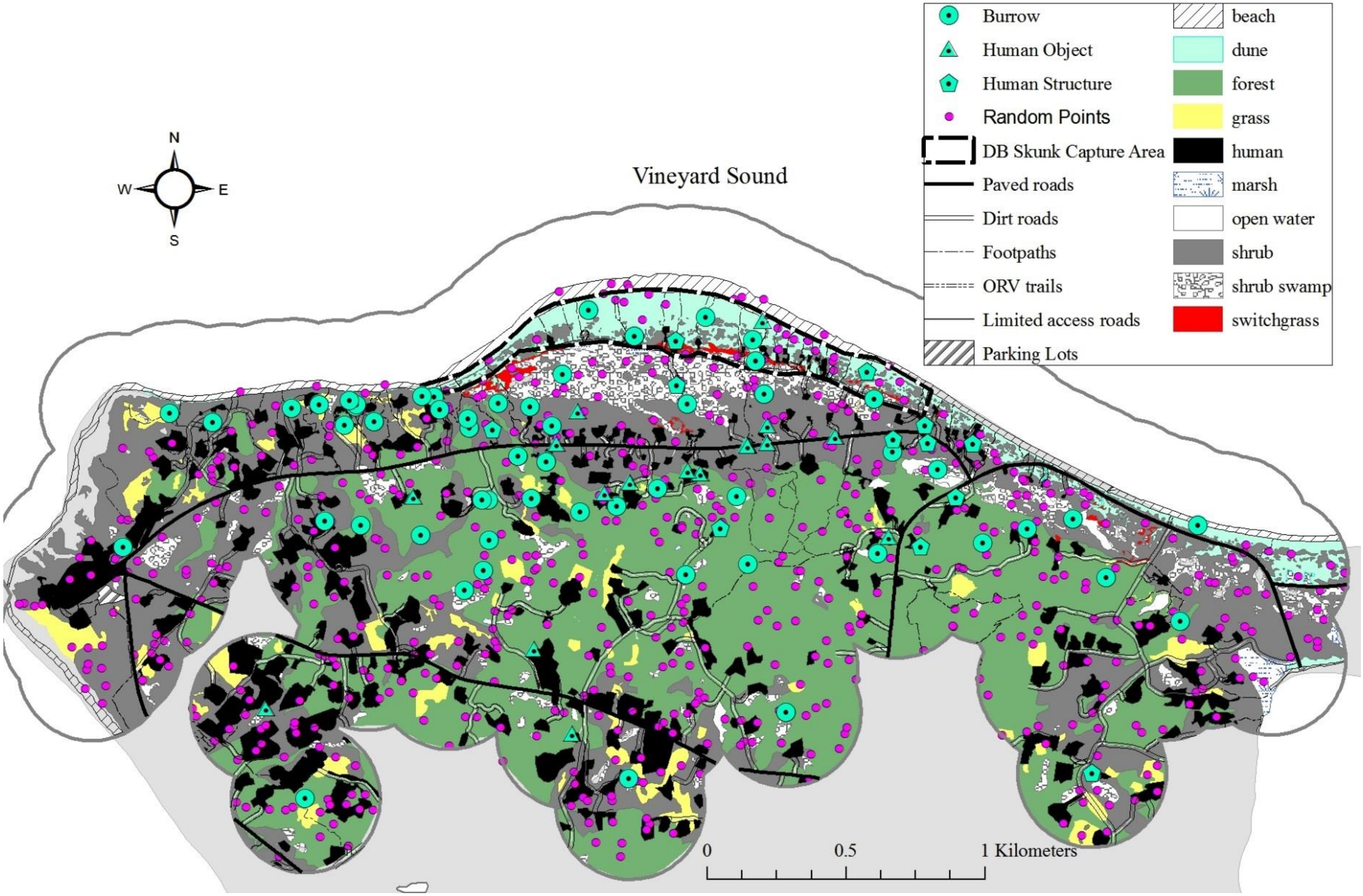


Figure 2.20. The LP study site showing skunk winter dens (blue) and random points (pink) used for resource selection analysis during the winter denning season within the estimated area of available habitat from resident skunk locations in all seasons.

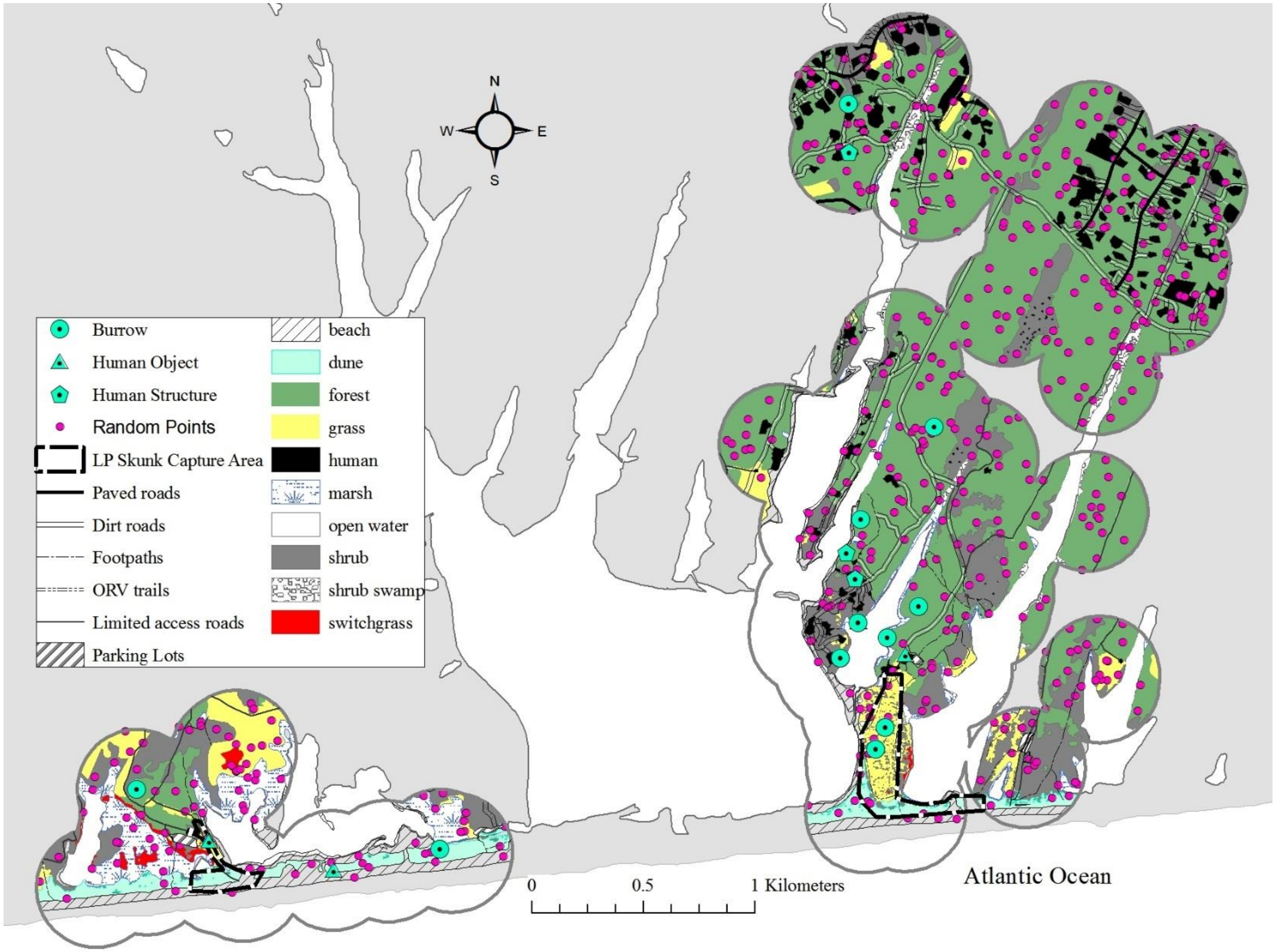


Figure 2.21. The NPW study site showing skunk winter dens (blue) and random points (pink) used for resource selection analysis during the winter denning season within the estimated area of available habitat from resident skunk locations in all seasons.