



Bat Inventory of Assateague Island National Seashore

Natural Resource Technical Report NPS/NCBN/NRTR—2010/284



ON THE COVER

Eastern red bat (*Lasiurus borealis*)

Photograph by: Joshua B. Johnson

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Abstract

As significant nocturnal insectivores, bats are an integral part of many ecosystems. Determining bat species composition in an area is a critical first step in managing for this important resource. Little information exists concerning the bat species composition of Maryland's Coastal Plain, which is located on the northern periphery of the geographic ranges of some bat species occurring in the southeastern United States. We conducted mist net surveys for bats at Assateague Island National Seashore, a barrier island on Maryland's coast, in summer 2005, and summer and autumn 2006. In 2005, we captured 133 bats representing 3 species, including 2 big brown bats (*Eptesicus fuscus*), 129 eastern red bats (*Lasiurus borealis*), and 2 alleged Seminole bats (*Lasiurus seminolus*). In 2006, we captured a total of 60 eastern red bats in summer and autumn. We used long-term acoustic monitoring to document 3 additional bat species, including silver-haired bats (*Lasionycteris noctivagans*), hoary bats (*Lasiurus cinereus*), and eastern pipistrelles (*Pipistrellus subflavus*). We documented silver-haired bats during spring and autumn, probably as they were migrating through the area. Eastern red bats, and possibly hoary bats and big brown bats over winter at ASIS. Bat activity was inconsistently predicted by weather conditions depending on season. We used Anabat II bat detectors to monitor bat activity at 5 habitats or cover types during summer 2005 and 2006 and found that activity was higher in forests and at freshwater pools than at bayside marshes, dune/shrub zones, and beach areas. Low species diversity at Assateague Island National Seashore likely is attributable to long distances to hibernacula and low roost diversity, as forests are almost entirely comprised of loblolly pine (*Pinus taeda*).

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Project Highlights

Eastern red bats (*Lasiurus borealis*) are the dominant bat species at Assateague Island National Seashore (ASIS). We positively identified 4 other bat species, including, in decreasing order of frequency, big brown bats (*Eptesicus fuscus*), hoary bats (*L. cinereus*), eastern pipistrelles (*Pipistrellus subflavus*), and silver-haired bats (*Lasionycteris noctivagans*). We captured 2 bats that we identified in the field as Seminole bats (*Lasiurus seminolus*), which would be the first records of this species in Maryland. However, based on our photographic evidence and morphological measurements, wildlife professionals were divided in their identification of this species, with some speculating that both bats could have been dark-morph red bats. Without confirmation by genetic analysis, our captures of Seminole bats remain debatable. All other species inventoried at ASIS are considered common throughout their ranges.

Some bat species migrate through ASIS, and others, including eastern red bats and big brown bats, produce and raise offspring during the summer months at ASIS. Inventories of bat species were most successfully accomplished by long-term monitoring with bat detectors. Bat activity was inconsistently predicted by weather conditions depending on season. Bats were most active from April–December. There was more bat activity in the loblolly forests and at freshwater pools than at bayside marshes, shrub/dune zones, and beaches during summer. We found no evidence of bats roosting in abandoned structures that we examined on the island. Bats use ASIS in a variety of ways, including as a place to produce and raise offspring during summer, a stopover site during spring and autumn migration, and some bats over winter at ASIS.

Low bat species richness and diversity at ASIS likely is a result of low roost diversity, i.e., the loblolly pine (*Pinus taeda*) monoculture, and long distances to hibernacula west of the Blue Ridge physiographic province.

Introduction

Much recent attention has focused on the conservation and management of bats because of their roles in ecosystems and as possible indicator species (Fenton 2003, Miller et al. 2003). Bats are a very beneficial component of ecosystems in the eastern United States in that they consume a wide variety of insects including harmful forest and crop pests (Griffith and Gates 1985). Bat population declines, real or perceived, have been attributed to a variety of human actions including hibernacula and maternity roost disturbance, and environmental degradation, from contaminants and land use change (Pierson 1998, Fenton 2003, O'Shea et al. 2003). In the United States, 45 bat species representing 4 families and 19 genera occur. Of these, 6 are either endangered species or subspecies and 20 are considered species of special concern (Harvey et al. 1999).

To implement informed management decisions regarding bat conservation, collecting baseline inventory data is an important and necessary initial undertaking. Although a general assessment of bat species composition for a given area can be determined by examining geographic ranges, verifying the presence and relative frequency of species through an inventory process facilitates more informed and accurate management decisions. Moreover, baseline inventories may be especially useful in areas located on peripheries of geographic ranges. For example, the few bat surveys that have occurred on Maryland's Coastal Plain suggest that the bat community there is similar to that of the southeastern United States (Harvey et al. 1999, Limpert 2003). Some bat species, including northern yellow bats (*Lasiurus intermedius*) and Seminole bats (*Lasiurus seminolus*), have geographic ranges with northern limits extending into Virginia, and few extralimital records in Pennsylvania, New Jersey, and New York (Poole 1932, 1949, Layne 1955, Koopman 1965). To positively identify the occurrence of these peripheral species requires the completion of bat inventories.

The distribution of bats and species composition in a region is positively associated with an increase in roost diversity (Humphrey 1975). Maryland has diverse geology and flora, from the northern hardwoods forest association on the Appalachian Plateau physiographic province in the west, to the loblolly pine (*Pinus taeda*)-dominated forests of the Coastal Plain in the east (Schmidt 1993). Bat species composition may be dissimilar in different areas of Maryland depending on forest associations or distance to hibernacula (Gates and Johnson 2005). Also, species composition may vary seasonally as bats migrate through an area (Cryan 2003). Ten bat species have been documented in Maryland, including big brown bats (*Eptesicus fuscus*), silver-haired bats (*Lasionycteris noctivagans*), eastern red bats (*Lasiurus borealis*), hoary bats (*Lasiurus cinereus*), eastern small-footed myotis (*Myotis leibii*), little brown myotis (*Myotis lucifugus*), northern myotis (*Myotis septentrionalis*), Indiana myotis (*Myotis sodalis*), evening bats (*Nycticeius humeralis*), and eastern pipistrelles (*Pipistrellus subflavus*) (Paradiso 1969, Appendix I). Myotine bats (e.g., northern myotis, little brown myotis) are commonly associated with the karst areas of the Blue Ridge, Ridge and Valley, and Appalachian Plateau physiographic provinces in Maryland (Paradiso 1969, Franz and Slifer 1976, Gates et al. 1984, Gates and Johnson 2005). Hoary bats and silver-haired bats probably occur throughout Maryland, but almost certainly occur more frequently during spring and autumn migration, with relatively few occurring in summer (Paradiso 1969, Cryan 2003). Eastern red bats, big brown bats, and eastern pipistrelles are considered common throughout Maryland in summer (Paradiso 1969, Gates and Johnson 2005). Evening bats have been documented only in Maryland's Piedmont and Coastal

Plain (Paradiso 1969, Limpert 2003). Bat species composition and other aspects of bat ecology on Maryland's barrier islands remain largely unclear.

Bat species distribution in a region may be dictated in part by roost diversity, and a general appraisal of bat species composition for a given area can be determined by examining geographic ranges. At a smaller scale, foraging habitat structure and water availability may influence bat species distribution, composition, and foraging activity (Ghert and Chelsvig 2004, Owen et al. 2004, Ford et al. 2005). Typically, there is higher bat activity and bat species richness at water sources and in riparian areas than in upland forests (Owen et al. 2004, Ford et al. 2005). The structure of foraging habitat, i.e., forest or vegetative spatial complexity, partially dictates species-specific activity (Ford et al. 2005, Menzel et al. 2005). Small-bodied bats (e.g., northern myotis, eastern small-footed myotis, and Indiana myotis) that emit a high-frequency echolocation call typically forage in the forest interior, or structurally cluttered habitats (Ratcliffe and Dawson 2003, Ford et al. 2005). Little brown myotis and eastern pipistrelles are small-bodied bats that emit high-frequency echolocation calls, but are less specialized in their foraging behavior, exploiting cluttered and open areas (Fujita and Kunz 1984, Ratcliffe and Dawson 2003, Ford et al. 2005). Larger-bodied bats (big brown bats and hoary bats) that emit low frequency echolocation calls typically forage in open areas, including large water bodies, riparian areas, and fields (Barclay 1986, Ford et al. 2005). Medium-bodied bats (e.g., silver-haired bats, eastern red bats, and evening bats) that emit medium frequency echolocation calls are able to forage in forested and open areas (Menzel et al. 2005, Ford et al. 2005). These generalizations can be useful in predicting bat activity and habitat use in areas where knowledge of bat species composition in an area is limited (Ford et al. 2005).

Different bat species not only have different foraging strategies, but their roosting strategies are sometimes different also. During summer, most bat species are sexually segregated; males and females typically roost separately. However, they may forage in the same areas (Barbour and Davis 1969). The females of some species form maternity colonies and other species roost singly. Males of most species roost singly or in small bachelor groups. Bats roost in caves, mines, tunnels, buildings, bridges, hollow trees, tree foliage, and under leaf litter and exfoliating tree bark (Barbour and Davis 1969, Appendix II).

In spring, bats leave their hibernacula or winter ranges and migrate to their summer ranges, although some may occupy the same area year round. Some bat species in the mid-Atlantic region migrate hundreds of kilometers between summer roosts and winter hibernacula. Females produce and raise 1 litter of offspring during summer. Most bat species in the region mate in autumn. Delayed fertilization allows females to postpone pregnancy until the following spring (Barbour and Davis 1969, Harvey et al. 1999).

Many bat species that are of special concern, threatened, or endangered occur on federal lands, including those administered by the National Park Service (NPS) (Johnson et al. 2005, 2006, Johnson and Gates 2007). National Park Service lands can serve as contiguous tracts of protected land in otherwise fragmented landscapes (Gates and Johnson 2005). Therefore, identifying sensitive species in parks not only facilitates informed management of species within the park, but further supports conservation efforts on a landscape and geographic scale. A paucity of information exists concerning bat communities at Assateague Island National Seashore (ASIS), a barrier island on Maryland's coast. Only incidental captures of bats during saw-whet owl

(*Aegolius acadicus*) surveys contribute to our knowledge of bat species composition at ASIS (D. Brinker, Maryland Department of Natural Resources, personal communication). Our objectives were to inventory bat species at ASIS, identify unique habitats, examine species distributions, estimate relative frequencies of species, and examine seasonal activity fluxes.

Study Area

We conducted bat inventories at the National Park Service-administered portion of Assateague Island National Seashore (ASIS), located on Assateague Island, Worcester County, Maryland (Figure 1). Assateague Island is a barrier island, 0.4–4.0 km wide and 59.6 km long, extending from the inlet at Ocean City, Maryland, to Chincoteague, Virginia. The terrestrial portion of ASIS lies mostly in Maryland, and comprises the northern 35.4 linear km of the island. Chincoteague National Wildlife Refuge, which lies mostly in Virginia, comprises the southern 24.2 linear km. Sinepuxent Bay and Chincoteague Bay are situated between ASIS and the mainland. These saltwater bays range in width from <1 km at the northern terminus of ASIS, to about 8 km near the southern terminus (Maryland-Virginia state line).

ASIS includes >3,600 ha of beaches, dunes, shrub lands, forests, marshes, and freshwater pools. The northern 8 km of ASIS is sparsely vegetated, consisting mostly of cordgrass (*Spartina* spp.) and shrubs (*Myrica* spp.). Bayside marsh vegetation consists largely of cordgrass. Forests are patchily distributed on the southern two-thirds of the island's western side and are comprised almost entirely of mature loblolly pine. Red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and wild black cherry (*Prunus serotina*) occur sporadically as canopy intermediates. The shrub layer beneath the forest canopy exists as dense, intermittent patches of waxmyrtle (*Myrica cerifera*), bayberry (*Myrica pensylvanica*), and groundsel-tree (*Baccharis halimifolia*). In many cases, the forest tracts were juxtaposed to bayside marshes with little or no vegetative transition, which, when present, consisted mostly of shrubs (e.g., waxmyrtle). The shrub lands exist as a transition between the forest zone and beach zone and are a mosaic of stunted loblolly pine, rushes (*Juncus* spp.), woolly beachheather (*Hudsonia tomentosa*), and shrubs scattered among the dunes (Higgins et al. 1971). Freshwater pools (<6 ha) occur throughout the island, but are mostly concentrated in shrub lands and forests. Approximately 75 pools exist at ASIS and many are ephemeral. ASIS has a mean annual precipitation of 112.6 cm, mean summer (June – August) temperature of 23.2° C, and mean winter (December – February) temperature of 3.6° C (NOAA 2004).

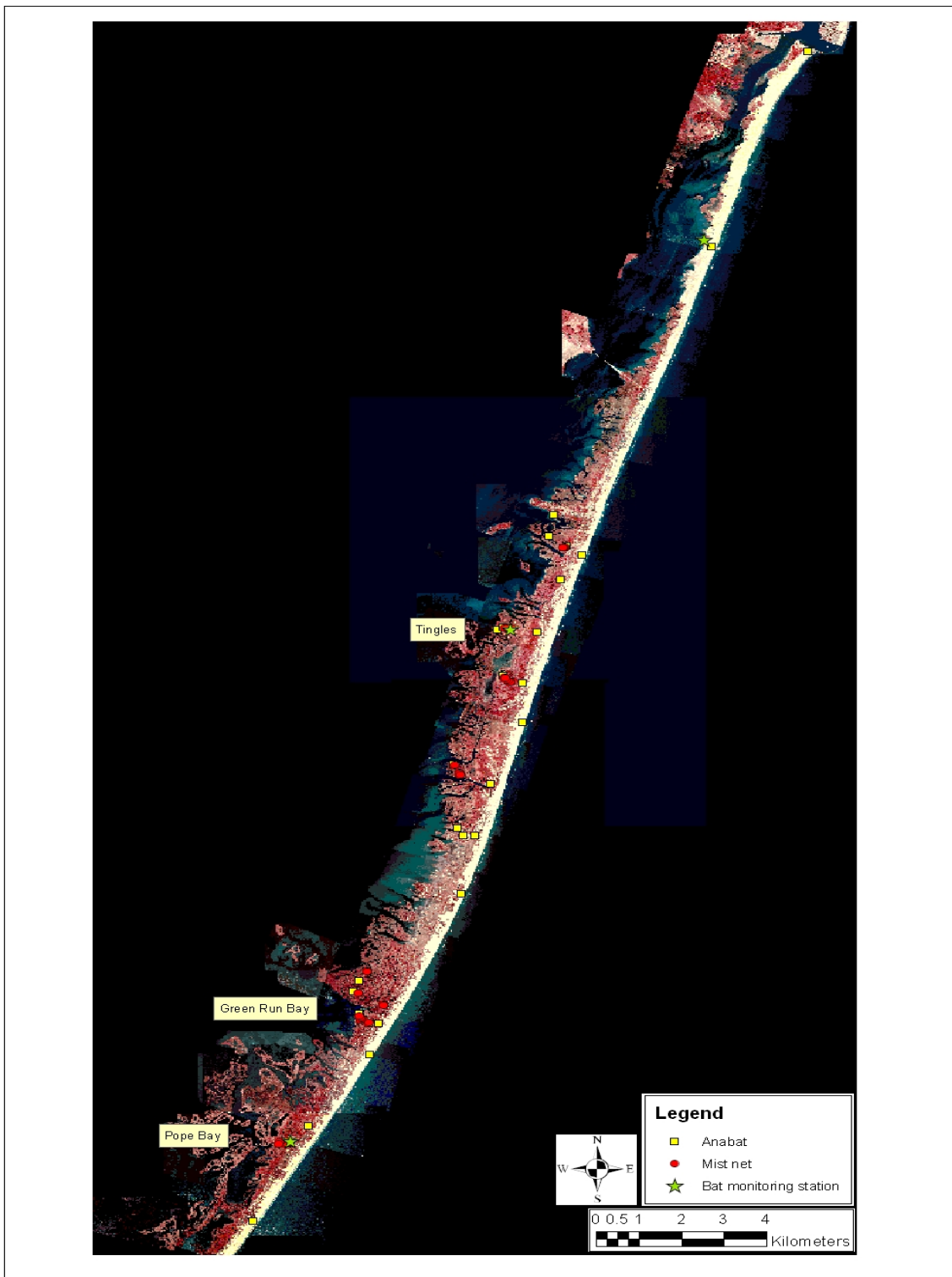


Figure 1. Bat inventory locations at Assateague Island National Seashore, 2005–2006.

Methods

To inventory the bat community at ASIS, we used mist nets, a combination of active and passive acoustic monitoring, and visual observations.

Mist Netting

To capture bats, we used 50-denier, 2-ply, 38 mm-mesh mist nets (Avinet, Inc., Dryden, New York, USA) measuring 2.6 m high and 6, 9, or 12 m long. Mist nets were erected over open and forested freshwater pools, and forested hiking trails and service roads. We used 1-tier and 3-tier mist net arrangements. A 3-tier mist net arrangement consisted of 3 mist nets stacked vertically (7.8 m total height) and suspended between a rope and pulley system on 2, 10-m telescoping poles (Gardner et al. 1989, Figure 2). Mist netting typically was conducted for >4 h following sunset. No bat surveys were conducted during periods of heavy rain, high wind (≥ 20 kph) or cold temperatures ($<10^\circ\text{C}$). The species of each captured bat was determined (Menzel et al. 2002b), as well as its weight, forearm length, sex, age, and reproductive condition before being released. We determined weight (g) with a spring scale (Pesola, Switzerland). Forearm length was measure to the nearest 0.5 mm using a bird wing rule (Avinet, Inc., Dryden, New York, USA). We determined age (i.e., adult or juvenile) by examining the level of epiphyseal-diaphyseal fusion in finger bones (Kunz and Anthony 1982). We palpated the abdomen and inspected mammary glands to determine reproductive condition of female bats (Racey 1988). In 2006, we marked captured bats' wings with non-toxic, temporary paint pens to facilitate identification of recaptures within a sampling night. We used a digital camera, Olympus Camedia C-5050 (5 megapixels; New York, New York, USA), to record photographic vouchers of every captured species (Figures 3 and 4). Bat capture and handling protocols were approved by the Institutional Animal Care and Use Committee (IACUC) of the University of Maryland Center for Environmental Science (UMCES) (Protocol Number F-AL-05-06) and followed the guidelines of the American Society of Mammalogists (Animal Care and Use Committee 2007).



Figure 2. Mist nets located at Green Run pond 29C, Assateague Island National Seashore, August 2005.

Acoustic Monitoring

We used Anabat II (Titley Electronics, Ballina, Australia) broadband, frequency-division bat detectors linked to compact flash storage Zero Crossing Analysis Interface Modules (ZCAIM) to actively monitor for bat activity in 5 habitats, including beaches, dune/shrub areas, forests, freshwater pools, and bayside marshes (Figures 5 and 6). We monitored 7 locations within each habitat 2 □ in 2005 and 2 □ in 2006. We conducted 20-min samples in 1–5 ($= 3.7 \pm 0.23$) habitats per night, between sunset and 0130 h (Johnson et al. 2002, Wickramasinghe et al. 2003, Ford et al. 2005). We used bat pass data, i.e., number of echolocation passes, recorded during active acoustic monitoring to compare bat activity among the 5 habitats. We used repeated measures, 2-way ANOVA, with year and habitat as effects. Data were not normally distributed according to Shapiro-Wilks Test results and unresponsive to transformation. Therefore, tests were conducted on ranked values of the number of bat passes per sample (PROC NPAR1WAY; SAS Institute, Inc. 2004). Differences among ranked means for each habitat were analyzed using Duncan's New Multiple Range Test.



Figure 3. Big brown bat (*Eptesicus fuscus*) captured at Green Run Lodge pond 30A on 22 July 2005



Figure 4. Eastern red bats (*Lasiurus borealis*) (top) and purported Seminole bat (*Lasiurus seminolus*) (bottom) captured at Green Run pond 29C, Assateague Island National Seashore, on 26 July 2005

In addition to actively monitoring for bat echolocation passes, we passively monitored for bat echolocation passes by establishing 3 autonomous bat monitoring stations (BMS); 1 each on the northern (5.8 km south of Ocean City Inlet), middle (11.8 km south of the northern BMS), and southern portions (15.2 km south of the middle BMS) of ASIS (Figure 7). Each BMS consisted of an Anabat II bat detector and ZCAIM contained in a weatherproof enclosure, which was attached to a guyed 10-m pole. A downward-facing microphone and 45° deflector were attached to the top of the pole and connected to the Anabat II via 10-m audio cable. The microphones of all 3 BMS were above the surrounding forest canopy and located near freshwater pools.

Vegetation near the northern-most BMS was a small (<0.5 ha) patch of shrubs. The middle BMS was located in a gap in the canopy of loblolly forest. The southern BMS was located in a stunted

loblolly forest. Power was maintained for each BMS using an external 12 V, 12 A•h battery recharged by a 10 W photovoltaic panel. The BMS monitored bat activity from 1700 hr to 0700 hr nightly throughout the year (August 2005–December 2006). Start and end times varied depending on local sunrise and sunset, but recording occurred for the entire night and some portion of time before sunset and after sunrise.

We used a 3-factor (BMS $\times$ night period $\times$ season) general linear model with Tukey's Honestly Significant Difference multiple means comparisons to examine differences in bat activity among the BMS stations, among night periods, and among seasons (PROC GLM; SAS Institute, Inc. 2004). For this analysis, bat activity (number of bat passes) was summed by category (i.e., night of year, BMS, night period, and season) for a total of 4,111 observations. Of these, 2,303 (56.0%) observations had no bat activity (0 bat passes). We defined the remaining 1,808 observations as low (1–10 bat passes) or high (>10 bat passes) bat activity. Nights were divided into 3 equal-length periods, including early (from 2 hr before to 3 hr after sunset), middle (from 3 hr after to 8 hr after sunset), and late (from 8 hr after sunset to 2 hr after sunrise). The year was divided into 3 equal-length seasons, including winter-spring (January 1 – April 31), summer (May 1 – August 31), and autumn-winter (September 1 – December 31), based on bat life histories, i.e., migration, maternal activity, etc. (Barbour and Davis 1969).

To examine the effects of weather on bat activity, we obtained data from the remote automated weather station located at the approximate center of Assateague Island. Data included hourly rain accumulations (Rain hr), hourly air temperature (Temp hr), daily maximum air temperature (Temp max), daily minimum air temperature (Temp min), hourly mean wind speed (Wind mean), hourly maximum wind gust (Wind max), hourly mean wind direction (Wind dir) (Zar 1984), hourly relative humidity (RelHum), and hourly barometric pressure (Baro). We calculated percentage of night period in which rainfall occurred (number of rain hr / number of night hr) and arcsine-transformed the data (Rain per). Relative humidity data also were arcsine-transformed (Zar 1984). Minimum wind speed (Wind min) data were obtained from the minimum hourly wind speed recorded during each night. Prior to analyzing effects of weather on bat activity, we tested explanatory variables for correlations because collinearity can lead to model over-fitting. We computed Pearson's product-moment correlation coefficient for all pairs of variables and censored 1 member of any pair having a correlation of >0.6 (PROC CORR; SAS Institute, Inc.)

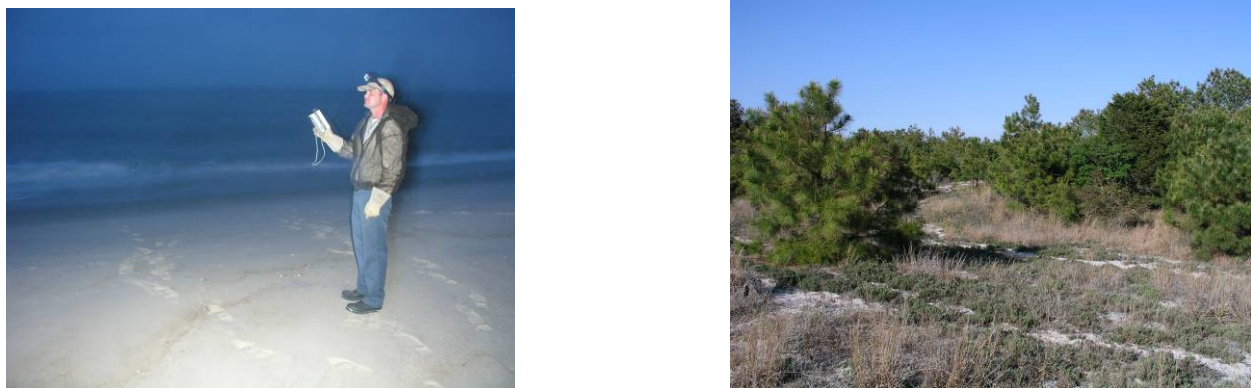


Figure 5. Active acoustic monitoring sites located in beach (top) and dune/shrub (bottom) habitats on Assateague Island National Seashore, 2005–2006



Figure 6. Active acoustic monitoring sites located in forest (top) and freshwater pool (middle) and bayside (bottom) habitats on Assateague Island National Seashore, 2005–2006

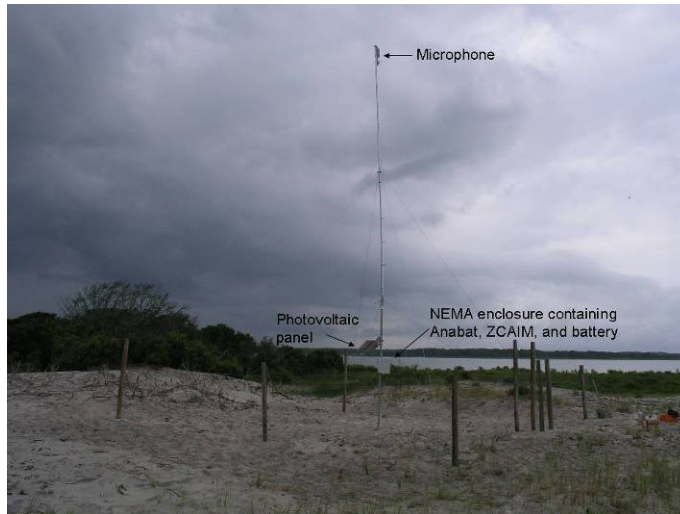


Figure 7. Bat monitoring stations (BMS) on northern (A), middle (B), and southern (C) portions of Assateague Island National Seashore, 2005–2006.

2004). Collinearity was significant in 7 variable pairs, including Rain hr and Rain per ($r = 0.83$), Temp hr and Temp max ($r = 0.96$), Temp hr and Temp min ($r = 0.96$), Temp max and Temp min ($r = 0.93$), Wind mean and Wind max ($r = 0.90$), Wind mean and Wind min ($r = 0.89$), Wind min and Wind max ($r = 0.70$). We excluded Rain hr from further analyses and retained Rain per because the periodicity of rain events may have more of an effect on bat activity than precipitation totals. In other words, a steady rain occurring throughout a night that accumulates to 1 inch (2.54 cm) likely will negatively impact overall bat activity more than 1 hr of rain accumulating to 1 inch. We excluded Temp max and Temp min from further analyses and retained Temp hr, because it represented mean temperatures recorded throughout the night when bats are active rather than maximum and minimum temperatures recorded during the day. We excluded Wind min and Wind max from further analyses and retained Wind mean data, which reported nightly sustained mean wind velocities rather than brief gusts. However, because previous research has indicated that lower minimum wind speeds are positively correlated with bat activity, particularly during migration (Reynolds 2006, K. Lott, University of Maryland Center for Environmental Science, personal communication), we replaced Wind mean with Wind min and executed analyses a second time. We used Pearson's chi-square analysis to examine for non-proportional distribution of seasonal bat activity among 8, 45° wind direction segments (PROC FREQ; SAS Institute, Inc. 2004).

We used general linear models to examine the influence of weather on bat activity (PROC GLM; SAS Institute, Inc. 2004). Although bat activity may vary significantly among BMS, it is unlikely that weather patterns differ significantly across ASIS, i.e., among BMS. However, weather patterns likely differ among seasons and may have different effects on bat activity depending on life history stage, e.g., migration. Indeed, Kruskal-Wallis tests indicated that weather variables, with exception of Rain per were significantly different among seasons (Table 1). Also, there was a non-proportional distribution of wind direction among seasons according to Pearson's chi-square analysis ($\chi^2 = 54.3$, $P < 0.001$). To eliminate within-night variation in bat activity, we analyzed weather effects on bat activity on a nightly basis. We maintained equal distribution of bat passes among bat activity categories for each season and analysis. There were nights when 1–3 BMS failed to operate. Therefore, we divided the total number of bat passes recorded each night by BMS effort, i.e., number of BMS in operation, resulting in a mean number of bat passes per night statistic. For winter-spring, bat activity categories were none (0 bat passes), low (1–7 bat passes), and high (>7 bat passes). For summer, bat activity categories were low (0–17 bat passes), moderately low (>17–40 bat passes), moderately high (>40–75 bat passes), and high (>75 bat passes). For autumn-winter, bat activity categories were low (<1 bat pass), moderately low (≥ 1 –14 bat passes), moderately high (>14–30 bat passes), and high (>30 bat passes).

We used the same techniques to identify bat echolocation passes recorded during active and passive acoustic monitoring. We used Analook 4.8p computer software in an attempt to determine which bat species produced each echolocation pass (Corben 2001). We used qualitative and quantitative identification methods (Fenton and Bell 1981, O'Farrell et al. 1999, Murray et al. 2001). We identified echolocation passes of some species by comparing our unknowns to a library comprised of echolocation passes collected from hand-released bats marked with chemiluminescent tags collected throughout the southeastern and mid-Atlantic

United States (Menzel et al. 2002a, Figures 8,9,10). We only attempted to identify echolocation passes containing ≥ 3 pulses (Johnson et al. 2002). A bat pass was defined as ≥ 1 pulse within a file that was emitted by an individual bat, i.e., there can be several bat passes of several bat species recorded within a file. Currently, no techniques exist to reliably distinguish male/female or adult/juvenile bat echolocation calls.

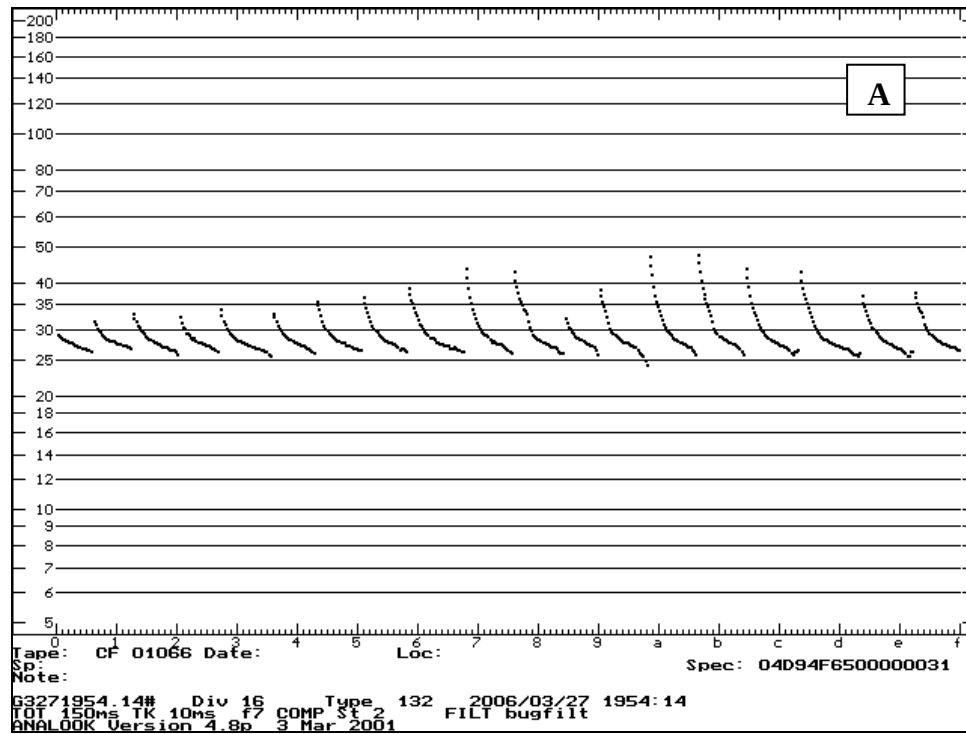


Figure 8. Graphical displays in Analook software of typical search-phase echolocation passes of big brown bat (*Eptesicus fuscus*) (A).

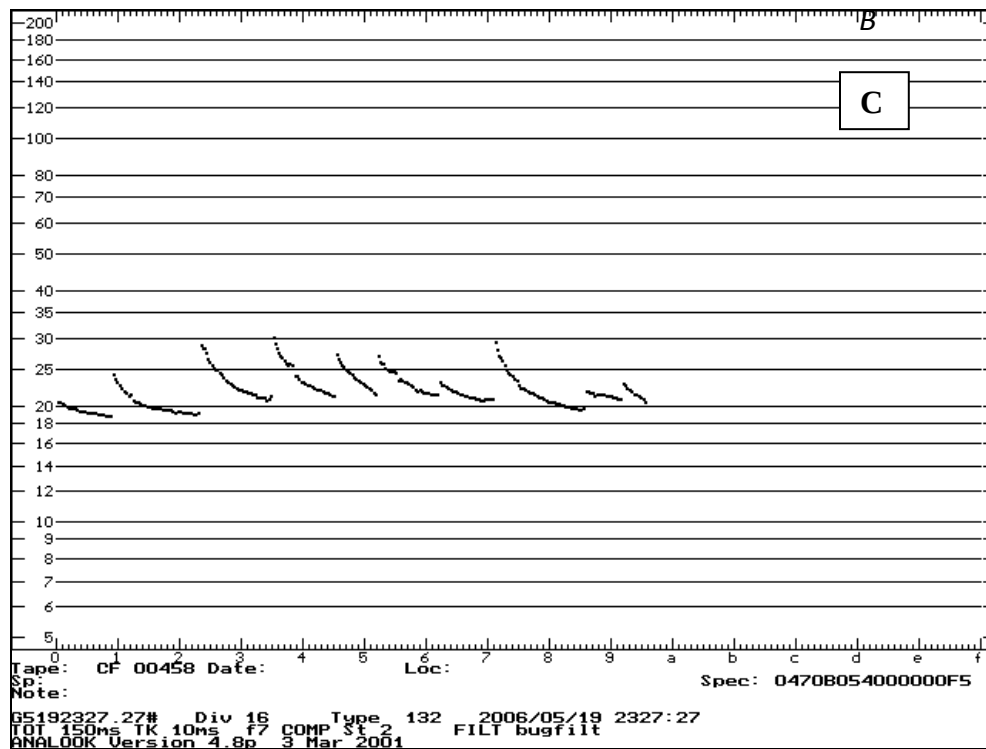
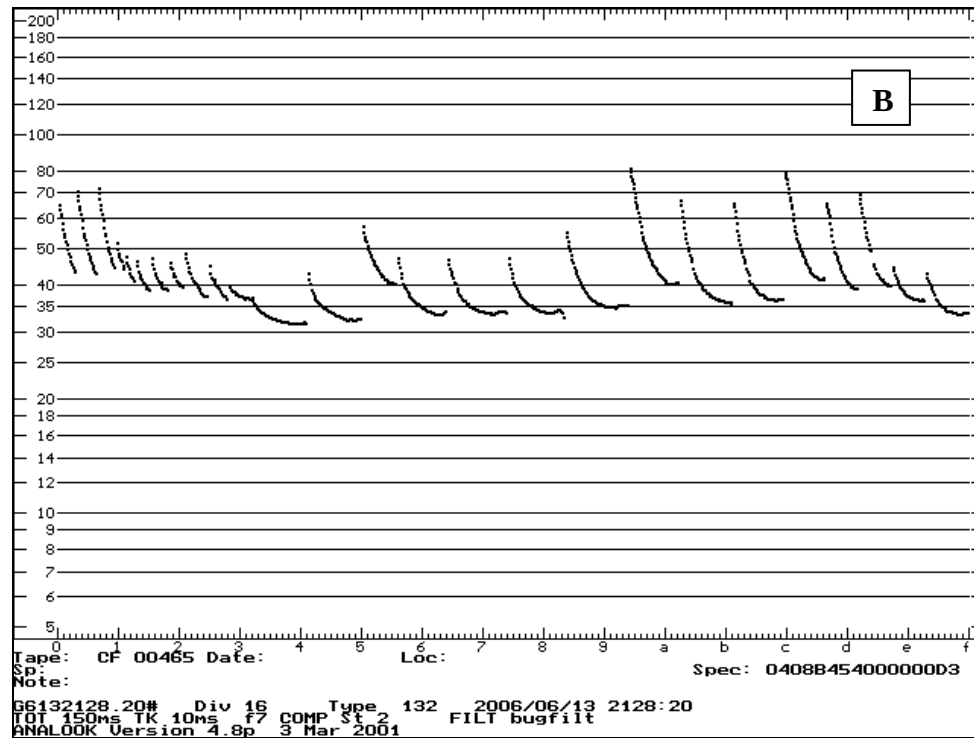


Figure 9. Graphical displays in Analook software of typical search-phase echolocation passes of eastern red bat (*Lasiurus borealis*) (B) and hoary bat (*Lasiurus cinereus*) (C).

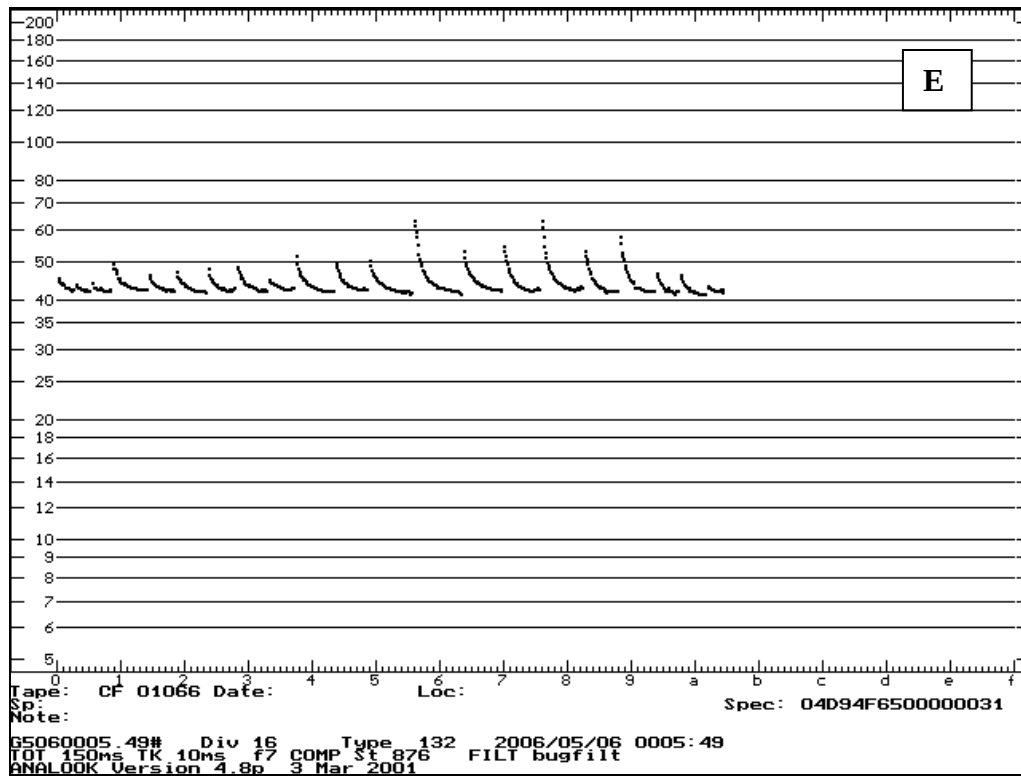
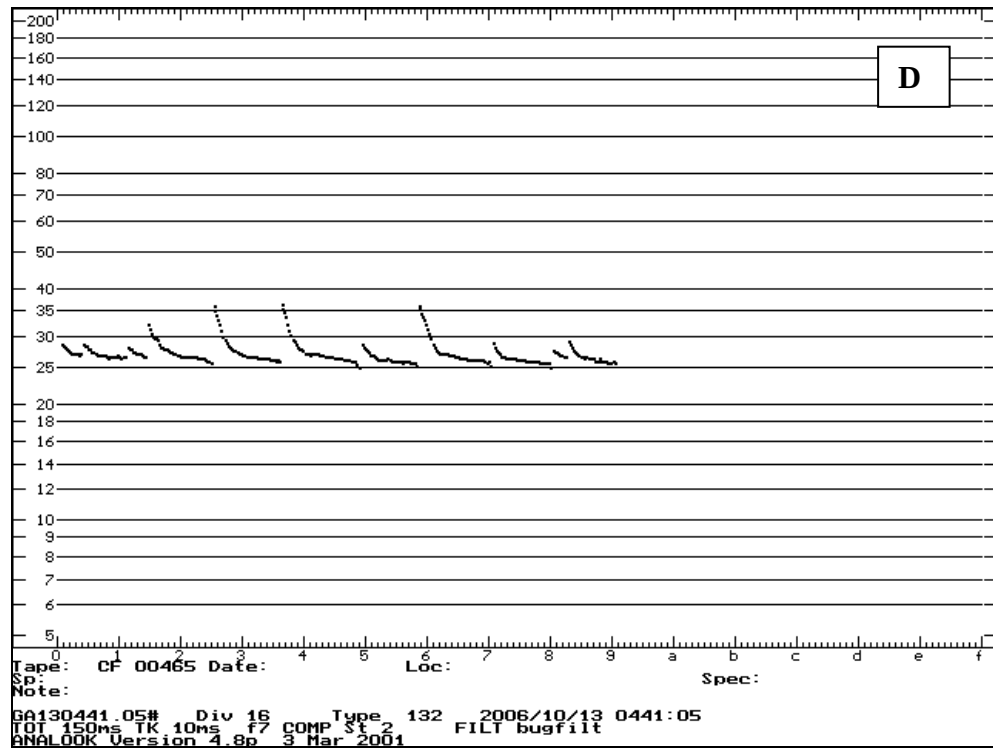


Figure 10. Graphical displays in Analoek software of typical search-phase echolocation passes of silver-haired bat (*Lasionycteris noctivagans*) (D), and eastern pipistrelle (*Pipistrellus subflavus*) (E).

Structure Evaluations

Ten abandoned structures exist at ASIS and are in various states of dilapidation. Potentially, these buildings could be used as roosts. We examined the buildings for roosting bats and evidence of bat use (e.g., staining or guano around holes in walls) in summer 2006. At sunset, observers, aided by spotlights and bat detectors, surrounded a building and watched for emerging bats. Buildings were observed for >30 min after sunset.

Diet Analysis

To gain some insight into the feeding habits of bats at ASIS, we collected and examined fecal samples from bats captured in summer 2005. We placed captured bats in plastic containers for ≤ 10 min or until fecal samples were obtained. Sampled bats and those that did not void feces within 10 min were released unharmed. We analyzed stomach and fecal samples collected from eastern red bats that were either road-killed or dispatched due to injury sustained during mist netting. Samples were frozen until analysis. We used a 20–40 $\times$ dissection microscope to examine fecal samples, which were placed in a petri dish and teased apart into a uniform layer in 70% isopropyl alcohol (Whitaker 1988). To facilitate insect identification, we used a reference insect collection and referred to dichotomous keys and figures in texts (e.g., Whitaker 1988, Triplehorn and Johnson 2005). We identified insects to order, and superfamily or family when possible. We followed the insect taxonomic classification system in Triplehorn and Johnson (2005). We visually estimated percent volume of each insect order in each sample by backlighting a transparent 1-mm² grid beneath the petri dish (Whitaker 1988). We estimated percent volume of Lepidoptera according to Whitaker (1988) and a bat food habits study in West Virginia (Carter et al. 2003). We calculated average percent volume and percent frequency of insect orders for the dataset. The average percent volume was the average percentage by volume of each insect order in the total sample. This measure is useful for determining if, on average, certain insect orders comprise a large portion of bat species' diets. The percent frequency was the number of bats consuming each insect order divided by the total number of sampled bats (Whitaker 1988). This metric determines if consumption of a certain insect order is widespread among individuals of a bat species. Together, average percent volume and percent frequency can be used to examine if a few individuals of a bat species are consuming a particular insect order or are more general in their prey preference.

Table 1. Weather variables recorded by a remote automated weather station located at the approximate center of Assateague Island National Seashore, 2005 – 2006.

Season ^a	<i>n</i>	Weather variable ^c									
		Wind _{mean}		Temp _{hr}		Rain _{per}		RelHum		Baro	
		Mean ^b	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter-spring	120	3.08A	0.14	6.51A	0.39	4.68A	1.13	73.74A	1.47	102.60AB	0.07
Summer	174	2.44B	0.10	21.61B	0.29	4.33A	0.95	83.33B	0.72	102.49A	0.03
Autumn-winter	228	3.21A	0.14	12.90C	0.47	6.77A	1.25	78.26C	0.83	102.72B	0.05

^a Winter-spring: 1 January – 31 April; Summer: 1 May – 31 August; Autumn-winter: 1 September – 31 December.

^b Means with different capital letters down columns differ as determined by Tukey's Honestly Significant Difference multiple means comparisons.

^c Wind _{mean}: hourly mean wind speed (m/s); Temp _{hr}: hourly air temperature (°C); Rain _{per}: percentage of night period with rainfall; RelHum: hourly relative humidity; Baro: barometric pressure (kPa)

Global Positioning System Data

The geographic locations of our acoustic monitoring and mist net inventory sites were determined with a Thales MobileMapper (Santa Clara, California, USA) global positioning system (GPS) or were hand-digitized in ArcGis 9 ArcMap (ESRI, Redlands, California, USA) using digital orthophoto quarter quadrangles provided by the National Park Service. We attempted to limit position data capture to when Positional Dilution of Precision (PDOP) was ≤ 6.0 and when receiving position data from ≥ 4 satellites. We collected position data for ≥ 1 min at each sample site. Unlike Trimble GeoExplorer GPS (Sunnyvale, California, USA), Thales MobileMapper GPS is unable to suspend position data collection when PDOP and satellite criteria are not met. Differential correction of position data was conducted when possible using data from nearby continuously operating reference stations (Cambridge, Maryland, and Wachapreague, Virginia). We hand-digitized locations that we were unable to collect via GPS, or, after differential correction, were a significant distance (e.g., outside park boundary) from actual positions. We noted the location of our inventory sites in relation to recognizable park features (e.g., trails, roads, pools, kilometer markers, etc.) (Appendix III).

Species Richness, Evenness, and Diversity, Rarefaction, and Horn's Index of Similarity (HIS)

We calculated Simpson's species diversity index (1-D) and a measure of evenness ($E = 1/D$) for ASIS with capture data only (Krebs 1999). Acoustic survey data provide species presence and relative activity levels, but do not provide information on number of individual bats recorded, which is a required input for calculating species diversity and evenness. Measuring bat species abundance, i.e., actual numbers or densities, at ASIS would be extremely difficult because bats violate many assumptions of abundance models (Krebs 1999). However, we can evaluate relative frequencies among bat species, based on activity levels and number of sites where each bat was recorded. To determine if we inventoried all species of the bat community at ASIS, we used the rarefaction method, which examines the expected number of species given N captures (Krebs 1999). Although rarefaction analyses may not be completely appropriate for a small number of species, it is the best method available under our circumstances (Krebs 1999). We examined the number of new species recorded per mist net or active acoustic monitoring site. We used Horn's Index of Similarity (HIS) to compare species relative frequencies and compositions detected using acoustic monitoring and mist netting (Krebs 1999). Horn's Index of Similarity uses relative frequency data collected using acoustic monitoring and mist nets to calculate values ranging from 0–1; a higher value indicates relative frequencies and compositions are more similar.

Results

Mist Netting

During summer 2005, we conducted mist net surveys at 11 locations for 19 nights (94 mist net nights) and captured 133 bats representing 3 species, including 129 eastern red bats, 2 big brown bats, and 2 Seminole bats (Table 2, Figures 7–12, Appendix IV). During June 2006, we conducted bat surveys at 10 locations (3 of which were not sampled in 2005) for 14 nights (75 mist-net nights) and captured 52 eastern red bats. We mist netted at 4 locations for 2 nights (20 mist net nights) in October 2006 and captured 8 eastern red bats. Overall, we captured bats at 12 of 14 locations and during 31 of 35 nights. Overall catch per unit effort (CPUE) at ASIS was 0.0086 (Table 3). A typical night of mist netting consisted of monitoring 5, 9-m nets (2 low nets, 1 high net) equaling 117.0 m² for 5 hr (585 mist net hr). A CPUE of 0.0086 $\times$ 585 mist net hr equals about 5 bats captured per night. Capture rates were higher in 2005 (CPUE = 0.0119, about 7 bats per night) than in 2006 (CPUE = 0.0053, about 3 bats per night).

We did not recapture any bats with paint-marked wings in 2006 other than those that immediately flew into mist nets upon release. Because we did not mark captured bats in 2005, we are uncertain if we captured 2 Seminole bats or the same bat twice. The captures were on the same night, 18 min apart, and in the same mist net. Bat weights were the same, but forearm measurements differed by 0.5 mm, possibly an observer error.

Table 2. Bat captures at Assateague Island National Seashore, 2005 – 2006.

Year	Species	No. captures ^a	Male		Female	
			A	J	A	J
2005	<i>Eptesicus fuscus</i>	2	1	0	1	0
	<i>Lasiurus borealis</i>	129	7	30	55	28
	<i>Lasiurus seminolus</i> ^b	2	0	0	2	0
2006	<i>Lasiurus borealis</i>	60	8	0	48	0
Total	<i>Eptesicus fuscus</i>	2	1	0	1	0
	<i>Lasiurus borealis</i>	189	15	30	103	28
	<i>Lasiurus seminolus</i> ^b	2	0	0	2	0

^a Discrepancies in total number of bats captured and sum of males and females are because bats escaped before sex was determined.

^b Our identification of *L. seminolus* based on morphological features has been questioned by some bat experts, contending that the 2 bats may have been dark-morph *L. borealis*.

Table 3. Number of bats captured per unit effort [no. captures/(mist net surface area × hr)] at Assateague Island National Seashore, 2005 – 2006.

Year	<i>n</i> ^a	No. nights	Mist net nights	Mist net hours ^b	Species ^c			
					All	EPFU	LABO	LASE ^d
2005	11	19	94	11178.73	0.0119	0.0002	0.0115	0.0002
2006	10	16	95	11229.19	0.0053	–	0.0053	–
Total	14	35	189	22407.92	0.0086	0.0001	0.0084	0.0001

^a Number of mist net sites.

^b Mist net hours = mist net surface area (m²) × hr.

^c All = all species combined; EPFU = *Eptesicus fuscus*; LABO = *Lasiurus borealis*; LASE = *L. seminolus*.

^d Our identification of *L. seminolus* based on morphological features has been questioned by some bat experts, contending that the 2

22 bats may have been dark-morph *L. borealis*

Acoustic Monitoring

During active acoustic monitoring, we recorded 1,361 echolocation passes (1,045 in 2005 and 316 in 2006). No active acoustic monitoring was conducted at the same time as mist netting in October 2006 (Table 4, Appendix V). Eastern red bat was the most frequently recorded species in both years, both as a percentage of total echolocation passes (75.2% in 2005, 74.1% in 2006, and 74.9% combined) and percentage of locations at which they were recorded (77.1% in 2005, 68.6% in 2006, and 85.7% combined). Big brown bat echolocation passes comprised 1.4% of total echolocation passes recorded in 2005, 6.3% in 2006, and 2.6% combined. Big brown bats were recorded at 11.4% of locations in 2005, 14.3% in 2006, and 20.0% combined. Overall, bats were recorded at 80.0% of locations in 2005, 74.3% in 2006, and 88.6% combined.

There was a year effect on total bat activity ($F_{1, 130} = 10.15$, $P = 0.002$) and eastern red bat activity ($F_{1, 130} = 8.43$, $P = 0.004$); both were greater in 2005 than in 2006 (Table 5). Big brown bat activity ($F_{1, 130} = 0.01$, $P = 0.939$) was similar between years. There was a habitat effect on total bat activity ($F_{4, 130} = 9.58$, $P < 0.001$) and eastern red bat activity ($F_{4, 130} = 9.13$, $P < 0.001$); both were higher in forested areas and at freshwater pools. There was no significant interaction between year and habitat effects ($F_{4, 130} \geq 0.60$, $P \geq 0.665$).

Table 4. Bat echolocation passes recorded at Assateague Island National Seashore, 2005 – 2006.

Year	Total	Species ^a				
		NOID	EPFU	EPFUFB	LABO	LABOFB
2005	1,045	244	15	0	786	21
2006	316	62	20	1	234	6
Total	1,361	306	35	1	1,020	27

^a NOID = Unidentifiable bat pass; EPFU = *Eptesicus fuscus*; LABO = *Lasiurus borealis*; FB = feeding buzz.

The BMS recorded 39,384 echolocation passes overall of 5 species, including eastern red bats (59.33% of total echolocation passes), big brown bats (3.05%), hoary bats (0.13%), eastern pipistrelles (0.10%), and silver-haired bats (0.07%). The remaining 36.66% of recorded echolocation passes were not identifiable to species (Table 6). The middle and southern BMS recorded similar levels of nightly bat activity, but recorded more than the northern BMS ($F_{2, 4,084} = 316.23$, $P < 0.001$). Overall, bat activity was highest during the first few hours after sunset, next highest in the middle of the night, and lowest before sunrise ($F_{2, 4,084} = 215.03$, $P < 0.001$). In summer and autumn-winter, there was a brief peak in activity before sunrise (Figure 11). There was more nightly bat activity recorded in the summer season than in winter-spring or autumn-winter seasons. There was more bat activity recorded in the autumn-winter season than in the winter-spring season ($F_{2, 4,084} = 516.69$, $P < 0.001$). Eastern red bats comprised such a large portion of identifiable echolocation passes compared to other recorded species that we were prevented from analyzing the effects of weather among different bat species. Total bat activity gradually increased beginning in April, peaked in August, and declined gradually until December when very little bat activity was recorded (Figure 12). We recorded a large quantity of bat activity on 11 February, along with a few minor events in February and early March (Figure 12). Eastern red bats were recorded during all of the active (April–December) season, and also in February and early March (Figure 13A). They were recorded by all BMS. Big brown bats were recorded during all of the active season and also on 11 February and in March (Figure 13B). Hoary bats were recorded during all of the active season and by all BMS (Figure 14A). They were also recorded in February. Silver-haired bats were recorded mostly in autumn, and on only 2 nights in April (Figure 14B). Silver-haired bats and/or indiscernible silver-haired bat/big brown bat passes were recorded by all 3 BMS on the nights of 15 October 2005 and 2 November 2006. The odds of recording silver-haired bats and/or indiscernible silver-haired bat/big brown bat passes on all 3 BMS on any single night were 1 in 125,000. In contrast, there was a 15.3% chance of recording eastern red bat passes on all 3 BMS on any single night. Eastern pipistrelles were recorded from early May to early October and almost exclusively by the northern BMS (Figure 15). Only 1 (2.4%) eastern pipistrelle pass was recorded by the middle BMS and none on the southern BMS.

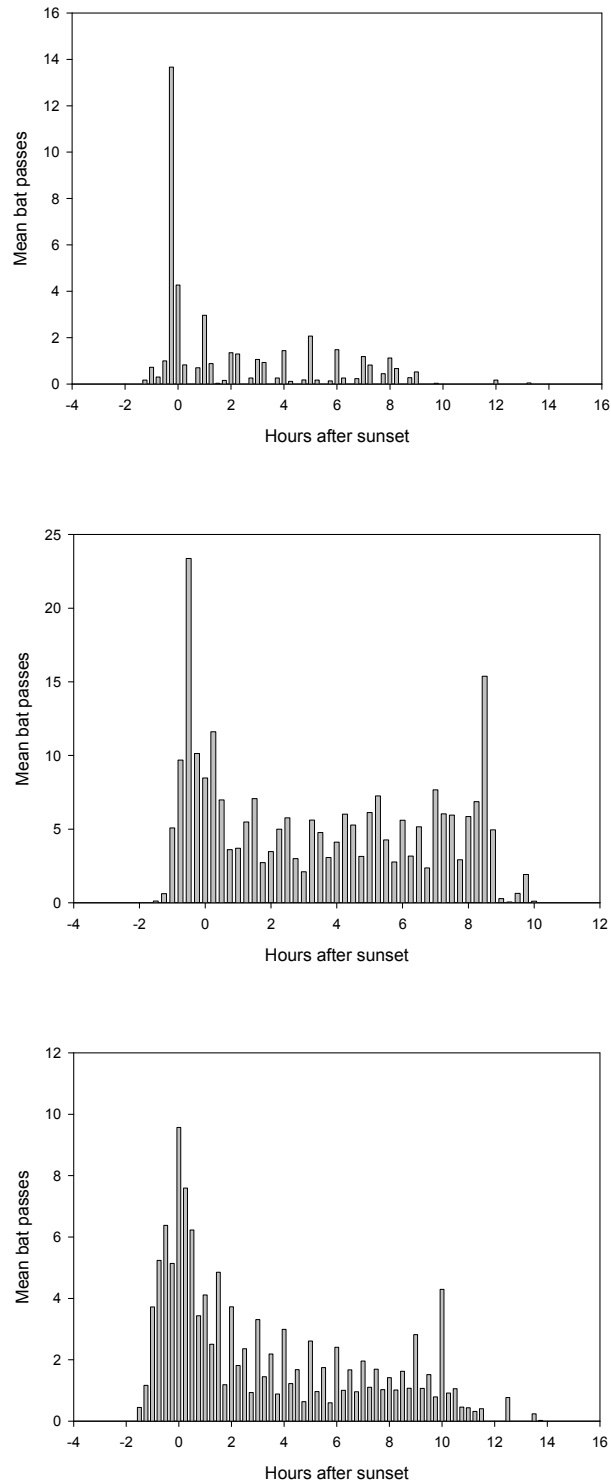


Figure 11. Hourly bat activity within nights recorded by bat monitoring stations from 1 January–31 April (A), 1 May–31 August (B), and 1 September–31 December (C) at Assateague Island National Seashore.

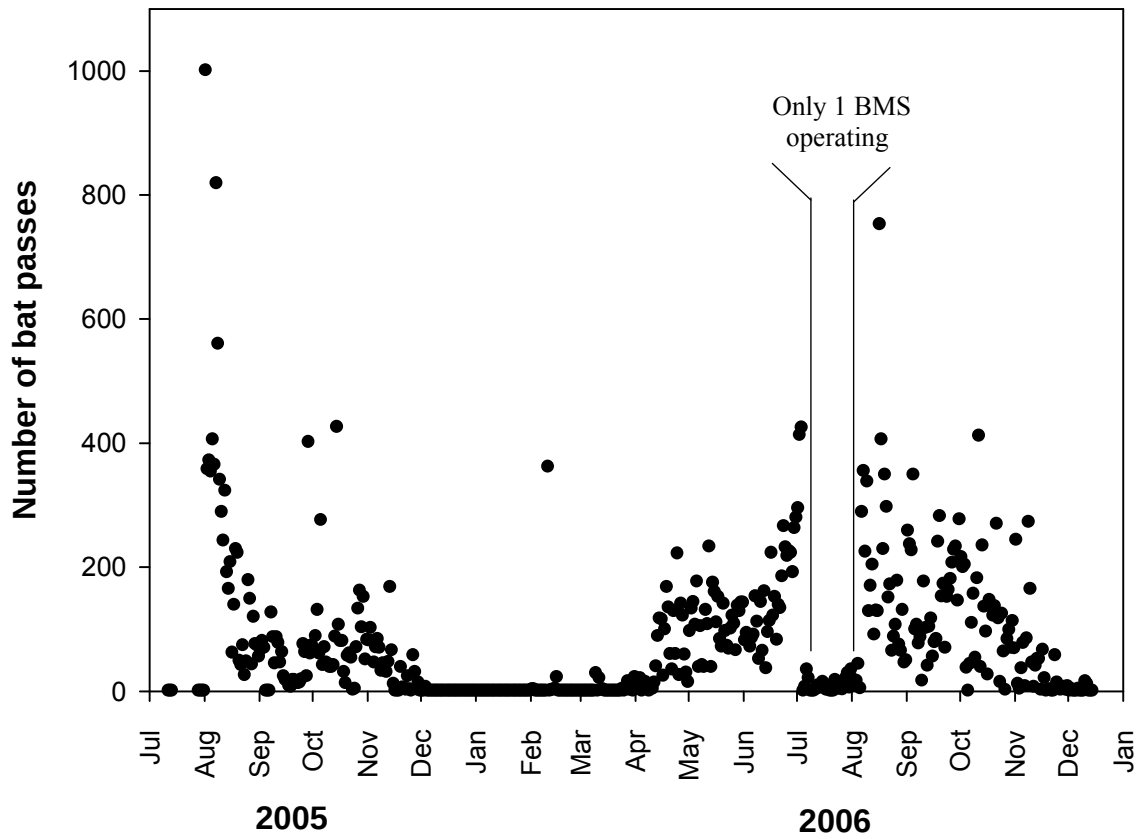


Figure 12. Nightly bat activity recorded by bat monitoring stations at Assateague Island National Seashore, 2005–2006.

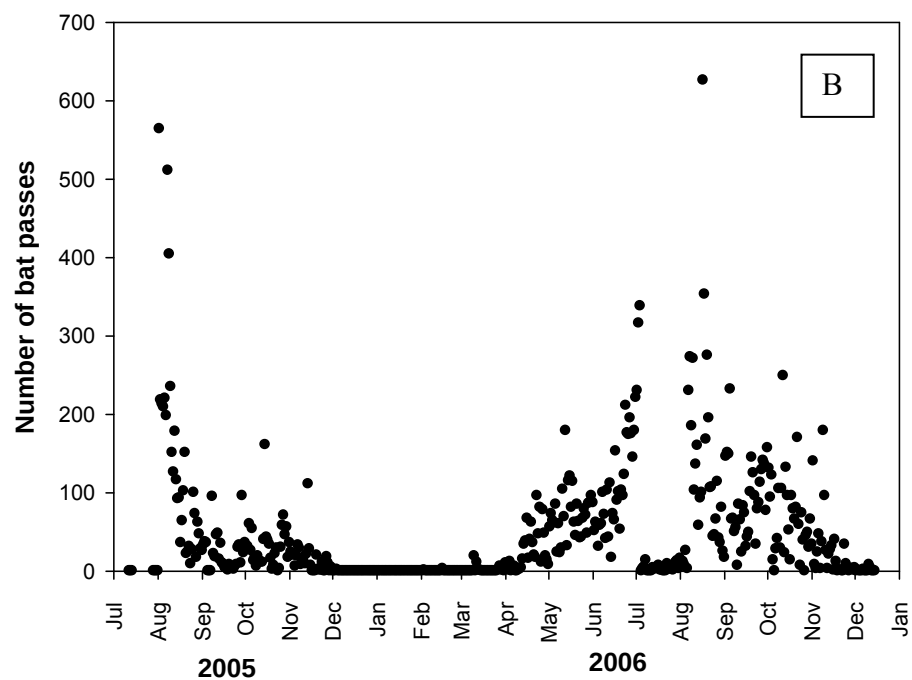
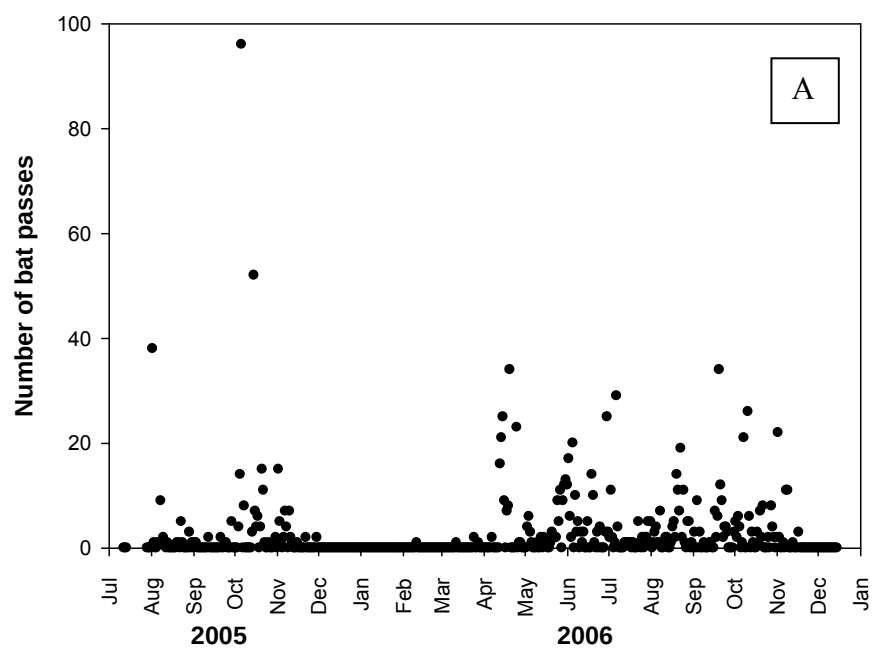


Figure 13. Nightly activity of big brown bat (*Eptesicus fuscus*) (A) and eastern red bat (*Lasiurus borealis*) (B) recorded by bat monitoring stations at Assateague Island National Seashore, 2005–2006.

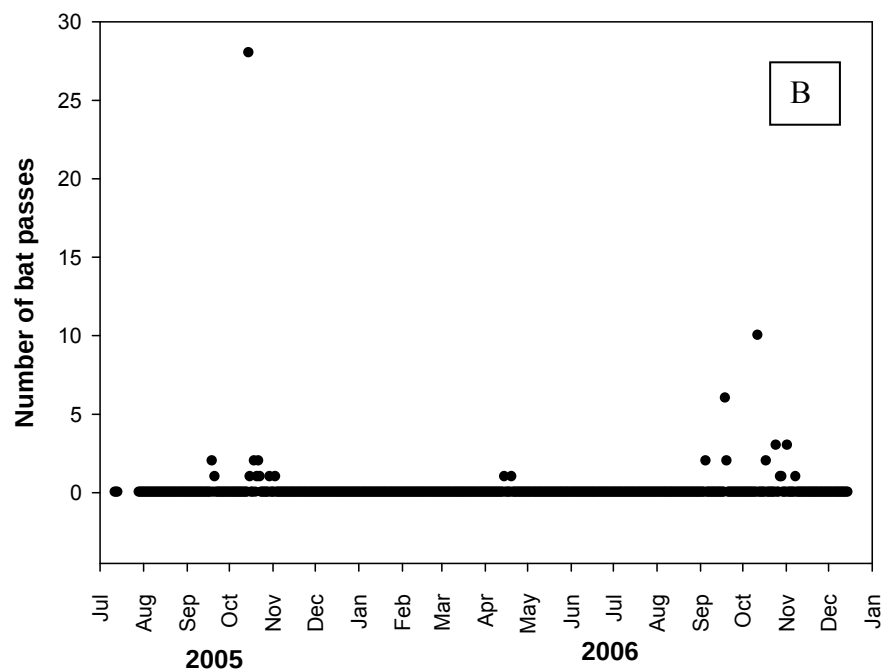
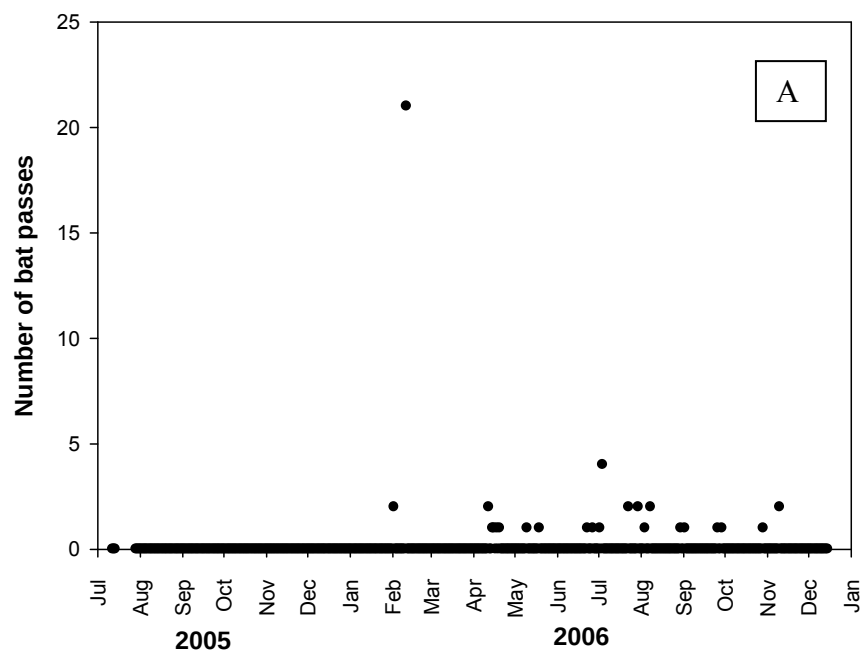


Figure 14. Nightly activity of hoary bat (*Lasiurus cinereus*) (A), and silver-haired bat (*Lasionycteris noctivagans*) (B) recorded by bat monitoring stations at Assateague Island National Seashore, 2005–2006. Silver-haired bat data include undetermined big brown bat or silver-haired bat echolocation passes.

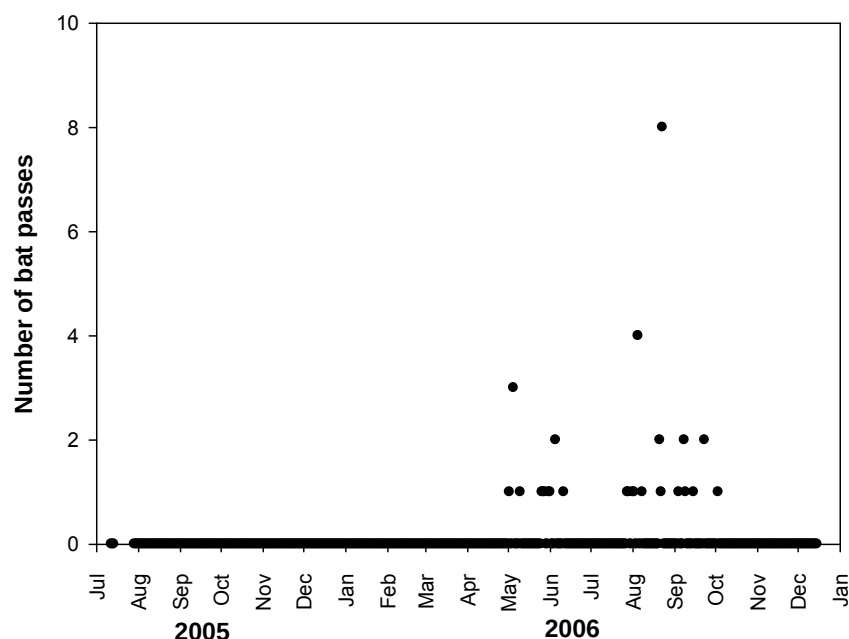


Figure 15. Nightly activity of eastern pipistrelle (*Pipistrellus subflavus*) recorded by bat monitoring stations at Assateague Island National Seashore, 2005–2006.

Weather variables were inconsistent predictors of bat activity among seasons. During winter-spring, bat activity was higher during nights with higher mean temperatures (Temp mean; $F_{2, 117} = 49.35$, $P < 0.001$), higher percentages of rain (Rain per; $F_{2, 117} = 49.35$, $P < 0.001$), and higher relative humidity (RelHum; $F_{2, 117} = 4.74$, $P = 0.011$). Barometric pressure (Baro; $F_{2, 117} = 1.51$, $P = 0.225$) and mean nightly wind speed (Wind mean; $F_{2, 117} = 0.07$, $P = 0.935$) had no effect on bat activity during winter-spring (Table 7). Minimum wind speeds had no significant effect on bat activity during winter-spring (Wind min; $F_{2, 117} = 0.69$, $P = 0.504$). Bat activity was disproportionately distributed among wind directions ($\chi^2 = 23.8$, $P = 0.048$). Northwesterly winds negatively affected bat activity, whereas southerly and southeasterly winds positively affected bat activity. During summer, weather variables were inconsistent predictors of bat activity, and typically showed no linear pattern in their effects on bat activity. Mean nightly wind speed (Wind mean; $F_{3, 170} = 2.62$, $P = 0.052$), mean temperatures (Temp mean; $F_{3, 170} = 9.44$, $P < 0.001$), relative humidity (RelHum; $F_{3, 170} = 3.05$, $P = 0.030$), and barometric pressure (Baro; $F_{3, 170} = 4.78$, $P = 0.003$) had significant, but non-linear effects on bat activity (Table 7). Nightly percentages of rain (Rain per; $F_{3, 170} = 2.19$, $P = 0.092$), minimum wind speeds (Wind min; $F_{3, 170} = 2.19$, $P = 0.092$), and wind direction ($\chi^2 = 20.2$, $P = 0.511$) had no significant effect on bat activity during summer (Table 7). During autumn-winter, bat activity was higher during nights with lower wind speeds (Wind mean; $F_{3, 224} = 4.41$, $P = 0.005$), higher mean temperatures (Temp mean; $F_{3, 224} = 47.17$, $P < 0.001$), and lower percentages of rain (Rain per; $F_{3, 224} = 6.00$, $P < 0.001$). Relative humidity (RelHum; $F_{3, 224} = 2.22$, $P = 0.086$) and barometric pressure (Baro; $F_{3, 224} = 1.12$, $P = 0.341$) had no effect on bat activity during autumn-winter (Table 7). Lower minimum wind speeds had a positive effect on bat activity during autumn-winter (Wind min; $F_{3, 224} = 6.00$, $P < 0.001$). Bat activity was not disproportionately distributed among wind directions ($\chi^2 = 24.5$, $P = 0.269$).

Table 5. Mean ($\pm$ SE) bat echolocation passes recorded during 20-min samples at Assateague Island National Seashore, Maryland, 2005–2006

Variable ^a	Habitat									
	Forest (n = 28)		Pool (n = 28)		Bay (n = 28)		Shrub lands (n = 28)		Beach (n = 28)	
	2005 ^b	2006	2005	2006	2005	2006	2005	2006	2005	2006
Total	34.2 (13.0) ^A	5.9 (2.5) ¹	22.5 (7.4) ^{AB}	8.4 (3.0) ¹	8.2 (2.2) _{AB}	4.4 (1.3) ¹	8.6 (3.5) ^B	1.7 (0.6) ¹	1.1 (0.5) ^C	0.2 (0.2) ²
EPFU	0.0 (0.0) ^A	0.1 (0.1) ¹	0.4 (0.4) ^A	0.2 (0.2) ¹	0.2 (0.2) ^A	0.0 (0.0) ¹	0.1 (0.1) ^A	0.1 (0.1) ¹	0.0 (0.0) ^A	0.0 (0.0) ¹
LABO	24.6 (9.5) ^A	5.0 (2.2) ¹	19.4 (6.8) ^{AB}	6.7 (2.6) ¹	5.8 (1.6) _{AB}	3.6 (1.2) ¹	5.8 (2.4) ^B	1.1 (0.5) ^{1,2}	0.5 (0.3) ^C	0.2 (0.2) ²

^a Total = total number of echolocation passes; EPFU = *Eptesicus fuscus*; LABO = *Lasiurus borealis*; LABOFB = *Lasiurus borealis* feeding activity.

^b Means with different superscript capital letters or numbers across columns differ as determined by Duncan's New Multiple Range Test. Differences were analyzed using ranked data, but actual data are presented

Table 6. Bat echolocation passes recorded using long-term monitoring with Anabat II bat detectors at Assateague Island National Seashore, 2005–2006.

BMS ^a	Year	n ^b	Total	Species											
				NOID	EPFU	EPFUFB	EPFULACI	EPFULANO	EPFULANOFB	LABO	LABOFB	LACI	LANO	PISU	PISUFB
North	2005	159	391	172	46	0	0	14	1	159	1	0	0	0	0
	2006	337	4,131	1,299	301	5	0	6	0	2,451	36	14	20	40	1
	All	496	4,522	1,471	347	5	0	20	1	2,610	37	14	20	40	1
Middle	2005	141	8,982	4,059	95	1	0	5	0	4,823	226	0	0	0	0
	2006	317	10,256	3,486	144	30	0	1	0	6,615	437	6	3	1	0
	All	458	19,238	7,545	239	31	0	6	0	11,438	663	6	3	1	0
South	2005	118	3,592	1,885	213	3	0	21	0	1,473	24	0	0	0	0
	2006	303	12,032	3,539	404	14	207	0	0	7,846	225	33	3	0	0
	All	421	15,624	5,424	617	17	207	21	0	9,319	249	33	3	0	0
All	2005	418	12,965	6,116	354	4	0	40	1	6,455	251	0	0	0	0
	2006	957	26,419	8,324	849	49	207	7	0	16,912	698	53	26	41	1
	All	1,375	39,384	14,440	1,203	53	207	47	1	23,367	949	53	26	41	1

^a Bat Monitoring Station.

^b Number of detector nights.

^c NOID = Unidentifiable bat pass; EPFU = *Eptesicus fuscus*; EPFULACI = undetermined *E. fuscus* or *Lasiurus cinereus* pass; EPFULANO = undetermined *E. fuscus* or *Lasiurus cinereus* pass; LABO = *Lasiurus borealis*; LACI = *Lasiurus cinereus*; LANO = *Lasiurus noctivagus*; PISU = *Pipistrellus subflavus*; FB = feeding buzz.

Table 7. Weather variables recorded during various levels of bat activity (number of echolocation passes recorded/night) at Assateague Island National Seashore, 2005 – 2006.

Season ^a	Bat activity ^b	n	Weather variable ^d											
			Wind _{min}		Wind _{mean}		Temp _{hr}		Rain _{per} ^e		RelHum ^e		Baro	
			Mean ^c	SE	Mean ^c	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter-spring	None (0)	76	1.58A	0.17	3.08A	0.18	4.47A	0.38	3.26A	1.20	70.27A	1.96	102.66A	0.08
	Low (1–7)	22	1.65A	0.29	3.16A	0.31	8.21B	0.69	3.50AB	1.94	80.54B	2.61	102.66A	0.17
	High (>7)	22	1.20A	0.32	2.99A	0.36	11.83C	0.58	10.77B	4.00	78.91AB	2.63	102.35A	0.16
Summer	Low (0–17)	54	1.06A	0.18	2.48AB	0.20	22.93A	0.48	7.55A	2.60	85.10A	1.16	102.58A	0.05
	Mod. Low (>17–40)	41	0.63A	0.17	2.10A	0.19	19.65B	0.71	0.56A	0.32	79.79B	1.64	102.28B	0.07
	Mod. High (>40–75)	38	1.27A	0.20	2.87B	0.20	20.47B	0.51	4.25A	1.55	83.54AB	1.73	102.46AB	0.08
	High (>75)	41	1.01A	0.14	2.34AB	0.15	22.88A	0.47	3.94A	1.37	84.36AB	1.21	102.58A	0.07
Autumn-winter	Low (<1)	61	2.00A	0.31	3.68A	0.38	5.74A	0.79	11.62A	3.37	76.02A	1.81	102.87A	0.12
	Mod. Low (=1–14)	52	2.13A	0.23	3.69A	0.25	14.09B	0.95	11.69A	3.09	79.12A	1.79	102.72A	0.12
	Mod. High (>14–30)	56	1.54AB	0.20	2.99AB	0.23	16.46B	0.58	2.16B	1.35	81.64A	1.37	102.64A	0.09
	High (>30)	59	1.15B	0.16	2.50B	0.17	15.87B	0.62	1.80B	1.02	76.60A	1.55	102.64A	0.08

^a Winter-spring: 1 January – 31 April; Summer: 1 May – 31 August; Autumn-winter: 1 September – 31 December.

^b Number of bat passes/night in parenthesis.

^c Means with different capital letters down columns within seasons differ as determined through Tukey's Honestly Significant Difference multiple means comparisons.

^d Wind_{mean}: hourly mean wind speed (m/s); Temp_{hr}: hourly air temperature (°C); Rain_{per}: percentage of night period with rainfall; RelHum: hourly relative humidity; Baro: barometric pressure (kPa).

^e Analyses performed on arcsine-transformed data. Actual numbers reported in table.

Species richness, evenness, and diversity, rarefaction, and Horn's Index of Similarity (HIS)

Simpson's diversity index was 0.041 and species evenness was 0.348 overall at ASIS. A higher number indicates higher species diversity and evenness (range 0–1). Species richness was 3 (eastern red bat, big brown bat, Seminole bat) when examining capture data only. Active acoustic monitoring recorded only 2 species, eastern red bats and big brown bats. Passive acoustic monitoring with BMS added 3 species (silver-haired bat, eastern pipistrelle, and hoary bat) that were not captured or detected during active acoustic monitoring (Table 8).

Theoretically, it would be necessary to capture 57 bats to document 2 species (eastern red bat and big brown bat) at ASIS. To capture a 3rd species, it would be necessary to capture 191 bats. The maximum number of mist net sites and nights sampled needed to capture 3 bat species was 7 (Table 9). Slightly more active acoustic monitoring effort would be required to document the same species richness (Table 9). We documented 2 species by the 37th 20-min acoustic monitoring sample. Thirty-seven acoustic monitoring samples typically were completed in 5–6 nights.

The 3 methods we used to inventory bats at ASIS were complementary in terms of bat species relative frequencies common to all 3 methods, resulting in HIS values of ≥ 0.99 (Table 10). Eastern red bats were the most frequently detected species among the 3 methods, whereas big brown bats were the least frequently detected. Seminole bats were detected only with mist nets, Whereas hoary bats, eastern pipistrelles, and silver-haired bats were detected only with BMS (Table 11).

Table 8. Simpson's diversity index (1-D), measure of evenness ($E_{1/D}$), and species richness at Assateague Island National Seashore, 2005–2006.

Variable	Value
Simpson's diversity index ^a	0.041
Simpson's measure if evenness ^b	0.348
Capture species richness ^c	3.000
Acoustic species richness ^d	5.000
Combined species richness ^e	6.000

^a Higher number indicates higher species diversity.

^b Higher number indicates higher species evenness.

^c Number of bat species captured in mist nets.

^d Number of bat species detected during acoustic monitoring.

^e Number of bat species captured in mist nets or detected during acoustic monitoring.

Table 9. Number of mist net locations, captured individuals, and acoustic survey locations needed to assess bat species communities at Assateague Island National Seashore, 2005–2006.

Method ^a	Type ^b	<i>n</i> ^c	No. species ^d		
			1	2	3
Capture	Locations	14	1	5	7
	Nights	35	1	5	7
	Individuals	193	1	57	191
Acoustic	Locations	140	2	37	–

^a Capture = mist net survey; Acoustic = Anabat acoustic survey.

^b Locations = mist net or acoustic survey locations; Nights = sample nights; Individuals = individual bat captures.

^c Number of mist net locations, captured individuals, and acoustic survey locations within the park.

^d Number of bat species recorded.

Table 10. Horn's index of similarity among 3 bat inventory methods at Assateague Island National Seashore, Maryland, 2005–2006. A higher number indicates that the relative frequencies and compositions are more similar between methods.

Method	Method		
	Capture	Active acoustic monitoring	Passive acoustic monitoring
Capture	1.00	0.99	0.99
Active acoustic monitoring		1.00	1.00
Passive acoustic monitoring			1.00

Structure Evaluations

In June 2006, we examined 7 buildings 1 □ each for roosting bats (Figures 16 -18, Table 12). We did not observe any roosting bats, emerging bats, or evidence of bat use.

Diet Analysis

We examined fecal samples of 4 eastern red bats (2 juvenile males and 2 juvenile females) captured in August 2005. We examined the stomach and fecal contents of 2 eastern red bats (2 juvenile males) dispatched in late-July and August. We identified 5 insect orders (families) including Coleoptera (Scarabaeidae, beetles), Diptera (flies), Hemiptera (Corixidae, water boatmen), Hymenoptera (Formicidae, flying ants), and Lepidoptera (moths). Hymenoptera was the most frequently identified insect order in all samples and comprised the largest average volume (Table 13). We did not positively identify any diagnostic remains (e.g., wings) of Culicidae (mosquitoes) in any samples.

Incidental Captures and Observations

On 25 July 2005, a post-lactating female eastern red bat struck our vehicle as we traveled on Old Ferry Landing road. The bat was too mangled for us to retain in a study specimen collection. We captured and released unharmed a catbird (*Dumetella carolinensis*) from a mist net at Tingles pond 18A on 6 June 2006. On 7 June 2006, a mouse (*Peromyscus* sp.) was captured and released from the lower shelf of a mist net adjacent to Life of Forest Trail pond 15A. We captured and released unharmed a Carolina wren (*Thryothorus ludovicianus*) from a mist net at Pine Tree on 8 June 2006. We captured and released unharmed a catbird from a mist net at Pine Tree on 22 June 2006. At 2000 hr (after sunset) on 19 October 2006, we captured and released unharmed a yellow-rumped warbler (*Dendroica coronata*) from a mist net over Green Run pond 29C.

Table 11. Relative frequencies of bat species documented using 3 inventory methods at Assateague Island National Seashore, Maryland, 2005–2006.

Species	Method		
	Capture	Active acoustic monitoring	Passive acoustic monitoring
<i>Eptesicus fuscus</i>	0.010	0.033	0.049
<i>Lasionycteris noctivagans</i>	–	–	0.001
<i>Lasiurus borealis</i>	0.979	0.967	0.946
<i>Lasiurus cinereus</i>	–	–	0.002
<i>Lasiurus seminolus</i>	0.010	–	–
<i>Pipistrellus subflavus</i>	–	–	0.002



Figure 16. Dwellings on Assateague Island National Seashore examined for bat use during June 2006: Bunting's (top), Clement's (bottom)

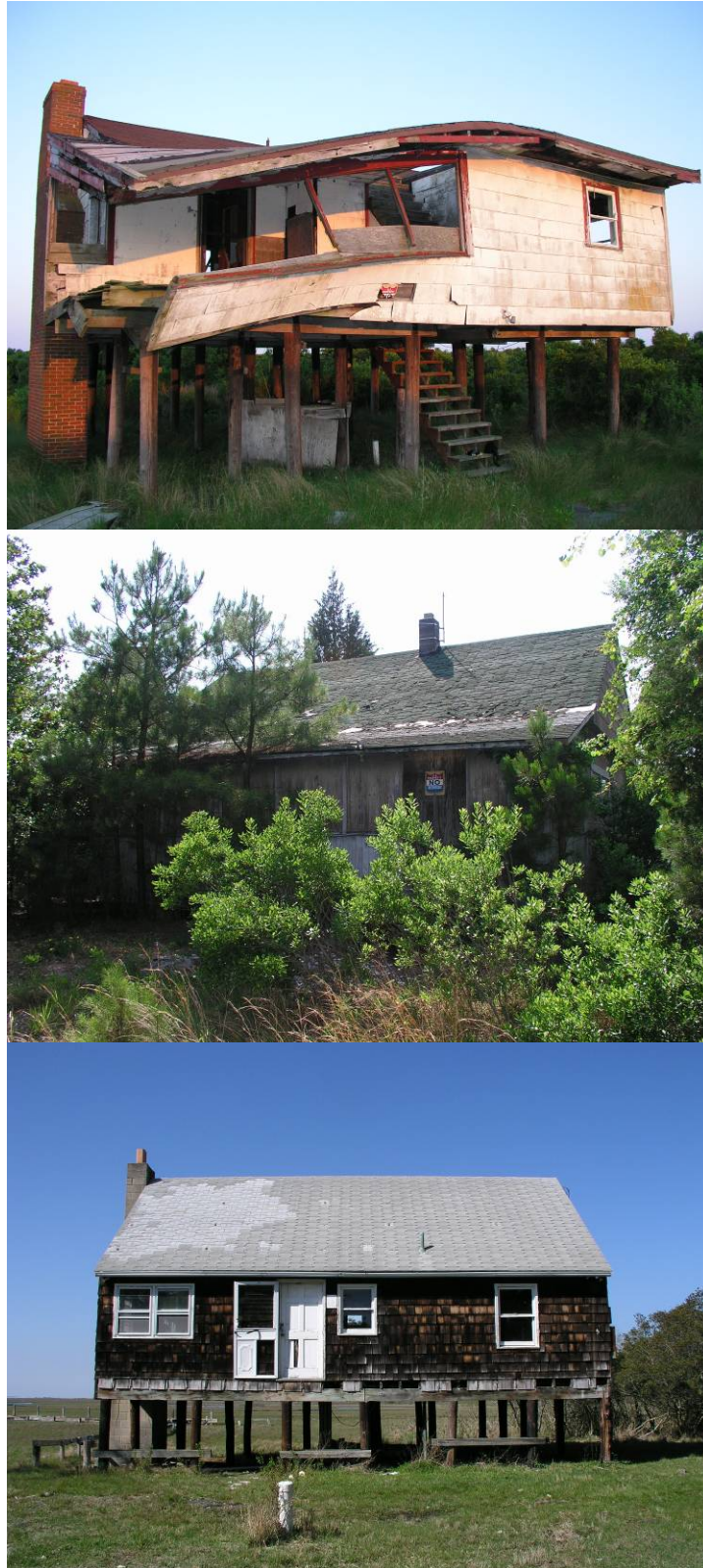


Figure 17. Dwellings on Assateague Island National Seashore examined for bat use during June 2006: Musser's (top), Peoples/Lynch (middle), and Valentine's (bottom).



Figure 18. Dwellings on Assateague Island National Seashore examined for bat use during June 2006: Green Run Lodge (top), High Winds (bottom)

Table 12. Structures examined for evidence of roosting bats or bats emerging at dusk at Assateague Island National Seashore, Maryland, June 2006.

Structure	Date	Time	Notes
Bob Odell	N/A	N/A	Structure located on small island. Did not check for bat use.
Buntings	2 June 2006	2010 – 2050	No bats emerged. No evidence of roosting bats or bat use.
Clements	19 June 2006	2015 – 2105	No bats emerged. No evidence of roosting bats or bat use. Cedar shingle siding, open/broken windows. Some holes in siding.
Clements Boathouse	N/A	N/A	Did not check.
Green Run Lodge	5 June 2006	2015 – 2055	No bats emerged. No evidence of roosting bats or bat use.
High Winds	24 June 2006	1330	Checked during daytime. No evidence of roosting bats or bat use.
Musser	20 June 2006	2005 – 2105	No bats emerged. No evidence of roosting bats or bat use. Many holes and cracks in exterior. Broken windows.
Peoples/Lynch	15 June 2006	2000 – 2100	No bats emerged. No evidence of roosting bats or bat use. Many holes and cracks in exterior.
Valentines	13 June 2006	2015 – 2100	No bats emerged. No evidence of roosting bats or bat use. Cedar shingle siding, open windows.

Table 13. Insect orders found in fecal and stomach samples of *Lasiurus borealis* ($n = 6$) at Assateague Island National Seashore, Maryland, 2005.

	Insect order				
	Hymenoptera	Lepidoptera	Coleoptera	Diptera	Hemiptera
Percent volume ^a	43.1	41.8	10.1	1.9	3.1
Percent frequency ^b	83.3	66.7	66.7	50.0	33.3

^a Average percent volume of fecal samples occupied by insect orders among all sampled bats.

^b Percent of sampled bats in which each insect order occur.

Discussion

Bat species composition at ASIS is somewhat similar to Coastal Plain bat communities found in the southeastern United States (Menzel et al. 2000b, 2003a). Some bat species that occur on the Coastal Plain of the United States, including Seminole bats, northern yellow bats, Rafinesque's big-eared bats (*Corynorhinus rafinesquii*), Brazilian free-tailed bats (*Tadarida brasiliensis*), and southeastern myotis (*Myotis austroriparius*), reach the northern periphery of their respective geographic ranges in southeastern Virginia and therefore were not expected to occur at ASIS (NAUS 2006). However, we documented 2 post-lactating Seminole bats on 20 July 2005. As this southeastern bat species had not previously been captured in Maryland, our captures would be a new addition to the bats of Maryland. However, there were doubts expressed by some wildlife professionals about our visual identification. As a result, photographs of the Seminole bat captured at ASIS were circulated among 8 bat experts in the southeastern United States. There was disagreement among them over whether the photographs were of a Seminole bat or a dark-morph eastern red bat. Without genetic analysis, our capture and identification of a Seminole bat remains questionable. Currently, it is not possible to distinguish Seminole bat echolocation calls from eastern red bat echolocation calls. Few records of Seminole bats are known north of ASIS: 2 in southeastern Pennsylvania (Poole 1932, 1949) and 1 in central New York (Layne 1955). Only 1 Seminole bat record is known from Virginia, in the Great Dismal Swamp National Wildlife Refuge (Linzey 1998). The geographic range of the Seminole bat is commonly associated with the range of Spanish moss (*Tillandsia usneoides*) in the southeastern United States (Barbour and Davis 1969). Seminole bats have been documented roosting in Spanish moss year round (Constantine 1958, Hein et al. 2005). The closest locality for Spanish moss in relation to ASIS is Northampton County, Virginia, just west of the town of Eastville on the Delmarva Peninsula, about 100 km south of where we captured the Seminole bats. In 2005, this population of Spanish moss was quite small, occurring on American holly (*Ilex opaca*) and loblolly pine. It was much more extensive early in the 20th century, growing on trees and even telephone lines (W.A. McAvoy, Delaware Natural Heritage Program, personal communication). Although Spanish moss is now extirpated in Maryland, in 1650 Colonel Henry Norwood described festoons of Spanish moss hanging from oak trees on the Eastern Shore of Maryland in what today is Worcester County (Wise 1988, Mountford 2004a, 2004b). Its extirpation from Maryland and decline on the Virginia portion of the Peninsula are likely due to a combination of factors. Spanish moss is at the northern limits of its geographic range on the Delmarva Peninsula and populations are likely stressed due to its sensitivity to poor air quality (C. Frye, Maryland Wildlife and Heritage Service, personal communication, W.A. McAvoy, Delaware Natural Heritage Program, personal communication). However, the ecological conditions necessary for the occurrence of the Seminole bat appear to be still present in the vicinity of Assateague Island.

Evening bats are commonly documented during bat surveys on the Coastal Plain of the southeastern United States, and have been captured in the nearby Pocomoke River watershed, about 18 km west of ASIS (Menzel et al. 2000b, 2003a, Limpert 2003). Evening bats and big brown bats in the Pocomoke River watershed preferred roosting in loblolly pine snags damaged by bark beetles (*Dendroctonus frontalis*, *D. terebrans*, *Ips* spp.). There have been no recent outbreaks of bark beetles at ASIS, and few snags occur in otherwise healthy loblolly stands (J. Kumer, National Park Service, personal communication). A shortage of snags may account for few big brown bats and no evening bats being documented at ASIS (Miles et al. 2006).

Moreover, the scarcity of cavity trees may contribute to myotine bats not being documented at ASIS. Only 1 myotine bat was documented during survey efforts in the nearby Pocomoke River watershed (Limpert 2003). On the Coastal Plain of the southeastern United States, myotine bats are documented less frequently than they are from the Piedmont west (Menzel et al. 2000b, 2003a). Although it is unclear why myotine bats are not common on the Coastal Plain, it is possible that long distances from hibernacula and, particularly at ASIS, a low diversity of roosting structures prevent them from occurring (Humphrey 1975, Furlonger et al. 1987).

The majority of our captures were eastern red bats, many of which were reproductive females and juveniles, indicating that ASIS provides important maternity roosts and foraging areas. Ford et al. (2002) suggested that female eastern red bats were more common on the Coastal Plain than on the Appalachian Highlands because of warmer summer temperatures at lower elevations. It is unknown if eastern red bats are roosting in loblolly pines or selecting for hardwoods, which typically are canopy intermediates at ASIS. In pine-mixed hardwoods forests in coastal Georgia, eastern red bats selected canopy dominant hardwoods for roost sites, whereas Seminole bats roosted primarily in pines (Menzel et al. 1998, Hein et al. 2005). In a managed pine forest in Mississippi, eastern red bats roosted in loblolly pines and canopy intermediate hardwood trees (Elmore et al. 2004).

Silver-haired bats probably only occur at ASIS as spring and autumn migrants (Paradiso 1969, Cryan 2003); they have been captured during northern saw-whet owl (*Aegolius acadicus*) surveys in autumn (D. Brinker, Maryland Department of Natural Resources, personal communication). The silver-haired bat events recorded with the BMS on 15 October 2005 and 2 November 2006 were probably a result of migrants passing through ASIS. Hoary bats probably migrate through ASIS as well, but a few may occur during summer, as is the case in other parts of Maryland (Paradiso 1969, Gates and Johnson 2005). Eastern pipistrelles likely occur sporadically on Maryland's Coastal Plain, as evidenced by our surveys and a few individuals captured in a survey of the Pocomoke River watershed (Paradiso 1969, Limpert 2003). They are known to occur along the coast and on the Coastal Plain of the southeastern United States (Menzel et al. 2000b, 2003a). Eastern pipistrelles are not known to migrate long distances (<55 km), and therefore may become less abundant farther away from their hibernacula (Barbour and Davis 1969). However, it is unclear why eastern pipistrelles, which are thought to be a short-distance migrant, would occur at ASIS; while myotine bats, which are known to migrate >200 km from their winter hibernacula to their summer ranges, do not (Griffin 1940). It is possible that eastern pipistrelles are migrating longer distances than previously documented, or they are hibernating closer to ASIS in atypical structures, including buildings and storm sewers (Fujita and Kunz 1984).

Acoustic Monitoring

During active acoustic monitoring, we recorded more bat activity in 2005 than in 2006. This difference is supported by capture data. It is likely that higher activity in 2005 was a result of additional activity contributed by juveniles. We captured no juveniles in 2006, but our surveys were conducted in June, which was too early in the summer to detect juvenile activity (LaVal and LaVal 1979). In July and August 2005, 45% of captured eastern red bats were juveniles.

Bat foraging activity was highest in forested areas and at freshwater pools at ASIS. Eastern red bats, which contributed a majority of recorded activity, commonly forage over water and in

fragmented areas in other parts of their range (Hutchinson and Lacki 1999, Elmore et al. 2005). On Sapelo Island, a barrier island off Georgia's coast, radio-tracked Seminole bats, northern yellow bats, and evening bats foraged in oak (*Quercus* spp.) stands and loblolly-slash pine (*Pinus elliotii*) stands more often than over dunes, marshes, and clearings (Krishon et al. 1997). It is possible that insects at ASIS may be more concentrated in or near the forests and freshwater pools, but this possibility has not been verified. In the Netherlands, *Pipistrellus pipistrellus* foraged along the leeward side of tree lines where insects, primarily Diptera (flies), were more concentrated (Verboom and Spoelstra 1999). It is common for insects to concentrate on the leeward side of windbreaks (Lewis and Stephenson 1966, Lewis and Dibley 1970).

The April–December active season for bats on ASIS documented by the BMS is typical for the mid-Atlantic region (Barbour and Davis 1969). The BMS also detected eastern red bat activity in February and early March, which indicates that some eastern red bats over winter at ASIS, probably roosting in leaf litter and emerging on warm winter days to forage (Whitaker et al. 1997, Dunbar and Tomasi 2006). In West Virginia and South Carolina, eastern red bats have been observed roosting under leaf litter during winter and spring (Moorman et al. 1999, Rodrigue et al. 2001). In Kentucky, 2 eastern red bats were found hanging from an American beech (*Fagus grandifolia*) on a warm, late-December day, but were not found the following day (Koontz and Davis 1991). The large quantity of activity recorded on 11 February may have been an equipment malfunction because the calls collected were very unusual in that their pulse durations were unusually large and there was much interference (ultrasonic or internal malfunction) within the data. The software developer assured us that these data were accurate, but in our experience, they were unlike any data we have hitherto collected and we suspect they were the result of an equipment malfunction, at least in part. Silver-haired bats, hoary bats, and eastern pipistrelles were only occasionally detected during our surveys, and only by the BMS. The northern BMS recorded far fewer bat echolocation passes, on average, than the middle and southern BMS because it was located far from mature forest stands where bats were more likely to roost. Bats recorded by the northern BMS, as well as those recorded during active acoustic monitoring on the northern portion of ASIS, probably roost on the mainland or Fenwick Island to the north and have home ranges encompassing the northern portion of ASIS. Overall, the 3 BMS recorded more bat activity during summer than in any other season, which was expected as female resident bats with young consistently forage in the same, relatively small (<400 ha) area and forage longer to meet energetic demands of reproduction, thus increasing perceived activity levels (Whitaker 1995, Hutchinson and Lacki 2000, Menzel et al. 2000a, Walters et al. 2007). In the spring and autumn, bats were recorded either migrating through ASIS or beginning to establish their summer home ranges within ASIS. More activity was recorded during autumn than spring at ASIS, possibly because of the addition of juveniles to the bat community occurring during summer and bats migrating to their winter ranges. Limited food resources, i.e., insects, prevent most bats from over wintering at ASIS (Fleming and Eby 2003). During the active season, bats were most active within the first few hours after sunset and became less active through the night (Hayes 1997, Reynolds 2006).

The effects of weather on bat activity have received much recent research attention. In general, high winds, low temperatures, high precipitation, high barometric pressure, and low relative humidity are negatively associated with bat activity (Lacki 1984, Paige 1995, Erickson and West 2002, Parsons et al. 2003, Reynolds 2006). These generalizations sometimes supported our findings, depending on the season. During winter-spring, bats were more active on nights with

higher temperatures, higher relative humidity, and higher percentage of rain, the last of which is confounding. As spring progresses, bat activity should increase as a result of warmer temperatures, which result in higher humidity and percentages of rain. However, average nightly percentage of rain in January was $6.8 \pm 0.7\%$ and $7.9 \pm 0.8\%$ in April. During winter-spring, bat activity was negatively associated with winds from the northwest, which typically are colder than winds from other directions. Some vagueness in effects of winter-spring weather conditions on bat activity may be partly explained by our categorization of data; 63.3% of nights had no bat activity and the remaining 36.7% was evenly distributed among low and high activity categories. High and low category sample sizes were relatively low compared to the “no activity” category. In summer, there were no clear associations between weather and bat activity. Temperature commonly has a positive effect on bat activity, but we found that the highest level of bat activity and low bat activity occurred at similar high mean nightly temperatures. Similarly, higher relative humidity, higher barometric pressure, and moderate wind speeds were positively associated with high bat activity and low bat activity. Again, some of the ambiguity may be attributable to data categorization. Regression analyses may show relationships that are easier to explain, but our data were not normally distributed and unresponsive to transformation. Moreover, regression analyses may show that the weather conditions explain bat activity as a concave-down function; a higher resolution of what we have already established. During autumn-winter, bat activity showed more of an expected response to weather conditions. Activity was lower during nights with high winds, low temperatures, and higher percentage of precipitation. During this time of year, bats are migrating and may be more sensitive to weather conditions because they are more physiologically stressed (Fleming and Eby 2003). Differences in responses of bats to weather conditions among seasons may be partly explained by their yearly life history traits, although we would expect similar responses between winter-spring and autumn-winter seasons when bats are migrating. Surely migrating bats are more physiologically stressed in spring than in autumn because insect resources are more readily available during summer when bats are preparing for autumn migration (Fleming and Eby 2003). Seasonal differences in effects of weather conditions on bat activity may be explained by differences in bat behavior and timing between the spring and autumn migrations, although migration remains one of the most poorly understood aspects of bat ecology

Species Richness, Evenness, and Diversity, Rarefaction, and Horn's Index of Similarity (HIS)

The Simpson's diversity index, species richness, and species evenness for the bat community at ASIS were much lower than bat communities inventoried in other areas in the mid-Atlantic (Edwards et al. 2001, Gates and Johnson 2005, Castleberry et al. 2006, Gates and Johnson 2007) and southeastern United States (Menzel et al. 2003b, Miller 2003, Ford et al. 2004). The narrow range of habitats (i.e., roosting and foraging opportunities) within ASIS likely contribute to the relatively low bat species diversity (Humphrey 1975). The species diversity value was low because of low species evenness caused by the large proportion of eastern red bats contributing to the total number of captured individuals.

The minimum number of captured bats, mist net sites, and acoustic monitoring sites needed to record all bat species at ASIS probably depends on species evenness, abundance, and distribution. Mist net sites are established within home ranges of an unknown number of bats and bat species. Potentially, few of the bats with home ranges encompassing the mist net sites may be captured. Moreover, we may 'miss' bats due to temporal aspects of bat ecology (e.g.,

migration). Identical mist-net sets may capture different species and numbers nightly at the same site (Edwards et al. 2001, Gates and Johnson 2007). In West Virginia, a small pool of water was mist netted for 14 nights over 2 summers before an Indiana myotis was captured (Edwards et al. 2001). However, 7 species commonly detected throughout their inventory were captured by the 5th night of mist netting various streams, pools, and corridors. At ASIS, with so few species occurring, increased mist net efforts may not result in additional species being documented. More species were documented using unobtrusive, long-term monitoring with bat detectors.

Minimum active acoustic monitoring effort needed to detect all species was slightly more than minimum mist-net effort. However, during our inventory, we could acoustically monitor multiple sites each night, but comparatively few sites with mist nets. Active acoustic monitoring recorded only 2 species that were captured in mist nets; but, to our knowledge, it did not record Seminole bat echolocation calls, which are indistinguishable from eastern red bat echolocation calls. Differences in bat species detection when using acoustic or capture methods are well documented (Kunz and Brock 1975, Murray et al. 1999, O'Farrell and Gannon 1999). In Missouri, significantly more species were detected with acoustic surveys than with mist nets (Murray et al. 1999). O'Farrell and Gannon (1999) found that a combination of acoustic and capture methods was most effective in completely evaluating species compositions in the western United States. At ASIS, the best method for documenting bat species was long-term passive acoustic monitoring with BMS. We eliminated potential and realized differences in nightly and season bat activity by monitoring year round (Hayes 1997, Milne et al. 2004). Also, some bat species are more effectively documented using acoustic monitoring than with capture techniques. For example, hoary bats are infrequently documented during mist netting in the mid-Atlantic region, but commonly are recorded during acoustic monitoring, possibly because they forage over the forest canopy and thus over mist nets (Shump and Shump 1982b, Gates and Johnson 2005). However, echolocation call data provide no information on age, sex, or reproductive condition of recorded bats. This information can only be reliably obtained using capture methods.

At ASIS, mist netting complemented active and passive acoustic monitoring in documenting relative frequencies of species common to our methods, according to Horn's Index of Similarity. In other words, the proportion of the total number of captured bat species was similar to the proportion of the total number of species-specific echolocation passes. For example, eastern red bats comprised 97.9% of the total capture, 96.7% of echolocation passes recorded during active acoustic monitoring, and 94.6% of echolocation passes recorded by BMS. Monitoring over the course of a year with BMS resulted in the addition of 3 species to the inventory, whereas mist netting contributed the Seminole bat captures.

Structure Evaluations

We did not observe any roosting bats, emerging bats, or any other evidence of bat use at any of the buildings at ASIS. It is possible that we may have missed a few individual bats roosting in the buildings. We examined the buildings during the peak of maternity season for bats, and it is unlikely that we missed any maternity colonies roosting in the buildings. Although the buildings are potential bat-roost sites, there are few bat species that occur or potentially occur at ASIS that will roost in buildings. The dominant bat species at ASIS is the eastern red bat, which typically roosts among tree foliage (Shump and Shump 1982a). A few big brown bats occur at ASIS and could potentially roost in buildings, either within the structures or under the cedar shingle siding

of some buildings. Evening bats could also use buildings, but we did not document them during our inventory. We were unable to access the Bob Odell structure, which is on a small island in Chincoteague Bay; and we did not check Clement's Boathouse, which is too small to provide a suitable roost site for bats.

Diet Analysis

Although ASIS is notorious for its mosquito population, we did not positively identify any mosquito remains (e.g., wings) in our samples. Dipterans, which may have included mosquitoes, comprised a small volume of bat diets, but were encountered in half the samples, indicating that eastern red bats do prey on flies, but not as much as other insect orders (Fascione et al. 1991). Eastern red bats are considered moth specialists (Dunning et al. 1992), but they have also been documented consuming coleopterans, dipterans, hemipterans, hymenopterans, orthopterans, and trichopterans (Ross 1961, Carter et al. 2003, Carter et al. 2004). Whitaker et al. (1997) reported red bats consuming lepidopterans and dipterans in winter months in Great Dismal Swamp, North Carolina and Virginia. Interestingly, Hymenoptera, especially flying ants, were the most important part of eastern red bat diets in our sample. The bats likely encountered and preyed upon concentrations of these insects, as we encountered up to 12 mandibles in individual samples (Griffith and Gates 1985). In 2 samples, we identified the hemelytra of water boatmen, which may occur at freshwater pools or brackish pools above the high-tide mark (Triplehorn and Johnson 2005). Our diet analysis provides only a small insight into the insect prey consumed by bats at ASIS. We analyzed diets of only a few individuals of 1 bat species and during a short period in the summer. The prey preferences of bats may vary seasonally depending on prey availability and energetic requirements (Whitaker 1995, Menzel et al. 2000a). We made no attempt to compare proportions of insect orders in bat diets to proportions of insect orders available at ASIS.

Conclusions

In summary, the loblolly pine-dominated forests at ASIS likely do not provide suitable roosting habitat for bat species that commonly roost in tree cavities or canopy dominant deciduous trees (Humphrey 1975). A combination of low roost diversity and long distances from hibernacula may have contributed to no myotis bats being documented at ASIS. Establishing bat houses may help increase bat species diversity at ASIS. Eastern red bats are the predominant bat species at ASIS, but big brown bats, hoary bats, silver-haired bats, and eastern pipistrelles occur there in limited numbers during summer, or spring and autumn migration. Our finding that bat activity was concentrated at freshwater pools in and around forested areas could be confirmed by radio telemetry studies. Freshwater pools are an important component of the ecosystem at ASIS, providing bats and other organisms freshwater on an island surrounded by saltwater. Inventories of bat species were most successfully accomplished by long-term monitoring with bat detectors. Bat activity was inconsistently predicted by weather conditions depending on season. Bats were most active from April–December. Bats use ASIS in a variety of ways, e.g., as a place for parturition and rearing offspring during summer, a stopover site during spring and autumn migration, and an over winter site for some species.

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Appendix I.

Accounts of bat species occurring or potentially occurring at Assateague Island National Seashore, Maryland.

Family Vespertilionidae

All bat species inhabiting or potentially inhabiting Assateague Island National Seashore (ASIS) belong to the Vespertilionidae family. This family contains 42 genera and 355 species on 6 continents (Nowak 1994). Within the United States, 10 genera and 45 species occur (Harvey et al. 1999). Potentially, up to 6 genera and 8 species occur at ASIS.

Big brown bat (*Eptesicus fuscus*)

Morphology: Of the 11 subspecies of big brown bat, 1 (*E. f. fuscus*) occurs at ASIS. Big brown bats are 1 of the largest bat species that occur in the region. Their fur is dark brown, similar to that of the little brown myotis (*Myotis lucifugus*), but their body size is much larger. Weights typically range from 13–25 g and head to tail lengths range from 10–13 cm (Kurta and Baker 1990). Longevity records of up to 19 years have been reported (Paradiso and Greenhall 1967).

Range and migration: The big brown bat is common throughout its range, which includes southern Canada, the continental United States, Central America, and northern South America (Kurta and Baker 1990). Migratory distances typically are <80 km between hibernacula and summer roosts (Griffin 1940, Beer 1955, Mills et al. 1975).

Roosting: Big brown bats typically hibernate in mines (Pearson 1962), caves (Hall and Brenner 1968, Gates et al. 1984), storm sewers (Goehring 1954), tunnels (Gates et al. 1984), and sometimes buildings (Whelden 1941, Whitaker and Gummer 2000). In summer, big brown bats roost in snags, buildings, and caves (Hall and Brenner 1968, Barbour and Davis 1969, Betts 1996). Females form maternity colonies that commonly are located in snags and buildings (Davis et al. 1968, Barbour and Davis 1969), and occasionally in rock crevices (Lausen and Barclay 2002). Big brown bats commonly return to the same structure to form maternity colonies each year, typically in May (Davis et al. 1968, Mills et al. 1975).

Reproduction: Maternity colonies may consist of >100 individuals (Brigham 1991). After a 60-day gestation period, females give birth to 1–2 young each in June. Young become volant at 3–5 weeks of age (Barbour and Davis 1969, Kurta and Baker 1990). Some female young return to their natal roost the next year (Mills et al. 1975).

Foraging: Big brown bats are among the first bats observed at dusk (Kunz 1973). Big brown bats often are observed foraging around streetlights (Furlonger et al. 1987), but they also forage in open areas, forest stands, forested riparian areas, and over waterways (Kurta 1982, Owen et al. 2004).

Big brown bats consume a variety of insects including coleopterans (beetles, weevils), dipterans (flies, mosquitoes), hemipterans (true bugs), hymenopterans (flying ants, wasps), lepidopterans (moths), orthopterans (locusts, katydids, crickets, grasshoppers), and trichopterans (caddisflies).

The majority of the big brown bat's diet consists of coleopterans, including many agricultural pests, e.g., spotted cucumber beetles (*Diabrotica undecimpunctata*; Griffith and Gates 1985, Whitaker 1995, Agosta and Morton 2003, Carter et al. 2003).

Status at ASIS: Big brown bats were the second-most commonly recorded bat species at ASIS. Most of the big brown bat activity was in the southern portion of ASIS, where the oldest forest tracts occur. We captured big brown bats only in the southern portion of ASIS, specifically the Green Run Lodge area. Few loblolly pine snags may occur at ASIS, providing few roosting opportunities for big brown bats. We captured a reproductively active female, indicating that big brown bats produce and raise offspring at ASIS.

Silver-haired bat (*Lasionycteris noctivagans*)

Morphology: The silver-haired bat is the only species in Genus *Lasionycteris*, and it is monotypic. It is a relatively average-sized bat compared to other bat species occurring at ASIS. The dorsal fur is mostly black with white or silver tips. Weights range from 8–11 g, and head to tail lengths range from 9–11 cm (Kunz 1982).

Range and migration: The silver-haired bat is considered common throughout the continental United States, southern Canada and Pacific coast to southern Alaska (Kunz 1982). The winter range of the silver-haired bat is the southern half of the continental United States. In spring, they migrate to the northern United States and Canada (Izor 1979). No studies have focused on migratory distances of silver-haired bats. During migration, silver-haired bats are known to collide with tall structures including lighthouses (Saunders 1930) and wind turbines (Johnson et al. 2003).

Roosting: Silver-haired bats have been documented hibernating in caves (Beer 1956, Krutzsch 1966), house basements (Bartsch 1956, Gosling 1977), mines (Pearson 1962), and in hollow trees (Jackson 1961). Summer and winter roosting colonies are small at <20 individuals (Barbour and Davis 1969). Little is known about specific summer roost characteristics of the silver-haired bat in the mid-Atlantic. The majority of silver-haired bat summer roosts have been documented in coniferous forests of the Pacific Northwest and Canada. Silver-haired bats have been documented roosting in abandoned woodpecker holes in Ontario, Saskatchewan, and British Columbia (Vonhof and Barclay 1996, Parsons et al. 1986). Crampton and Barclay (1998) found silver-haired bats roosting in cavities of trees in early stages of decay. In Washington, silver-haired bats have been found roosting under loose bark and in tree cavities (Campbell et al. 1996). In Manitoba, migrating silver-haired bats roosted singly in heavily furrowed bark and splits in tree trunks (Barclay et al. 1988). In West Virginia, Menzel et al. (2000b) found a silver-haired bat roosting beneath leaf litter, possibly during its fall migration.

Reproduction: During summer, females form maternity colonies of 3–16 individuals (Betts 1996). Females give birth to 1–2 young in late June after a 50–60 day gestation (Easterla and Watkins 1970, Kunz 1982). The young become volant by late July (Kunz 1971). Males typically occur singly throughout their range during summer (Kunz 1982).

Foraging: Silver-haired bats commonly forage in riparian areas near coniferous and mixed deciduous forests (Jones 1966, Edwards et al. 2001, Owen et al. 2004). The echolocation call structure and wing morphology of silver-haired bats are suited for foraging in the open and near trees (Barclay 1986, Patriquin and Barclay 2003). Silver-haired bats consume a wide variety of insects. In West Virginia, silver-haired bat diets consisted mainly of lepidopterans, but also dipterans, hemipterans, and coleopterans (Carter et al. 2003). Black (1974) considered silver-haired bats a moth-specialist. Other insects that have been consumed by silver-haired bats include trichopteran, and neuropterans (dobsonflies, lacewings) (Whitaker 1972, Brack 1983, Warner 1985).

Status at ASIS: During our inventories, we documented silver-haired bats only during spring and autumn migration. They migrate through ASIS and probably use the park as a stopover site. ASIS probably is too far south to be within the summer range (i.e., maternity range) of silver-haired bats.

Eastern red bat (*Lasiurus borealis*)

Morphology: Of the 5 subspecies of eastern red bat, only 1 (*L. b. borealis*) occurs at ASIS. It is a medium-sized bat with weights ranging from 10–13 g, and head to tail lengths averaging 11 cm (Shump and Shump 1982a). It is a rusty-orange color with hairs tipped with white, which is particularly evident in females. The dorsal portion of the tail membrane is furred.

Range and migration: The eastern red bat is considered common throughout its range, which includes the continental United States (except for the Rocky Mountain region), south through Central and South America into Argentina and Chile. Eastern red bats are migratory, traveling to northern latitudes in April–June for summer and to southern latitudes in August–October for winter (Shump and Shump 1982a, Cryan 2003). They migrate in groups during fall and sometimes collide with tall structures including buildings (Terres 1956), lighthouses (Saunders 1930), communications towers (Crawford and Baker 1981), and wind turbines (Johnson et al. 2003). Eastern red bats have been documented <210 km from land over the Atlantic Ocean during migration (Norton 1930, Carter 1950, Mackiewicz and Backus 1956).

Roosting: During winter, eastern red bats roost under tree foliage, in woodpecker holes (Fassler 1975), or under leaf litter (Moorman et al. 1999). During summer, eastern red bats roost under foliage of deciduous (McClure 1942, Mager and Nelson 2001) and coniferous trees (Menzel et al. 1998), behind shingles, under leaf litter (Mager and Nelson 2001), and in rare instances have been found in caves (Quay and Miller 1955). When roosting under tree foliage, eastern red bats may be 1.5–16.5 m above ground (McClure 1942, Menzel et al. 1998, Hutchinson and Lacki 1999, Mager and Nelson 2001). Roost tree switching occurs every 1–3 days (Menzel et al. 1998, Hutchinson and Lacki 1999, Mager and Nelson 2001). Eastern red bats roost in riparian and upland forests (Menzel et al. 1998, Hutchinson and Lacki 1999).

Reproduction: Females roost singly under tree foliage during the maternity season. In June, they give birth to as many as 4 young (Gates and Wolcott 1946, Packard 1956, Stains 1965, LaVal and LaVal 1979). Young become volant in 3–6 weeks (Barbour and Davis 1969).

Foraging: Eastern red bats typically forage within the first 2 hr after sunset (Kunz 1973) over open areas and wooded streams (Hart et al. 1993, Owen et al. 2004). In Kentucky, eastern red bats foraged 1.2–7.4 km from roosting sites and had home ranges encompassing 334.0 ha ($\pm$ 82.1 SE) (Hutchinson and Lacki 1999).

Eastern red bats are considered a moth specialist (Dunning et al. 1992), but they have also been documented consuming coleopterans, dipterans, hemipterans, hymenopterans, orthopterans, and trichopterans (Ross 1961, Carter et al. 2003, Carter et al. 2004). Whitaker et al. (1997) reported eastern red bats consuming lepidopterans and dipterans in winter months in Great Dismal Swamp, North Carolina and Virginia.

Status at ASIS: Eastern red bats are unequivocally the most abundant bat species at ASIS. They occur during all seasons, including winter when they likely roost in leaf litter and emerge on warm nights to forage. There are summer resident and spring and autumn migrant eastern red bats that occur at ASIS. Females produce and raise offspring at ASIS.

Hoary bat (*Lasiurus cinereus*)

Morphology: Of the 3 subspecies of hoary bat, 1 (*L. c. cinereus*) occurs at ASIS. It is the largest bat occurring in the region with weights ranging from 18–30 g, and head to tail lengths averaging 13 cm (Shump and Shump 1982b). Its fur is mahogany brown and tipped with white over most of its body. It has a furred tail membrane.

Range and migration: The range of the hoary bat includes Canada north to the tree line, the continental United States and Hawaii, south to Argentina and Chile (Shump and Shump 1982b). The hoary bat is considered common in the Pacific Northwest and prairie states, and uncommon in the eastern United States (Shump and Shump 1982b). Hoary bats have been documented in Iceland and far from land over the Atlantic Ocean during migration (Hayman 1959). The hoary bat occurs in the southern United States during winter and throughout the United States during summer. Fall migration occurs in concentrations of individuals in August–October. Spring migration is less organized in April–June (Findley and Jones 1964, Cryan 2003). During migration, hoary bats are known to collide with tall structures including lighthouses (Saunders 1930), communications towers (Crawford and Baker 1981), and wind turbines (Johnson et al. 2003).

Roosting: Few studies have investigated the roosting habits of hoary bats. Hoary bats have primarily been observed roosting singly in tree foliage 3–5 m from the ground (Constantine 1966, Tenaza 1966). In Saskatchewan, hoary bats were observed roosting on white spruce (*Picea glauca*) branches that were facing southeast and about 13 m above the ground (Willis and Brigham 2005). Occasionally, hoary bat remains are found in caves (Mumford 1953, Beer 1954). In Georgia, a hoary bat was observed roosting in a squirrel's nest (Neill 1952).

Reproduction: In June, females roost singly under tree foliage and give birth to 1–4 young, averaging 2 (Bogan 1972, Shump and Shump 1982b). Young become volant at 4–5 weeks of age (Bogan 1972).

Foraging: Hoary bats emerge for foraging subsequent to sympatric bat species (Kunz 1973). Barclay (1989) observed female hoary bats emerging from their roosts 30–45 min after sunset. Hoary bat foraging activity is highest after sunset and just before sunrise (Kunz 1973). Hoary bats forage in riparian areas, uncluttered areas (Owen et al. 2004), forest edges (Furlonger et al. 1987), and over waterways (Hart et al. 1993) and marshes (Barclay 1989). Hoary bats have been tracked foraging up to 20 km from their day roosts (Barclay 1989). The diet of the hoary bat consists primarily of lepidopterans (Black 1972). In West Virginia, lepidopterans comprised 98% of hoary bat diets (Carter et al. 2003). Other insects that hoary bats consume include coleopterans, dipterans, neuropterans, hymenopterans, and hemipterans (Zinn and Baker 1979, Warner 1985).

Status at ASIS: Hoary bats were documented at ASIS, but only with the 3 bat monitoring stations. It is likely that hoary bats migrate through ASIS, and a few may occur there during summer. ASIS probably is too far south to be within the summer range of female hoary bats.

Seminole bat (*Lasiurus seminolus*)

Morphology: *Lasiurus seminolus* is a monotypic species. It is a medium-sized bat with weights ranging from 9–14 g, and head to tail lengths averaging 10 cm (Wilkins 1987). Its fur is mahogany brown, darker than that of the similar eastern red bat.

Range and migration: The Seminole bat is considered common throughout its range, which includes the southeastern United States, from southeastern Virginia to Florida and west to Arkansas and eastern Texas. Extralimital records of Seminole bats have been documented in New York (Layne 1955), Pennsylvania (Poole 1932), southern Texas and Mexico (Wilkins 1987). The geographic range of the Seminole bat is considered to loosely coincide with the range of Spanish moss (Harvey et al. 1999). Seminole bats are not considered migratory.

Roosting: During winter, Seminole bats roost in Spanish moss, under pine leaf litter, and in pine needle clusters suspended from live vegetation (Barbour and Davis 1969, Hein et al. 2005). During summer, Seminole bats roost under foliage of deciduous and coniferous trees (Menzel et al. 1998), and in Spanish moss (Wilkins 1987). Seminole bats may roost on tree branches 1.0–16.3 m above ground (Wilkins 1987, Menzel et al. 1998, 1999).

Reproduction: Females roost singly under tree foliage during the maternity season. In June, they give birth to as many as 4 young (Barbour and Davis 1969).

Foraging: Seminole bats typically forage over open areas, pine barrens, and watercourses at treetop level (Wilkins 1987). In Georgia, the average distance Seminole bats foraged from their day roosts was <1 km. Home ranges encompassing <300 ha have been documented (Krishon et al. 1997). Seminole bats consume a variety of insects, including coleopterans, dipterans, hemipterans, and hymenopterans (Sherman 1935, Zinn 1977).

Status at ASIS: Wildlife professionals familiar with bat species in the southeastern United States have questioned our captures and identification of Seminole bats at ASIS, based on just morphological characteristics. As a result, photographs of the Seminole bat captured at ASIS

were circulated among 8 bat experts in the southeastern United States. There was disagreement among them over whether the photographs were of a Seminole bat or a dark-morph eastern red bat. Without genetic analysis, our purported capture of a Seminole bat remains debatable.

Little brown bat (*Myotis lucifugus*)

Morphology: Of the 6 subspecies of little brown myotis, 1 (*M. l. lucifugus*) potentially occurs at ASIS. Little brown myotis weights range from 4–8 g, and head to tail lengths average 9 cm (Fenton and Barclay 1980). It is brown in color, and usually has a glossy sheen. Little brown myotis have been documented living ≤ 30 years (Griffin and Hitchcock 1965, Keen and Hitchcock 1980).

Range and migration: The little brown myotis is considered common throughout its range, which includes Alaska, east through Canada, all continental U.S. except for the plains states, and parts of Florida and coastal areas of the southeastern U.S. (Fenton and Barclay 1980). Little brown myotis migrate < 272 km (Griffin 1940) between winter and summer ranges. They may form large groups that travel with cold fronts (Zimmerman 1937). There are no distinct latitudes occupied during summer and winter. Little brown myotis occupy northern and southern latitudes in the eastern U.S. year round (Barbour and Davis 1969).

Roosting: Little brown myotis hibernate in mines, road tunnels, and caves (Mohr 1942, Pearson 1962). They form loose aggregations within a hibernaculum, which may contain as many as 100,000 individuals (Barbour and Davis 1969). In summer, males and females roost in separate locations. Males may occupy caves (Krutzsch 1961, Hall and Brenner 1968), trees, and houses during summer (Fenton and Barclay 1980). Maternity colonies of hundreds to over a thousand individuals are established in barns, attics, and buildings (Cagle and Cockrum 1943, Smith and Goodpaster 1956, Davis et al. 1965). Few studies have documented non-commensal little brown myotis maternity roosts. Barclay and Cash (1985) documented a maternity colony of < 25 individuals in a hollow tree.

Reproduction: Gestation lasts 50–60 days before a single young is born in June (Wimsatt 1945, Kunz 1971). The young become volant at 3 weeks (Anthony and Kunz 1977).

Foraging: Little brown myotis emerge from their day roosts shortly after sunset to begin foraging along clearing edges (Patriquin and Barclay 2003), riparian areas (Owen et al. 2004), streams (Kurta 1982, Barclay 1991), and cluttered forest interiors (Adams 1996). In Canada, little brown myotis had a mean home range size of 30.1 ± 15.0 ha when pregnant and 17.6 ± 9.1 ha when lactating (Henry et al. 2002).

The diet of little brown myotis is diverse and may include coleopterans, dipterans, ephemeropterans (mayflies), hemipterans, hymenopterans, lepidopterans, neuropterans, and trichopterans (Buchler 1976, LaVal and LaVal 1980, Warner 1985, Carter et al. 2003)

Status in ASIS: Although the geographic range of the little brown myotis encompasses ASIS, we did not document any during our inventory. A few may occur at ASIS, but exist in such low numbers as to go undetected by our inventory. Indeed, little brown myotis are rarely encountered

on the Coastal Plain of the southeastern United States (Menzel et al. 2000b, 2003a, Limpert 2003).

Evening bat (*Nycticeius humeralis*)

Morphology: Of the 3 subspecies of evening bat, only 1 (*N. h. humeralis*) potentially occurs at ASIS. It is a medium-sized bat with weights ranging from 8 to 14 g, and head to tail lengths averaging 9 cm (Watkins 1972). It is similar in appearance to that of the big brown bat, but is smaller, with forearm lengths <40 mm.

Range and migration: Evening bats are considered common throughout their range, which includes the southeastern U.S. from southeastern Nebraska, east to New Jersey, south into Florida and west into northeastern Mexico (Watkins 1972). Evening bats migrate several hundred kilometers between summer and winter ranges (Humphrey and Cope 1968).

Roosting: During all seasons, evening bats roost under loose bark and tree cavities (Menzel et al. 1999, 2001a) and structures including barns (Humphrey and Cope 1968). Evening bats are not typically associated with caves (Barbour and Davis 1969). In May and June, females form maternity colonies of several hundred individuals in house attics and barns (Humphrey and Cope 1968, 1970, Wilkinson 1992). In South Carolina, tree cavities and loose bark provided roosts for smaller maternity colonies averaging 10.9 ± 5.8 (2 SE) individuals (Menzel et al. 2001a).

Reproduction: Each female evening bat gives birth to 1–4 young, averaging 2 (Watkins 1972). Parturition takes place from mid-May in southern latitudes to mid-June in the northern parts of its range. Young become volant at 3 weeks (Jones 1967).

Foraging: Evening bats fly in a slow, steady pattern while foraging (Watkins 1972). Menzel et al. (2002a) found that evening bat activity was higher along forest gaps and edges than within forest stands. Home ranges of evening bats on Sapelo Island, Georgia, averaged 15.11 ha with distances from day roosts averaging 157 ± 115 m (SE) (Krishon et al. 1997).

Diets of evening bats consist primarily of coleopterans, but they also consume dipterans, hemipterans, hymenopterans, lepidopterans, neuropterans, orthopterans, and trichopterans (Whitaker and Clem 1992, Carter et al. 2004).

Status at ASIS: We did not capture or acoustically detect evening bats at ASIS. Evening bats are considered common throughout their range and have been documented in the Pocomoke River watershed (Limpert 2003). This species may be more restricted to the Coastal Plain Province, rather than the Ridge and Valley or Blue Ridge Provinces of Maryland (Paradiso 1969). ASIS may not provide enough suitable roosting sites (i.e., snags, buildings) for a substantial evening bat population. Still, a few evening bats may occur at ASIS, but exist in such low numbers as to go undetected by our inventory.

Eastern pipistrelle (*Pipistrellus subflavus*)

Morphology: Of the 4 subspecies of eastern pipistrelle, only 1 (*P. s. subflavus*) occurs at ASIS. It is 1 of the smallest bats in the region, with weights ranging from 4–8 g, and lengths averaging

8 cm (Fujita and Kunz 1984). Its fur is rusty-orange and the dorsal sides of its forearms are pinkish-orange. Longevity records of >11 years have been recorded for eastern pipistrelles (Paradiso and Greenhall 1967).

Range and migration: The eastern pipistrelle is considered common throughout its range, which includes the eastern half of the continental United States, south to the Gulf of Mexico coastline (Fujita and Kunz 1984). Eastern pipistrelles may migrate up to 120 km, but typically migrate <50 km (Griffin 1940, 1945).

Roosting: During winter, eastern pipistrelles hibernate in storm sewers (Goehring 1954), mines (Pearson 1962, Menzel et al. 1997), and caves (Gates et al. 1984, Briggler and Prather 2003). They typically are the first bat species to enter and last to leave hibernacula (LaVal and LaVal 1980).

During summer, eastern pipistrelles segregate sexually. Males typically roost solitarily in leaf clusters (Findley 1954), caves (Hall and Brenner 1968), and mines (Johnson et al. 2006). Females have been documented forming maternity colonies of 11 individuals in a barn (Winchell and Kunz 1993), <29 individuals in barns, pavilions, sheds (Whitaker 1998), and <3 individuals in live- and dead-leaf clusters on broken branches of live trees (Carter et al. 1999, Veilleux et al. 2003). Females have been observed roosting singly in Spanish moss and understory trees (Menzel et al. 1999).

Reproduction: After a 44 day gestation period, females give birth to 2 young in June or early July (Wimsatt 1945, LaVal and LaVal 1980). The young become volant at 3 weeks of age (Lane 1946, Hoying 1983).

Foraging: Eastern pipistrelles are among the first bats to emerge at dusk to forage. They forage in forested riparian areas (Owen et al. 2004), over open water, in small forest gaps (Krusic and Neefus 1996), and along forest edges (Davis and Mumford 1962). Few studies have investigated home range size of eastern pipistrelles. A radio-telemetered female in Georgia had a home range of 389.2 ha and foraged 1137 m on average from her roost (Krishon et al. 1997). A radio-telemetered female in South Carolina had a home range of 395.5 ha (Carter et al. 1999). Eastern pipistrelles have a diverse diet that includes coleopterans, dipterans, hemipterans, hymenopterans, lepidopterans, and trichopterans (Sherman 1939, LaVal and LaVal 1980, Carter et al. 2003).

Status at ASIS: Eastern pipistrelles were infrequently detected during our inventory, and only by the bat monitoring stations in the northern and middle portions of ASIS. Few eastern pipistrelles may occur at ASIS from spring to autumn. Eastern pipistrelles are not considered to be a long-distance migrant. It is unknown if eastern pipistrelles at ASIS are migrating farther than previously documented migratory distances, or if they are hibernating nearby in unusual situations, including buildings and storm sewers. It is unclear if female eastern pipistrelles produce or raise offspring at ASIS.

Appendix II.

Bat roosting ecology and management at Assateague Island National Seashore, Maryland.

Bats potentially occurring at Assateague Island National Seashore (ASIS) are known to roost in tree canopies and tree cavities, under exfoliating tree bark and deciduous leaf litter, behind shutters and shingles, in buildings, bridges, caves, mines, tunnels, and storm sewers throughout their range (Barbour and Davis 1969). Typically, bats use caves, mines, and tunnels for hibernacula during winter. Bats have been documented using buildings for hibernacula, but this phenomenon probably does not occur at ASIS, or at least with any substantial frequency. Big brown bats (*Eptesicus fuscus*) are the most likely of the species occurring at ASIS to use buildings as hibernacula (Whelden 1941, Barbour and Davis 1969, Whitaker and Gummer 2000).

Although we received no reports of bats using buildings that are regularly occupied by National Park Service staff, future conflicts could arise if bats do move into these buildings. Potential conflicts exist between bat roosting behavior and park maintenance and visitor safety. Bats roosting in or on buildings during summer potentially can come in contact with park visitors creating health hazards. The most humane technique for limiting the conflict is to exclude the bats from within the structure. Excluding bats from buildings can be difficult because bats can gain access through very small holes and cracks (<1.5 cm). Access locations in buildings can be determined by observing bat emergence at dusk. Buildings should be sealed when bat occupancy is at a minimum (i.e., winter). The majority of bats in a colony disperse by September, but a few individuals may remain into November. Bats typically will return to summer roosts in April (Cagle and Cockrum 1943, Davis and Hitchcock 1965). Lost roosts should be mitigated by placement of bat houses nearby. Bat houses are most successful in attracting bat colonies when placed near lost roosts (Brittingham and Williams 2000, White 2004). Occupancy rates of >60% have been reported for bat houses placed near lost roosts (White 2004). Bat houses placed on trees or distant from existing colonies commonly have low occupancy rates. Mounting dark-colored (e.g., National Park Service brown) bat houses with large landing areas on buildings with solar exposure and existing colonies nearby have high potential for occupancy (White 2004). Bat colonies typically will not voluntarily relocate to a bat house from a building that has not been sealed (Brittingham and Williams 2000). Bat houses are available in a wide variety of shapes and sizes. Small bat houses can be placed when a small number of bats (<100) is displaced. Large bat houses and even bat condos can be used when hundreds or even thousands of bats are displaced. Because there is such a lack of roost diversity at ASIS, bat houses may attract species that were not frequently detected, or detected at all, during our inventory, including big brown bats, evening bats, and little brown myotis. Silver-haired bats also have been known to use bat houses (Kiser and Kiser 2001, Whitaker et al. 2006). Bats typically show fidelity to anthropogenic structures, possibly because of the relative permanency of such roosts. In contrast, roosts that are more ephemeral in nature (e.g., decaying trees) are used for shorter time periods (Lewis 1995).

Dead and dying trees that exist at ASIS may be used by several bat species, but may pose a hazard to visitor safety. Bat species that use cavities, crevices, and sloughing bark of dead and dying trees include big brown bats, silver-haired bats, and little brown myotis (Barbour and

Davis 1969). Bats using dead and dying trees sometimes switch roost trees as frequently as every few days (Brigham 1991, Lewis 1995). Dead and dying roost trees may be as small as 8.0 cm diameter at breast height (DBH), but more commonly are about 30 cm DBH and larger (Menzel et al. 2001b). Dead and dying trees should be retained, as they are potential roosts for bats and other wildlife species (Morrison et al. 1998). To limit direct impact to roosting bats, dead and dying trees may be felled in winter. Bats likely have evolved to adapt to the ephemeral nature of dead and dying tree roosts.

Some bat species, including big brown bats and eastern pipistrelles, that occur at ASIS are known to primarily hibernate in caves, mines, and tunnels, but no such hibernacula are present at ASIS (Barbour and Davis 1969). It is unknown where, or even if, hoary bats hibernate during winter. They are considered a long-distance migratory species, traveling hundreds of kilometers between their winter ranges in the southern North America and South America and their summer ranges in northern North America (Shump and Shump 1982b, Cryan 2003). Eastern red bats and silver-haired bats have been observed roosting under leaf litter during autumn, winter, and spring, which recently has raised concerns about the impact of prescribed fires on these bats (Moorman et al. 1999, Menzel et al. 2000c, Rodrigue et al. 2001).

Appendix III.

Site descriptions of mist net and acoustic monitoring sites located at Assateague Island National Seashore, 2005–2006.

Bat monitoring stations

Bat monitoring station 1	Acoustic monitoring site on northern portion of Assateague Island National Seashore, near kilometer 5.75.
Bat monitoring station 2	Acoustic monitoring site at Tingles, near pond 18A.
Bat monitoring station 3	Acoustic monitoring site at Pope Bay, near pond 33F.

Mist net sites

Site A	Mist net site at Tingles Canoe-In road and pond 18A.
Site B	Mist net site at Hungerford's road, near building and over pond 20G.
Site C	Mist net site at Life of Forest Trail near pond 15A.
Site D	Mist net site at Pine Tree Canoe-In.
Site E	Mist net site at Green Run pond 29C.
Site F	Mist net site at Green Run pond 29A and 29F.
Site G	Mist net site at Green Run Lodge pond 30A.
Site H	Mist net site at Hungerford's road and pond 20H.
Site I	Mist net site at Pine Tree near west forest edge.
Site J	Mist net site at Green Run Lodge Pond 30G.
Site K	Mist net site at Pope Bay road and near pond 33F.
Site L	Mist net site at Green Run, near the Valentine House.
Site M	Mist net site at Green Run Lodge Canoe-In.
Site N	Mist net site at Pope Bay Canoe-In.

Acoustic monitoring sites

Site 1	Acoustic monitoring (Anabat) site in forest by Hungerford's.
Site 2	Acoustic monitoring (Anabat) site at Hungerford's pond 20H.
Site 3	Acoustic monitoring (Anabat) site in shrub zone of Hungerford's.
Site 4	Acoustic monitoring (Anabat) site on beach at kilometer 20.
Site 5	Acoustic monitoring (Anabat) site at bayside of Tingles.
Site 6	Acoustic monitoring (Anabat) site on beach at kilometer 15.
Site 7	Acoustic monitoring (Anabat) site at bayside, Old Ferry Landing.
Site 8	Acoustic monitoring (Anabat) site at Tingles pond 18A.
Site 9	Acoustic monitoring (Anabat) site in forest at Tingles.
Site 10	Acoustic monitoring (Anabat) site in shrub zone at Tingles.
Site 11	Acoustic monitoring (Anabat) site at bayside of Pope Bay.
Site 12	Acoustic monitoring (Anabat) site on beach at kilometer 30.
Site 13	Acoustic monitoring (Anabat) site at Green Run Lodge pond 30G.
Site 14	Acoustic monitoring (Anabat) site at bayside of Green Run Lodge.
Site 15	Acoustic monitoring (Anabat) site in forest at Green Run Lodge.
Site 16	Acoustic monitoring (Anabat) site on beach at kilometer 25.
Site 17	Acoustic monitoring (Anabat) site at Life of Dunes trail.
Site 18	Acoustic monitoring (Anabat) site at Life of Forest trail pond 15A.

Site 19	Acoustic monitoring (Anabat) site at Life of Forest trail.
Site 20	Acoustic monitoring (Anabat) site at Life of Marsh trail.
Site 21	Acoustic monitoring (Anabat) site in forest at Fox Hills.
Site 22	Acoustic monitoring (Anabat) site in shrub zone at Fox Hills.
Site 23	Acoustic monitoring (Anabat) site at Fox Hills pond 24A.
Site 24	Acoustic monitoring (Anabat) site in shrub zone at Green Run.
Site 25	Acoustic monitoring (Anabat) site at Green Run pond 29C.
Site 26	Acoustic monitoring (Anabat) site at bayside of Pine Tree Canoe In.
Site 27	Acoustic monitoring (Anabat) site in forest at Pine Tree.
Site 28	Acoustic monitoring (Anabat) site in shrub zone at Pine Tree.
Site 29	Acoustic monitoring (Anabat) site at bayside of Green Run.
Site 30	Acoustic monitoring (Anabat) site at Green Run pond 29E.
Site 31	Acoustic monitoring (Anabat) site in shrub zone at Pope Bay.
Site 32	Acoustic monitoring (Anabat) site at forest at Green Run.
Site 33	Acoustic monitoring (Anabat) site on beach at kilometer 6.
Site 34	Acoustic monitoring (Anabat) site on beach at kilometer 0.
Site 35	Acoustic monitoring (Anabat) site on beach at kilometer 35

Appendix IV.

Bat captures during mist netting at Assateague Island National Seashore, 2005-2006.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
A	ASIS36	484813.562	4225507.341	7/12/2005	6	2100	0200	26.0	26.0	2130	LABO	A	F	lactating	15.75	41.0	2.6 × 9.0
A	ASIS36	484813.562	4225507.341	7/12/2005	6	2100	0200	26.0	26.0	2130	LABO	N/A	N/A	N/A	N/A	N/A	2.6 × 9.0
A	ASIS36	484813.562	4225507.341	7/12/2005	6	2100	0200	26.0	26.0	0107	LABO	A	F	lactating	14.50	43.0	2.6 × 9.0
A	ASIS37	484816.366	4225514.451	7/12/2005	6	2100	0200	26.0	26.0								2.6 × 9.0
A	ASIS38	484838.653	4225519.328	7/12/2005	6	2100	0200	26.0	26.0								2.6 × 12.0
A	ASIS39	484857.801	4225512.867	7/12/2005	6	2100	0200	26.0	26.0	2115	LABO	A	F	lactating	14.00	41.5	7.8 × 9.0
A	ASIS39	484857.801	4225512.867	7/13/2005	6	2100	0200	26.0	26.0	0010	LABO	A	F	lactating	14.50	41.5	7.8 × 9.0
A	ASIS39	484857.801	4225512.867	7/13/2005	6	2100	0200	26.0	26.0	0155	LABO	A	F	lactating	14.00	41.0	7.8 × 9.0
A	ASIS39	484857.801	4225512.867	7/13/2005	6	2100	0200	26.0	26.0	0200	LABO	A	F	lactating	13.50	40.0	7.8 × 9.0
A	ASIS36	484813.562	4225507.341	7/27/2005	6	2030	2200	30.0	27.0	2125	LABO	J	M	non-repro	9.25	38.5	2.6 × 9.0
A	ASIS36	484813.562	4225507.341	7/27/2005	6	2030	2200	30.0	27.0	2125	LABO	J	F	non-repro	8.75	40.5	2.6 × 9.0
A	ASIS37	484816.366	4225514.451	7/27/2005	6	2030	2200	30.0	27.0	2045	LABO	A	M	yes	10.25	38.5	2.6 × 9.0
A	ASIS37	484816.366	4225514.451	7/27/2005	6	2030	2200	30.0	27.0	2108	LABO	J	M	non-repro	8.75	39.5	2.6 × 9.0
A	ASIS38	484838.653	4225519.328	7/27/2005	6	2030	2200	30.0	27.0	2100	LABO	A	F	post-lactating	13.50	43.0	2.6 × 12.0
A	ASIS38	484838.653	4225519.328	7/27/2005	6	2030	2200	30.0	27.0	2125	LABO	A	F	post-lactating	17.00	40.5	2.6 × 12.0
A	ASIS39	484857.801	4225512.867	7/27/2005	6	2030	2200	30.0	27.0	2100	LABO	J	M	non-repro	8.50	38.0	7.8 × 9.0
A	ASIS39	484857.801	4225512.867	7/27/2005	6	2030	2200	30.0	27.0	2105	LABO	J	F	non-repro	9.50	40.0	7.8 × 9.0
A	ASIS39	484857.801	4225512.867	8/4/2005	6	2024	0130	28.0	26.0	2044	LABO	J	F	non-repro	11.50	42.0	7.8 × 9.0
A	ASIS39	484857.801	4225512.867	8/4/2005	6	2024	0130	28.0	26.0	2049	LABO	J	F	non-repro	9.25	41.0	7.8 × 9.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
A	ASIS39	484857.801	4225512.867	8/4/2005	6	2024	0130	28.0	26.0	2132	LABO	N/A	N/A	N/A	N/A	N/A	7.8 × 9.0
A	ASIS39	484857.801	4225512.867	8/4/2005	6	2024	0130	28.0	26.0	2140	LABO	J	F	non-repro	12.50	39.5	7.8 × 9.0
A	ASIS39	484857.801	4225512.867	8/4/2005	6	2024	0130	28.0	26.0	2231	LABO	N/A	N/A	N/A	N/A	N/A	7.8 × 9.0
A	ASIS39	484857.801	4225512.867	8/5/2005	6	2024	0130	28.0	26.0	0000	LABO	J	F	non-repro	12.00	41.0	7.8 × 9.0
A	ASIS39	484857.801	4225512.867	8/5/2005	6	2024	0130	28.0	26.0	0000	LABO	J	F	non-repro	14.00	40.0	7.8 × 9.0
A	ASIS38	484838.653	4225519.328	8/4/2005	6	2024	0130	28.0	26.0	2100	LABO	N/A	N/A	N/A	N/A	N/A	2.6 × 12.0
A	ASIS38	484838.653	4225519.328	8/4/2005	6	2024	0130	28.0	26.0	2157	LABO	J	M	yes	10.25	39.0	2.6 × 12.0
A	ASIS37	484816.366	4225514.451	8/4/2005	6	2024	0130	28.0	26.0								2.6 × 9.0
A	ASIS36	484813.562	4225507.341	8/4/2005	6	2024	0130	28.0	26.0	2115	LABO	N/A	N/A	N/A	N/A	N/A	2.6 × 9.0
A	ASIS36	484813.562	4225507.341	6/6/2006	5	2055	0100	18.0	18.0								2.6 × 9.0
A	ASIS37	484816.366	4225514.451	6/6/2006	5	2055	0100	18.0	18.0								2.6 × 6.0
A	ASIS38	484838.653	4225519.328	6/6/2006	5	2055	0100	18.0	18.0								2.6 × 12.0
A	ASIS39	484857.802	4225512.867	6/6/2006	5	2055	0100	18.0	18.0								2.6 × 9.0
A	ASIS42	484859.397	4225537.589	6/6/2006	5	2055	0100	18.0	18.0								2.6 × 12.0
A	ASIS40	484694.309	4225551.837	6/16/2006	6	2100	0145	23.0	19.0								7.8 × 12.0
A	ASIS41	484771.523	4225539.999	6/16/2006	6	2100	0145	23.0	19.0								2.6 × 9.0
A	ASIS37	484816.366	4225514.451	6/16/2006	6	2100	0145	23.0	19.0								2.6 × 6.0
A	ASIS36	484813.562	4225507.341	6/16/2006	6	2100	0145	23.0	19.0	2210	LABO	A	F	lactating	14.50	42.0	2.6 × 9.0
A	ASIS36	484813.562	4225507.341	10/20/2006	5	1850	2300	15.0	12.0	2034	LABO	A	M	non-repro	12.00	38.0	2.6 × 9.0
A	ASIS36	484813.562	4225507.341	10/20/2006	5	1850	2300	15.0	12.0	2034	LABO	A	M	non-repro	12.00	38.0	2.6 × 9.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
A	ASIS37	484816.366	4225514.451	10/20/2006	5	1850	2300	15.0	12.0	2111	LABO	A	M	non-repro	10.00	38.0	2.6 × 6.0
A	ASIS40	484694.309	4225551.837	10/20/2006	5	1850	2300	15.0	12.0	-	-	-	-	-	-	-	7.8 × 12.0
B	ASIS43	484711.442	4224151.518	7/13/2005	6	2045	0145	25.0	24.0	2120	LABO	A	F	lactating	14.00	42.0	2.6 × 9.0
B	ASIS43	484711.442	4224151.518	7/13/2005	6	2045	0145	25.0	24.0	2120	LABO	A	F	lactating	13.50	42.5	2.6 × 9.0
B	ASIS43	484711.442	4224151.518	7/13/2005	6	2045	0145	25.0	24.0	2220	LABO	A	F	lactating	14.50	43.0	2.6 × 9.0
B	ASIS43	484711.442	4224151.518	7/13/2005	6	2045	0145	25.0	24.0	2230	LABO	A	F	lactating	16.25	42.0	2.6 × 9.0
B	ASIS43	484711.442	4224151.518	7/13/2005	6	2045	0145	25.0	24.0	2249	LABO	A	F	lactating	17.75	41.5	2.6 × 9.0
B	ASIS44	484707.812	4224154.839	7/13/2005	6	2045	0145	25.0	24.0	-	-	-	-	-	-	-	2.6 × 9.0
B	ASIS45	484686.504	4224141.370	7/13/2005	6	2045	0145	25.0	24.0	-	-	-	-	-	-	-	7.8 × 12.0
B	ASIS46	484686.021	4224136.164	7/13/2005	6	2045	0145	25.0	24.0	2222	LABO	A	F	lactating	14.25	41.5	2.6 × 12.0
B	ASIS47	484732.419	4224094.026	6/1/2006	4	2040	0200	23.0	23.0	2310	LABO	A	F	pregnant	20.50	40.0	7.8 × 12.0
B	ASIS45	484686.504	4224141.370	6/2/2006	4	2040	0200	23.0	23.0	0015	LABO	N/A	N/A	N/A	N/A	N/A	7.8 × 12.0
B	ASIS45	484686.504	4224141.370	6/1/2006	4	2040	0200	23.0	23.0	2120	LABO	A	F	pregnant	19.00	42.0	2.6 × 9.0
B	ASIS47	484732.419	4224094.026	6/2/2006	4	2040	0200	23.0	23.0	0200	LABO	A	M	non-repro	10.50	43.0	2.6 × 9.0
B	ASIS47	484732.419	4224094.026	6/12/2006	7	2040	0145	18.0	16.0	-	-	-	-	-	-	-	2.6 × 9.0
B	ASIS45	484686.504	4224141.370	6/12/2006	7	2040	0145	18.0	16.0	-	-	-	-	-	-	-	7.8 × 12.0
B	ASIS48	484702.646	4224160.529	6/12/2006	7	2040	0145	18.0	16.0	-	-	-	-	-	-	-	2.6 × 9.0
B	ASIS44	484707.812	4224154.839	6/12/2006	7	2040	0145	18.0	16.0	2248	LABO	A	F	pregnant	20.00	41.0	2.6 × 9.0
B	ASIS43	484711.442	4224151.518	6/12/2006	7	2040	0145	18.0	16.0	-	-	-	-	-	-	-	2.6 × 9.0
B	ASIS43	484711.442	4224151.518	10/20/2006	5	1845	2300	15.0	12.0	-	-	-	-	-	-	-	2.6 × 9.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
B	ASIS45	484686.504	4224141.370	10/20/2006	5	1845	2300	15.0	12.0	2215	LABO	A	F	non-repro	12.25	43.0	7.8 × 12.0
B	ASIS47	484732.419	4224094.026	10/20/2006	5	1845	2300	15.0	12.0	-	-	-	-	-	-	-	2.6 × 9.0
C	ASIS49	486146.437	4227792.146	7/18/2005	4	2045	0145	30.0	25.0	-	-	-	-	-	-	-	2.6 × 6.0
C	ASIS50	486118.291	4227795.914	7/18/2005	4	2045	0145	30.0	25.0	-	-	-	-	-	-	-	2.6 × 12.0
C	ASIS51	486099.184	4227799.008	7/18/2005	4	2045	0145	30.0	25.0	2200	LABO	A	F	post-lactating	15.25	40.0	2.6 × 6.0
C	ASIS52	486114.626	4227815.019	7/18/2005	4	2045	0145	30.0	25.0	-	-	-	-	-	-	-	2.6 × 9.0
C	ASIS53	486065.709	4227798.000	7/25/2005	6	2035	0145	27.0	25.5	-	-	-	-	-	-	-	7.8 × 9.0
C	ASIS51	486099.184	4227799.008	7/25/2005	6	2035	0145	27.0	25.5	2155	LABO	A	F	post-lactating	15.00	40.5	2.6 × 6.0
C	ASIS50	486118.291	4227795.914	7/25/2005	6	2035	0145	27.0	25.5	-	-	-	-	-	-	-	2.6 × 12.0
C	ASIS52	486114.626	4227815.019	7/25/2005	6	2035	0145	27.0	25.5	-	-	-	-	-	-	-	2.6 × 9.0
C	ASIS49	486146.437	4227792.146	6/7/2006	7	2030	0200	23.0	19.0	2146	LABO	A	M	non-repro	10.50	42.0	2.6 × 9.0
C	ASIS50	486118.291	4227795.914	6/7/2006	7	2030	0200	23.0	19.0	2224	LABO	A	F	pregnant	17.50	45.0	2.6 × 9.0
C	ASIS51	486099.184	4227799.008	6/7/2006	7	2030	0200	23.0	19.0	-	-	-	-	-	-	-	2.6 × 9.0
C	ASIS52	486114.626	4227815.019	6/7/2006	7	2030	0200	23.0	19.0	-	-	-	-	-	-	-	2.6 × 6.0
C	ASIS53	486065.709	4227798.000	6/7/2006	7	2030	0200	23.0	19.0	-	-	-	-	-	-	-	7.8 × 9.0
D	ASIS54	483515.014	4221686.431	7/19/2005	4	2055	0155	30.0	29.0	-	-	-	-	-	-	-	7.8 × 12.0
D	ASIS55	483517.666	4221717.736	7/19/2005	4	2055	0155	30.0	29.0	-	-	-	-	-	-	-	2.6 × 9.0
E	ASIS56	481835.607	4215010.466	7/20/2005	6	2045	0145	28.0	26.0	-	-	-	-	-	-	-	2.6 × 6.0
E	ASIS57	481841.170	4215008.301	7/20/2005	6	2045	0145	28.0	26.0	2050	LABO	A	F	post-lactating	12.00	40.5	2.6 × 12.0
E	ASIS57	481841.170	4215008.301	7/20/2005	6	2045	0145	28.0	26.0	2105	LABO	A	F	post-lactating	13.50	42.5	2.6 × 12.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
E	ASIS57	481841.170	4215008.301	7/20/2005	6	2045	0145	28.0	26.0	2150	LABO	A	F	post-lactating	16.50	42.0	2.6 × 12.0
E	ASIS58	481849.559	4215001.803	7/20/2005	6	2045	0145	28.0	26.0	2055	LABO	A	F	post-lactating	12.50	41.5	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/20/2005	6	2045	0145	28.0	26.0	2055	LABO	A	F	post-lactating	N/A	N/A	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/20/2005	6	2045	0145	28.0	26.0	2105	LASE	A	F	post-lactating	12.00	40.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/20/2005	6	2045	0145	28.0	26.0	2123	LASE	A	F	post-lactating	12.00	40.5	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/20/2005	6	2045	0145	28.0	26.0	2148	LABO	A	F	post-lactating	14.25	43.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/20/2005	6	2045	0145	28.0	26.0	2210	LABO	A	F	post-lactating	13.50	40.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/20/2005	6	2045	0145	28.0	26.0	2250	LABO	A	F	post-lactating	15.50	42.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/20/2005	6	2045	0145	28.0	26.0	2325	LABO	A	F	post-lactating	14.25	44.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/21/2005	6	2045	0145	28.0	26.0	0015	LABO	J	F	non-repro	9.25	40.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/21/2005	6	2045	0145	28.0	26.0	0030	LABO	A	F	post-lactating	12.50	40.5	7.8 × 9.0
E	ASIS59	481853.248	4214998.030	7/20/2005	6	2045	0145	28.0	26.0	2115	LABO	A	F	post-lactating	12.75	40.5	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/20/2005	6	2045	0145	28.0	26.0	2126	LABO	A	F	post-lactating	14.75	41.0	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/20/2005	6	2045	0145	28.0	26.0	2210	LABO	A	F	post-lactating	14.75	43.0	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/20/2005	6	2045	0145	28.0	26.0	2250	LABO	J	F	non-repro	10.00	40.0	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/26/2005	6	2035	0135	26.0	25.0	2105	LABO	A	F	post-lactating	13.50	40.0	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/26/2005	6	2035	0135	26.0	25.0	2105	LABO	A	F	post-lactating	12.75	41.5	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/26/2005	6	2035	0135	26.0	25.0	2115	LABO	A	F	post-lactating	14.00	42.0	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/26/2005	6	2035	0135	26.0	25.0	2115	LABO	J	F	non-repro	11.00	42.0	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/26/2005	6	2035	0135	26.0	25.0	2135	LABO	A	M	non-repro	11.50	37.0	2.6 × 12.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
E	ASIS59	481853.248	4214998.030	7/26/2005	6	2035	0135	26.0	25.0	2145	LABO	J	M	non-repro	9.00	39.0	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/26/2005	6	2035	0135	26.0	25.0	2219	LABO	J	F	non-repro	9.50	41.0	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/26/2005	6	2035	0135	26.0	25.0	2232	LABO	A	F	post-lactating	14.25	39.5	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	7/26/2005	6	2035	0135	26.0	25.0	2255	LABO	A	F	post-lactating	16.75	42.0	2.6 × 12.0
E	ASIS58	481849.559	4215001.803	7/26/2005	6	2035	0135	26.0	25.0	2040	LABO	J	M	non-repro	8.00	38.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/26/2005	6	2035	0135	26.0	25.0	2125	LABO	J	M	non-repro	7.50	38.5	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/26/2005	6	2035	0135	26.0	25.0	2140	LABO	A	F	post-lactating	16.50	40.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/26/2005	6	2035	0135	26.0	25.0	2145	LABO	J	F	non-repro	9.25	42.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/26/2005	6	2035	0135	26.0	25.0	2200	LABO	J	M	non-repro	8.50	39.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/26/2005	6	2035	0135	26.0	25.0	2200	LABO	A	F	post-lactating	15.50	39.5	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	7/26/2005	6	2035	0135	26.0	25.0	2210	LABO	J	F	non-repro	9.50	39.5	7.8 × 9.0
E	ASIS57	481841.170	4215008.301	7/26/2005	6	2035	0135	26.0	25.0	2050	LABO	J	M	non-repro	7.25	36.5	2.6 × 12.0
E	ASIS57	481841.170	4215008.301	7/26/2005	6	2035	0135	26.0	25.0	2200	LABO	J	M	non-repro	8.75	37.0	2.6 × 12.0
E	ASIS57	481841.170	4215008.301	7/26/2005	6	2035	0135	26.0	25.0	2328	LABO	J	F	non-repro	10.50	39.5	2.6 × 12.0
E	ASIS57	481841.170	4215008.301	7/27/2005	6	2035	0135	26.0	25.0	0010	LABO	A	F	post-lactating	16.50	42.5	2.6 × 12.0
E	ASIS60	481854.498	4215005.003	7/26/2005	6	2035	0135	26.0	25.0	2137	LABO	J	F	non-repro	9.50	39.0	2.6 × 6.0
E	ASIS60	481854.498	4215005.003	7/26/2005	6	2035	0135	26.0	25.0	2240	LABO	J	M	non-repro	8.75	39.0	2.6 × 6.0
E	ASIS59	481853.248	4214998.030	8/12/2005	5	2020	0125	27.0	25.0	2224	LABO	J	F	non-repro	10.25	41.0	2.6 × 12.0
E	ASIS58	481849.559	4215001.803	8/12/2005	5	2020	0125	27.0	25.0	2052	LABO	N/A	N/A	N/A	N/A	N/A	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	8/12/2005	5	2020	0125	27.0	25.0	2053	LABO	J	M	yes	9.50	38.5	7.8 × 9.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
E	ASIS58	481849.559	4215001.803	8/12/2005	5	2020	0125	27.0	25.0	2058	LABO	N/A	N/A	N/A	N/A	N/A	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	8/12/2005	5	2020	0125	27.0	25.0	2103	LABO	A	M	yes	9.50	39.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	8/12/2005	5	2020	0125	27.0	25.0	2119	LABO	J	F	non-repro	11.00	42.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	8/12/2005	5	2020	0125	27.0	25.0	2226	LABO	J	F	non-repro	10.50	40.5	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	8/12/2005	5	2020	0125	27.0	25.0	2247	LABO	A	F	non-repro	11.50	43.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	8/13/2005	5	2020	0125	27.0	25.0	0040	LABO	J	F	non-repro	11.50	42.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	8/13/2005	5	2020	0125	27.0	25.0	0125	LABO	J	M	yes	9.25	42.0	7.8 × 9.0
E	ASIS57	481841.170	4215008.301	8/12/2005	5	2020	0125	27.0	25.0	2053	LABO	A	M	yes	9.00	39.5	2.6 × 12.0
E	ASIS60	481854.498	4215005.003	6/5/2006	5	2100	0200	20.0	15.0	2130	LABO	A	F	pregnant	14.50	41.0	2.6 × 6.0
E	ASIS60	481854.498	4215005.003	6/5/2006	5	2100	0200	20.0	15.0	2210	LABO	A	F	pregnant	18.50	44.0	2.6 × 6.0
E	ASIS60	481854.498	4215005.003	6/5/2006	5	2100	0200	20.0	15.0	2233	LABO	A	F	pregnant	19.50	42.0	2.6 × 6.0
E	ASIS60	481854.498	4215005.003	6/5/2006	5	2100	0200	20.0	15.0	2239	LABO	A	F	pregnant	15.50	43.0	2.6 × 6.0
E	ASIS58	481849.559	4215001.803	6/5/2006	5	2100	0200	20.0	15.0	2315	LABO	A	F	pregnant	19.50	40.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	6/5/2006	5	2100	0200	20.0	15.0	2315	LABO	A	F	pregnant	18.00	43.0	7.8 × 9.0
E	ASIS59	481853.248	4214998.030	6/5/2006	5	2100	0200	20.0	15.0	2335	LABO	A	F	pregnant	15.50	40.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	6/6/2006	5	2100	0200	20.0	15.0	0150	LABO	A	F	non-repro	12.00	41.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	6/5/2006	5	2100	0200	20.0	15.0	2305	LABO	A	F	pregnant	18.50	43.0	2.6 × 12.0
E	ASIS58	481849.559	4215001.803	6/6/2006	5	2100	0200	20.0	15.0	0136	LABO	A	F	pregnant	18.50	43.0	2.6 × 12.0
E	ASIS58	481849.559	4215001.803	6/26/2006	5	2250	0150	22.0	22.0	2110	LABO	A	F	lactating	14.50	42.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	6/26/2006	5	2250	0150	22.0	22.0	2110	LABO	A	F	lactating	13.50	41.0	7.8 × 9.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
E	ASIS59	481853.248	4214998.030	6/26/2006	5	2250	0150	22.0	22.0	2200	LABO	A	F	pregnant	14.50	40.0	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	6/26/2006	5	2250	0150	22.0	22.0	2310	LABO	A	F	pregnant	15.50	41.0	2.6 × 12.0
E	ASIS59	481853.248	4214998.030	6/27/2006	5	2250	0150	22.0	22.0	0150	LABO	A	F	lactating	14.75	42.0	2.6 × 12.0
E	ASIS60	481854.498	4215005.003	6/26/2006	5	2250	0150	22.0	22.0	2200	LABO	A	F	lactating	12.50	41.0	2.6 × 6.0
E	ASIS59	481853.248	4214998.030	10/19/2006	5	1845	2300	20.0	19.0								2.6 × 12.0
E	ASIS58	481849.559	4215001.803	10/19/2006	5	1845	2300	20.0	19.0	2000	LABO	N/A	N/A	N/A	N/A	N/A	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	10/19/2006	5	1845	2300	20.0	19.0	2020	LABO	N/A	N/A	N/A	N/A	N/A	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	10/19/2006	5	1845	2300	20.0	19.0	2105	LABO	A	M	non-repro	10.00	40.0	7.8 × 9.0
E	ASIS58	481849.559	4215001.803	10/19/2006	5	1845	2300	20.0	19.0	2135	LABO	N/A	N/A	N/A	N/A	N/A	7.8 × 9.0
E	ASIS60	481854.498	4215005.003	10/19/2006	5	1845	2300	20.0	19.0								2.6 × 6.0
F	ASIS61	481243.183	4215328.731	7/21/2005	4	2035	0138	27.0	27.0								2.6 × 9.0
F	ASIS62	481249.276	4215332.199	7/21/2005	4	2035	0138	27.0	27.0	2200	LABO	A	F	post-lactating	14.00	41.5	5.2 × 9.0
F	ASIS62	481249.276	4215332.199	7/21/2005	4	2035	0138	27.0	27.0	2200	LABO	A	F	post-lactating	16.00	42.5	5.2 × 9.0
F	ASIS62	481249.276	4215332.199	7/21/2005	4	2035	0138	27.0	27.0	2230	LABO	A	F	post-lactating	14.75	41.0	5.2 × 9.0
F	ASIS63	481262.844	4215336.406	7/21/2005	4	2035	0138	27.0	27.0								2.6 × 12.0
G	ASIS64	481299.168	4214571.967	7/22/2005	5	2020	0145	27.0	27.0	2040	LABO	A	F	post-lactating	13.25	41.0	2.6 × 12.0
G	ASIS64	481299.168	4214571.967	7/22/2005	5	2020	0145	27.0	27.0	2107	LABO	A	F	post-lactating	14.25	41.0	2.6 × 12.0
G	ASIS64	481299.168	4214571.967	7/22/2005	5	2020	0145	27.0	27.0	2120	LABO	A	F	post-lactating	13.25	40.5	2.6 × 12.0
G	ASIS64	481299.168	4214571.967	7/22/2005	5	2020	0145	27.0	27.0	2145	EPFU	A	M	yes	16.50	47.0	2.6 × 12.0
G	ASIS64	481299.168	4214571.967	7/22/2005	5	2020	0145	27.0	27.0	2155	LABO	J	M	non-repro	8.25	39.0	2.6 × 12.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
G	ASIS64	481299.168	4214571.967	7/22/2005	5	2020	0145	27.0	27.0	2214	LABO	A	F	post-lactating	15.75	44.5	2.6 × 12.0
G	ASIS64	481299.168	4214571.967	7/22/2005	5	2020	0145	27.0	27.0	2221	EPFU	A	F	lactating	20.50	46.5	2.6 × 12.0
G	ASIS64	481299.168	4214571.967	7/22/2005	5	2020	0145	27.0	27.0	2303	LABO	J	M	non-repro	10.25	40.0	2.6 × 12.0
G	ASIS64	481299.168	4214571.967	7/22/2005	5	2020	0145	27.0	27.0	2312	LABO	A	F	post-lactating	14.75	40.5	2.6 × 12.0
G	ASIS64	481299.168	4214571.967	7/23/2005	5	2020	0145	27.0	27.0	0040	LABO	A	F	post-lactating	11.75	40.5	2.6 × 12.0
G	ASIS65	481302.581	4214568.952	7/22/2005	5	2020	0145	27.0	27.0	2055	LABO	A	F	post-lactating	13.00	45.0	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	7/22/2005	5	2020	0145	27.0	27.0	2105	LABO	A	F	post-lactating	14.00	42.0	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	7/22/2005	5	2020	0145	27.0	27.0	2156	LABO	J	F	non-repro	8.75	39.5	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	7/22/2005	5	2020	0145	27.0	27.0	2227	LABO	A	F	post-lactating	15.00	41.0	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	7/22/2005	5	2020	0145	27.0	27.0	2250	LABO	A	F	post-lactating	14.75	41.5	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	7/22/2005	5	2020	0145	27.0	27.0	2318	LABO	J	M	non-repro	7.00	38.5	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	7/22/2005	5	2020	0145	27.0	27.0	2319	LABO	A	F	post-lactating	14.75	40.0	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	7/22/2005	5	2020	0145	27.0	27.0	2345	LABO	A	F	post-lactating	12.50	40.0	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	7/22/2005	5	2020	0145	27.0	27.0	2353	LABO	J	F	non-repro	8.75	39.0	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	7/22/2005	5	2020	0145	27.0	27.0	2354	LABO	J	M	non-repro	8.50	40.5	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	7/23/2005	5	2020	0145	27.0	27.0	0055	LABO	A	F	post-lactating	13.50	39.5	7.8 × 12.0
G	ASIS66	481360.729	4214593.318	7/22/2005	5	2020	0145	27.0	27.0								2.6 × 6.0
G	ASIS65	481302.581	4214568.952	8/10/2005	4	2010	0122	28.0	24.0	2122	LABO	J	M	yes	10.25	39.0	7.8 × 12.0
G	ASIS64	481299.168	4214571.967	8/10/2005	4	2010	0122	28.0	24.0	2105	LABO	J	M	non-repro	8.50	37.0	2.6 × 12.0
G	ASIS65	481302.581	4214568.952	6/21/2006	4	2040	0200	24.0	22.0	2110	LABO	A	F	pregnant	18.00	42.0	7.8 × 12.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X*	UTM Y*	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
G	ASIS65	481302.581	4214568.952	6/21/2006	4	2040	0200	24.0	22.0	2130	LABO	A	F	lactating	15.50	42.0	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	6/21/2006	4	2040	0200	24.0	22.0	2210	LABO	A	F	lactating	16.50	43.0	7.8 × 12.0
G	ASIS65	481302.581	4214568.952	6/21/2006	4	2040	0200	24.0	22.0	2250	LABO	A	M	non-repro	13.50	39.0	7.8 × 12.0
G	ASIS64	481299.168	4214571.967	6/21/2006	4	2040	0200	24.0	22.0								2.6 × 12.0
H	ASIS67	484892.493	4224058.413	7/28/2005	5	2030	0023	26.0	25.0	2202	LABO	J	F	non-repro	10.75	41.0	2.6 × 9.0
H	ASIS67	484892.493	4224058.413	7/28/2005	5	2030	0023	26.0	25.0	2233	LABO	J	M	non-repro	9.50	39.0	2.6 × 9.0
H	ASIS68	484836.115	4224041.657	7/28/2005	5	2030	0023	26.0	25.0								2.6 × 12.0
H	ASIS69	484836.859	4224027.981	7/28/2005	5	2030	0023	26.0	25.0								2.6 × 12.0
H	ASIS70	484828.309	4224025.312	7/28/2005	5	2030	0023	26.0	25.0	2139	LABO	J	F	non-repro	11.50	42.0	2.6 × 12.0
H	ASIS71	484794.186	4224078.894	7/28/2005	5	2030	0023	26.0	25.0	2050	LABO	J	M	non-repro	7.75	38.0	2.6 × 9.0
H	ASIS71	484794.186	4224078.894	7/28/2005	5	2030	0023	26.0	25.0	2139	LABO	J	M	non-repro	10.75	39.5	2.6 × 9.0
H	ASIS71	484794.186	4224078.894	7/28/2005	5	2030	0023	26.0	25.0	2200	LABO	J	F	non-repro	11.00	40.5	2.6 × 9.0
H	ASIS71	484794.186	4224078.894	7/28/2005	5	2030	0023	26.0	25.0	2351	LABO	J	M	non-repro	9.25	38.5	2.6 × 9.0
H	ASIS47	484732.419	4224094.026	8/5/2005	3	2020	0130	26.0	26.0								2.6 × 9.0
H	ASIS71	484794.186	4224078.894	8/5/2005	3	2020	0130	26.0	26.0								2.6 × 9.0
H	ASIS67	484892.493	4224058.413	8/5/2005	3	2020	0130	26.0	26.0	2115	LABO	J	M	non-repro	10.00	41.5	2.6 × 9.0
I	ASIS73	483649.736	4221458.483	7/29/2005	5	2030	0000	25.0	24.0	2101	LABO	J	M	non-repro	10.25	38.5	2.6 × 12.0
I	ASIS74	483641.307	4221486.815	7/29/2005	5	2030	0000	25.0	24.0	2033	LABO	J	M	non-repro	11.75	42.5	7.8 × 9.0
I	ASIS74	483641.307	4221486.815	7/29/2005	5	2030	0000	25.0	24.0	2136	LABO	J	F	non-repro	11.00	41.0	7.8 × 9.0
I	ASIS74	483641.307	4221486.815	7/29/2005	5	2030	0000	25.0	24.0	2136	LABO	J	F	non-repro	12.50	42.5	7.8 × 9.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X*	UTM Y*	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
I	ASIS74	483641.307	4221486.815	7/29/2005	5	2030	0000	25.0	24.0	2150	LABO	A	M	yes	12.50	39.0	7.8 × 9.0
I	ASIS74	483641.307	4221486.815	7/29/2005	5	2030	0000	25.0	24.0	2205	LABO	A	F	post-lactating	15.50	42.5	7.8 × 9.0
I	ASIS75	483633.846	4221504.365	7/29/2005	5	2030	0000	25.0	24.0								2.6 × 6.0
I	ASIS73	483649.736	4221458.483	8/11/2005	5	2025	0125	28.0	27.0	2045	LABO	J	M	yes	9.25	39.0	2.6 × 12.0
I	ASIS73	483649.736	4221458.483	8/11/2005	5	2025	0125	28.0	27.0	2050	LABO	A	M	yes	9.25	38.0	2.6 × 12.0
I	ASIS73	483649.736	4221458.483	8/11/2005	5	2025	0125	28.0	27.0	2103	LABO	A	M	yes	9.75	39.0	2.6 × 12.0
I	ASIS73	483649.736	4221458.483	8/11/2005	5	2025	0125	28.0	27.0	2141	LABO	J	M	yes	8.75	38.0	2.6 × 12.0
I	ASIS74	483641.307	4221486.815	8/11/2005	5	2025	0125	28.0	27.0	2048	LABO	J	F	non-repro	9.50	38.0	7.8 × 9.0
I	ASIS75	483633.846	4221504.365	8/11/2005	5	2025	0125	28.0	27.0	2035	LABO	J	M	yes	10.50	38.0	2.6 × 6.0
I	ASIS75	483633.846	4221504.365	8/11/2005	5	2025	0125	28.0	27.0	2050	LABO	N/A	N/A	N/A	N/A	N/A	2.6 × 6.0
I	ASIS76	483647.671	4221438.271	6/8/2006	6	2045	0145	21.0	19.0								2.6 × 12.0
I	ASIS72	483645.235	4221446.818	6/8/2006	6	2045	0145	21.0	19.0								2.6 × 12.0
I	ASIS73	483649.736	4221458.483	6/8/2006	6	2045	0145	21.0	19.0	2130	LABO	A	F	non-repro	13.50	38.0	2.6 × 12.0
I	ASIS73	483649.736	4221458.483	6/8/2006	6	2045	0145	21.0	19.0	2200	LABO	A	F	pregnant	19.50	42.0	2.6 × 12.0
I	ASIS74	483641.307	4221486.815	6/8/2006	6	2045	0145	21.0	19.0	2130	LABO	A	F	pregnant	15.50	43.0	7.8 × 9.0
I	ASIS74	483641.307	4221486.815	6/8/2006	6	2045	0145	21.0	19.0	2230	LABO	A	F	pregnant	22.50	40.0	7.8 × 9.0
I	ASIS74	483641.307	4221486.815	6/8/2006	6	2045	0145	21.0	19.0	2345	LABO	A	F	pregnant	23.00	42.0	7.8 × 9.0
I	ASIS74	483641.307	4221486.815	6/22/2006	5	2045	0145	21.0	25.0								7.8 × 9.0
I	ASIS73	483649.736	4221458.483	6/22/2006	5	2045	0145	21.0	25.0								2.6 × 12.0
I	ASIS77	483650.047	4221428.346	6/22/2006	5	2045	0145	21.0	25.0								2.6 × 9.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
J	ASIS78	481486.047	4214489.552	8/3/2005	4	2025	0130	26.0	18.0	.	.	.	.	.	.	.	7.8 × 9.0
J	ASIS79	481503.415	4214512.843	8/3/2005	4	2025	0130	26.0	18.0	.	.	.	.	.	.	.	2.6 × 9.0
K	ASIS80	479640.138	4211123.820	8/8/2005	4	2020	0110	29.0	26.0	2020	LABO	J	F	non-repro	9.50	42.5	2.6 × 6.0
K	ASIS81	479609.750	4211135.135	8/8/2005	4	2020	0110	29.0	26.0	.	.	.	.	.	.	.	2.6 × 6.0
K	ASIS82	479627.041	4211182.088	8/8/2005	4	2020	0110	29.0	26.0	2040	LABO	N/A	N/A	N/A	N/A	N/A	2.6 × 12.0
K	ASIS82	479627.041	4211182.088	8/8/2005	4	2020	0110	29.0	26.0	2120	LABO	J	M	non-repro	9.50	39.0	2.6 × 12.0
K	ASIS83	479652.349	4211186.897	8/8/2005	4	2020	0110	29.0	26.0	.	.	.	.	.	.	.	2.6 × 6.0
K	ASIS80	479640.138	4211123.820	6/9/2006	4	2050	0150	18.5	18.0	2115	LABO	A	F	pregnant	17.50	42.0	2.6 × 6.0
K	ASIS81	479609.750	4211135.135	6/9/2006	4	2050	0150	18.5	18.0	2050	LABO	A	F	non-repro	14.50	42.0	2.6 × 6.0
K	ASIS82	479627.041	4211182.088	6/9/2006	4	2050	0150	18.5	18.0	.	.	.	.	.	.	.	2.6 × 12.0
K	ASIS83	479652.349	4211186.897	6/9/2006	4	2050	0150	18.5	18.0	2145	LABO	A	F	pregnant	18.50	43.0	2.6 × 9.0
L	ASIS85	481458.718	4215933.504	6/13/2006	5	2110	0200	21.0	18.5	2135	LABO	A	F	non-repro	13.50	43.0	7.8 × 6.0
L	ASIS85	481458.718	4215933.504	6/14/2006	5	2110	0200	21.0	18.5	0027	LABO	A	F	pregnant	18.00	43.0	7.8 × 6.0
L	ASIS86	481454.305	4215946.887	6/13/2006	5	2110	0200	21.0	18.5	.	.	.	.	.	.	.	2.6 × 6.0
L	ASIS87	481451.853	4215955.281	6/13/2006	5	2110	0200	21.0	18.5	.	.	.	.	.	.	.	2.6 × 12.0
M	ASIS88	481324.623	4214622.658	6/15/2006	6	2120	0200	20.0	17.0	.	.	.	.	.	.	.	2.6 × 6.0
M	ASIS89	481297.553	4214638.725	6/15/2006	6	2120	0200	20.0	17.0	.	.	.	.	.	.	.	2.6 × 12.0
M	ASIS90	481289.042	4214650.263	6/15/2006	6	2120	0200	20.0	17.0	2130	LABO	A	F	pregnant	18.00	42.0	7.8 × 12.0
M	ASIS90	481289.042	4214650.263	6/15/2006	6	2120	0200	20.0	17.0	2250	LABO	A	F	lactating	15.50	42.5	7.8 × 12.0
M	ASIS90	481289.042	4214650.263	6/15/2006	6	2120	0200	20.0	17.0	2250	LABO	A	F	lactating	14.50	41.0	7.8 × 12.0

Appendix IV. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	No. nets	Time open	Time close	°C at open	°C at close	Time	Species ^b	Age	Sex	Repro. cond.	Weight (g)	Forearm (mm)	Net dimensions (m)
M	ASIS90	481289.042	4214650.263	6/15/2006	6	2120	0200	20.0	17.0	2340	LABO	A	F	pregnant	17.50	44.0	7.8 × 12.0
M	ASIS90	481289.042	4214650.263	6/15/2006	6	2120	0200	20.0	17.0	2340	LABO	A	F	pregnant	21.00	41.0	7.8 × 12.0
M	ASIS90	481289.042	4214650.263	6/15/2006	6	2120	0200	20.0	17.0	2350	LABO	A	F	pregnant	18.50	40.0	7.8 × 12.0
M	ASIS90	481289.042	4214650.263	6/15/2006	6	2120	0200	20.0	17.0	2355	LABO	A	F	pregnant	17.00	43.0	7.8 × 12.0
M	ASIS90	481289.042	4214650.263	6/16/2006	6	2120	0200	20.0	17.0	0030	LABO	A	F	lactating	15.50	42.0	7.8 × 12.0
M	ASIS90	481289.042	4214650.263	6/16/2006	6	2120	0200	20.0	17.0	0150	LABO	A	M	non-repro	11.00	41.0	7.8 × 12.0
M	ASIS91	481278.908	4214681.808	6/15/2006	6	2120	0200	20.0	17.0	2325	LABO	A	F	pregnant	18.50	41.0	2.6 × 9.0
M	ASIS91	481278.908	4214681.808	6/16/2006	6	2120	0200	20.0	17.0	0100	LABO	A	F	pregnant	16.50	42.0	2.6 × 9.0
M	ASIS88	481324.623	4214622.658	10/19/2006	5	1850	2300	20.0	19.0	23	23	23	23	23	23	23	2.6 × 12.0
M	ASIS90	481289.042	4214650.263	10/19/2006	5	1850	2300	20.0	19.0	23	23	23	23	23	23	23	7.8 × 12.0
M	ASIS91	481278.908	4214681.808	10/19/2006	5	1850	2300	20.0	19.0	23	23	23	23	23	23	23	2.6 × 9.0
N	ASIS92	479416.922	4211169.752	6/27/2006	6	2045	0015	23.0	N/A	23	23	23	23	23	23	23	7.8 × 12.0
N	ASIS93	479421.380	4211183.133	6/27/2006	6	2045	0015	23.0	N/A	23	23	23	23	23	23	23	2.6 × 6.0
N	ASIS94	479386.815	4211171.982	6/27/2006	6	2045	0015	23.0	N/A	2120	LABO	A	F	lactating	14.50	41.0	2.6 × 12.0
N	ASIS95	479379.000	4211122.919	6/27/2006	6	2045	0015	23.0	N/A	23	23	23	23	23	23	23	2.6 × 9.0

^a Universal Transverse Mercator coordinates in North American Datum 83, 18 North.

^b EPFU = *Eptesicus fuscus*; LABO = *Lasiurus borealis*; LASE = *Lasiurus seminolus*.

Appendix V.

Bat echolocation calls collected at Assateague Island National Seashore, 2005–2006.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	Start time	Total	NOID ^b	NOID FB	EPFU	EPFU FB	LABO	LABO FB
1	ASIS1	484668.606	4224210.372	7/12/2005	2053	0	0	0	0	0	0	0
				7/28/2005	2207	7	0	0	0	0	7	0
				6/16/2006	2136	5	1	0	0	0	4	0
				6/24/2006	0013	0	0	0	0	0	0	0
2	ASIS2	484839.315	4224060.961	7/12/2005	2118	2	2	0	0	0	0	0
				8/1/2005	2142	49	6	0	0	0	43	0
				6/16/2006	2113	8	1	0	0	0	7	1
				6/24/2006	0035	1	0	0	0	0	1	0
3	ASIS3	485138.790	4223999.739	7/12/2005	2144	0	0	0	0	0	0	0
				7/28/2005	2235	27	5	0	0	0	22	1
				6/16/2006	2051	1	0	0	0	0	1	0
				6/24/2006	0058	2	1	0	0	0	1	0
4	ASIS4	485123.054	4222910.271	7/12/2005	2211	0	0	0	0	0	0	0
				7/29/2005	2121	0	0	0	0	0	0	0
				6/8/2006	2328	0	0	0	0	0	0	0
				6/12/2006	2222	0	0	0	0	0	0	0

Appendix V. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	Start time	Total	NOID ^b	NOID FB	EPFU	EPFU FB	LABO	LABO FB
5	ASIS5	484540.371	4225490.156	7/12/2005	2305	11	2	0	0	0	9	0
				8/1/2005	2039	7	1	0	0	0	6	0
				3/27/2006	1840	0	0	0	0	0	0	0
				6/6/2006	2100	5	2	0	0	0	3	0
				6/19/2006	2210	11	1	0	0	0	10	0
6	ASIS6	486527.363	4227591.239	7/13/2005	2102	0	0	0	0	0	0	0
				7/25/2005	2214	0	0	0	0	0	0	0
				6/7/2006	2204	0	0	0	0	0	0	0
				6/16/2006	2310	0	0	0	0	0	0	0
7	ASIS7	485756.754	4228101.558	7/13/2005	2134	1	0	0	0	0	1	0
				7/25/2005	2247	0	0	0	0	0	0	0
				6/7/2006	2056	0	0	0	0	0	0	0
				6/16/2006	2213	0	0	0	0	0	0	0
8	ASIS8	484811.558	4225516.218	7/13/2005	2215	0	0	0	0	0	0	0
				8/1/2005	2106	57	4	0	0	0	53	0
				6/12/2006	2150	41	4	0	0	0	37	2
				6/19/2006	2255	0	0	0	0	0	0	0
9	ASIS9	484658.571	4225556.170	7/13/2005	2238	6	1	0	0	0	5	0

Appendix V. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	Start time	Total	NOID ^b	NOID FB	EPFU	EPFU FB	LABO	LABO FB
10	ASIS10	485465.261	4225418.350	8/1/2005	2044	123	25	0	0	0	98	0
				6/6/2006	2122	5	0	0	0	0	5	0
				6/19/2006	2233	6	0	0	0	0	6	0
				7/13/2005	2306	3	2	0	0	0	1	0
				8/1/2005	2109	1	0	0	0	0	1	0
				6/12/2006	2126	7	1	0	0	0	6	0
				6/19/2006	2320	1	1	0	0	0	0	0
11	ASIS11	479448.895	4211173.058	7/14/2005	2052	9	6	0	0	0	3	0
				7/22/2005	2121	11	2	0	3	0	6	1
				6/9/2006	2053	6	0	0	0	0	6	0
				6/15/2006	2319	1	1	0	0	0	0	0
12	ASIS12	481519.283	4213613.039	7/14/2005	2144	0	0	0	0	0	0	0
				7/22/2005	2049	0	0	0	0	0	0	0
				6/9/2006	2206	0	0	0	0	0	0	0
				6/15/2006	2226	2	0	0	0	0	2	0
13	ASIS13	481503.822	4214487.649	7/14/2005	2206	10	4	0	0	0	6	0
				7/21/2005	2257	28	4	0	0	0	24	2
				6/13/2006	2225	22	5	0	2	0	15	2

Appendix V. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	Start time	Total	NOID ^b	NOID FB	EPFU	EPFU FB	LABO	LABO FB
14	ASIS14	481273.085	4214754.660	6/26/2006	2332	12	1	0	0	0	11	1
				7/14/2005	2231	7	1	0	0	0	6	0
				7/21/2005	2226	4	0	0	0	0	4	0
				6/13/2006	2142	14	3	0	0	0	11	0
15	ASIS15	481361.826	4214597.606	6/26/2006	2247	0	0	0	0	0	0	0
				7/14/2005	2255	12	10	0	0	0	2	0
				7/21/2005	2157	71	15	0	0	0	56	1
				6/13/2006	2203	4	0	0	0	0	4	0
16	ASIS16	483673.737	4218117.328	6/26/2006	2309	20	1	0	0	0	19	0
				7/15/2005	2055	0	0	0	0	0	0	0
				8/1/2005	2201	0	0	0	0	0	0	0
				6/8/2006	2243	0	0	0	0	0	0	0
17	ASIS17	486033.616	4226902.027	6/21/2006	2226	0	0	0	0	0	0	0
				7/15/2005	2138	0	0	0	0	0	0	0
				7/25/2005	2141	0	0	0	0	0	0	0
				6/7/2006	2239	1	0	0	0	0	1	0
18	ASIS18	486091.888	4227792.575	6/20/2006	2222	0	0	0	0	0	0	0
				7/15/2005	2204	3	1	0	0	0	2	0

Appendix V. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	Start time	Total	NOID ^b	NOID FB	EPFU	EPFU FB	LABO	LABO FB
19	ASIS19	486172.229	4227828.514	7/29/2005	2047	1	0	0	0	0	1	0
				6/12/2006	2052	0	0	0	0	0	0	0
				6/16/2006	2240	3	0	0	0	0	3	0
				7/15/2005	2231	0	0	0	0	0	0	0
				7/25/2005	2114	7	2	0	0	0	5	0
				6/7/2006	2310	0	0	0	0	0	0	0
				6/20/2006	2247	0	0	0	0	0	0	0
				7/15/2005	2300	0	0	0	0	0	0	0
				7/25/2005	2044	0	0	0	0	0	0	0
				6/7/2006	2125	0	0	0	0	0	0	0
20	ASIS20	485860.923	4228700.789	6/20/2006	2315	0	0	0	0	0	0	0
				7/19/2005	2037	31	6	0	0	0	25	1
				7/29/2005	2151	5	1	0	0	0	4	0
				6/8/2006	2126	5	2	0	0	0	3	0
				6/21/2006	2200	4	3	0	0	0	1	0
22	ASIS22	483735.269	4219743.377	7/19/2005	2101	5	2	0	0	0	3	0
				7/29/2005	2238	2	1	0	0	0	1	0
				6/8/2006	2150	0	0	0	0	0	0	0

Appendix V. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	Start time	Total	NOID ^b	NOID FB	EPFU	EPFU FB	LABO	LABO FB
23	ASIS23	484009.545	4219730.572	6/21/2006	2132	1	1	0	0	0	0	0
				7/19/2005	2125	0	0	0	0	0	0	0
				7/29/2005	2215	0	0	0	0	0	0	0
				6/8/2006	2213	0	0	0	0	0	0	0
24	ASIS24	481728.893	4214476.833	6/21/2006	2109	2	0	0	0	0	2	0
				7/19/2005	2216	33	12	0	0	0	21	0
				7/22/2005	2226	7	2	0	0	0	5	1
				6/9/2006	2232	0	0	0	0	0	0	0
25	ASIS25	481836.629	4215014.193	6/15/2006	2354	1	0	0	0	0	1	0
				7/19/2005	2249	91	7	0	0	0	84	4
				7/22/2005	2306	39	4	0	6	0	29	0
				3/27/2006	1935	27	12	0	15	1	0	0
26	ASIS26	483495.721	4221733.661	6/13/2006	2113	9	4	0	0	0	5	0
				6/15/2006	2159	9	4	0	0	0	5	0
				7/20/2005	2119	13	5	0	0	0	8	0
				8/5/2005	2028	26	10	0	0	0	16	2
				6/12/2006	2256	2	2	0	0	0	0	0
				6/26/2006	2104	6	1	0	0	0	5	0

Appendix V. Continued.

Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	Start time	Total	NOID ^b	NOID FB	EPFU	EPFU FB	LABO	LABO FB
27	ASIS27	483648.420	4221459.356	7/20/2005	2144	8	1	0	0	0	7	0
				8/5/2005	2050	42	17	0	0	0	25	0
				6/12/2006	2318	0	0	0	0	0	0	0
				6/26/2006	2125	0	0	0	0	0	0	0
28	ASIS28	484367.860	4221184.545	7/20/2005	2210	1	1	0	0	0	0	0
				8/5/2005	2120	0	0	0	0	0	0	0
				6/8/2006	2053	0	0	0	0	0	0	0
				6/26/2006	2149	1	1	0	0	0	0	0
29	ASIS29	481446.234	4215962.783	7/20/2005	2333	3	1	0	0	0	2	0
				8/3/2005	2142	23	3	0	0	0	20	5
				6/15/2006	2132	10	0	0	0	0	10	0
				6/21/2006	2307	7	1	0	0	0	6	0
30	ASIS30	481147.141	4215378.309	7/20/2005	2357	17	2	0	0	0	15	0
				8/3/2005	2057	18	3	0	0	0	15	0
				6/13/2006	2256	10	2	0	0	0	8	0
				6/21/2006	2356	1	0	0	1	0	0	0
31	ASIS31	480075.854	4211621.412	7/21/2005	2048	36	12	0	0	0	24	0
				7/22/2005	2148	5	0	0	2	0	3	0
				6/9/2006	2140	3	1	0	0	0	2	0

Appendix V. Continued.

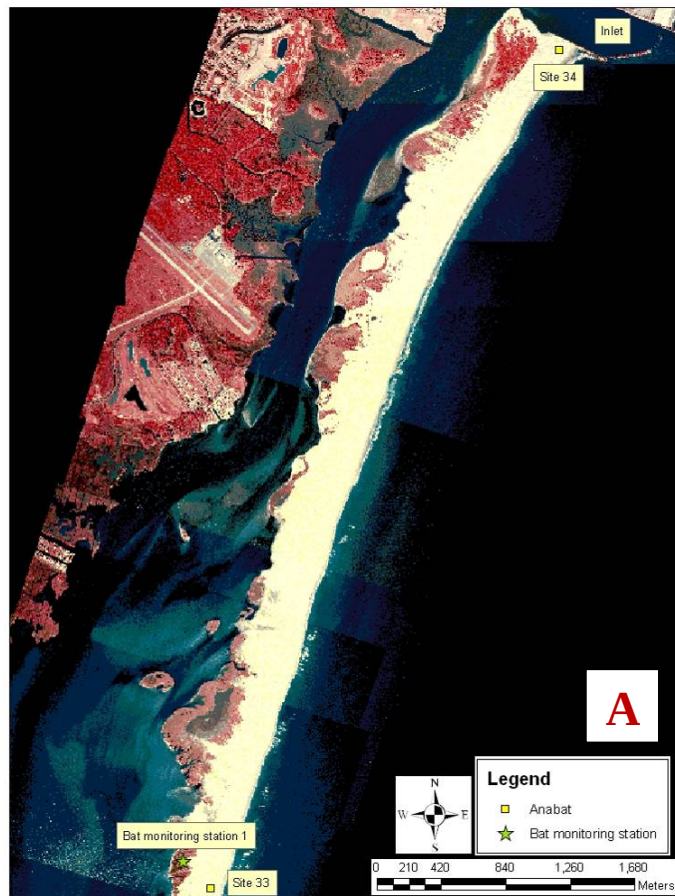
Site no.	GPS data file	UTM X ^a	UTM Y ^a	Date	Start time	Total	NOID ^b	NOID FB	EPFU	EPFU FB	LABO	LABO FB
32	ASIS32	481284.755	4215683.794	6/15/2006	2253	6	1	0	1	0	4	0
				7/22/2005	0000	13	6	0	0	0	7	0
				8/3/2005	2120	154	50	0	0	0	104	3
				6/13/2006	2319	33	4	0	1	0	28	0
				6/21/2006	2332	0	0	0	0	0	0	0
33	ASIS33	489573.902	4236213.668	8/10/2005	2038	1	0	0	0	0	1	0
				8/10/2005	2158	3	2	0	0	0	1	0
				6/22/2006	2102	0	0	0	0	0	0	0
				6/22/2006	2302	0	0	0	0	0	0	0
34	ASIS34	491840.379	4241671.360	8/10/2005	2115	5	1	0	4	0	0	0
				8/10/2005	2235	5	2	0	0	0	3	0
				6/22/2006	2142	1	0	0	0	0	1	0
				6/22/2006	2302	0	0	0	0	0	0	0
35	ASIS35	478764.330	4208954.781	8/11/2005	2031	2	0	0	0	0	2	0
				8/11/2005	2229	0	0	0	0	0	0	0
				6/19/2006	2110	0	0	0	0	0	0	0
				6/20/2006	2111	0	0	0	0	0	0	0

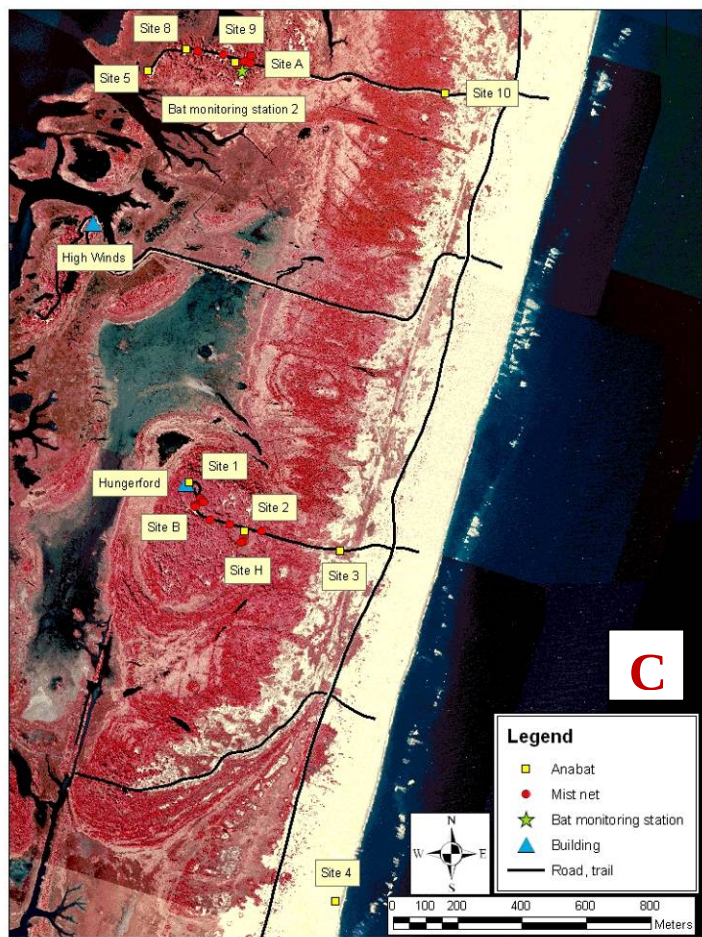
^a Universal Transverse Mercator coordinates in North American Datum 83, 18 North.
feeding buzz.

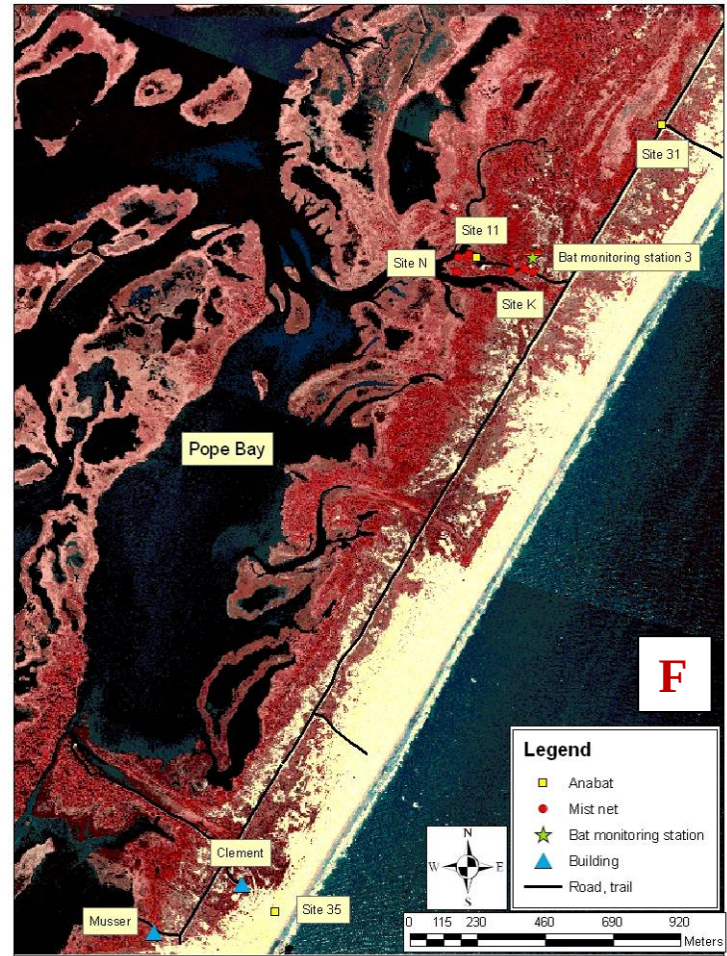
^b NOID = Unidentifiable bat call; EPFU = *Eptesicus fuscus*; LABO = *Lasiurus borealis*; FB =

Appendix VI.

Bat inventory sites on the northern portion (A), between kilometer 13–16 (B), between kilometer 16–20 (C), between kilometer 20–25 (D), between kilometer 25–30 (E), and between kilometer 30–35 (F) on Assateague Island National Seashore, 2005–2006.

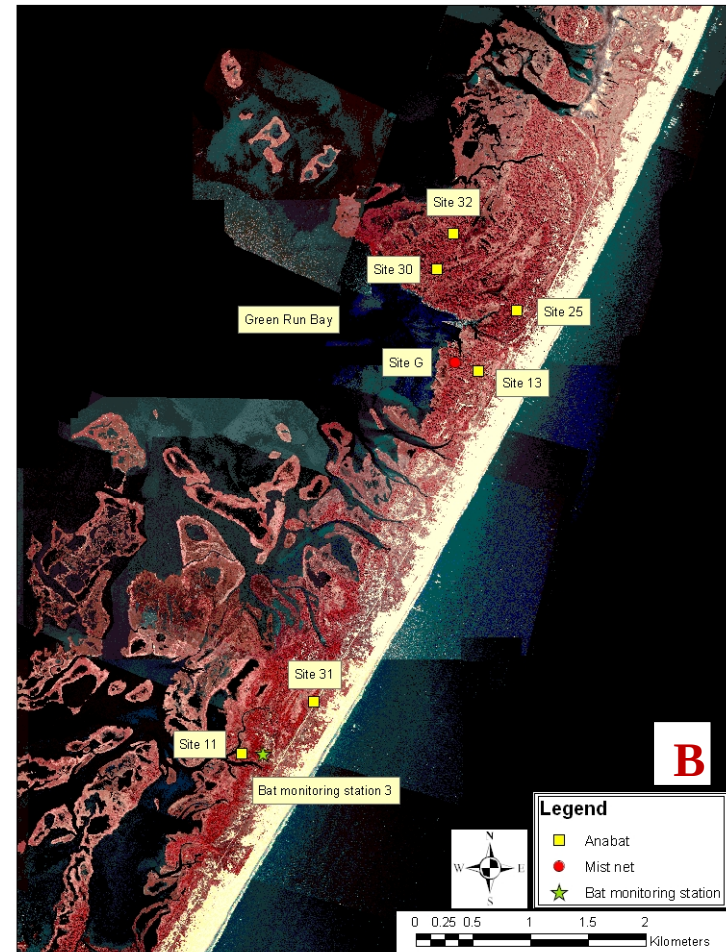
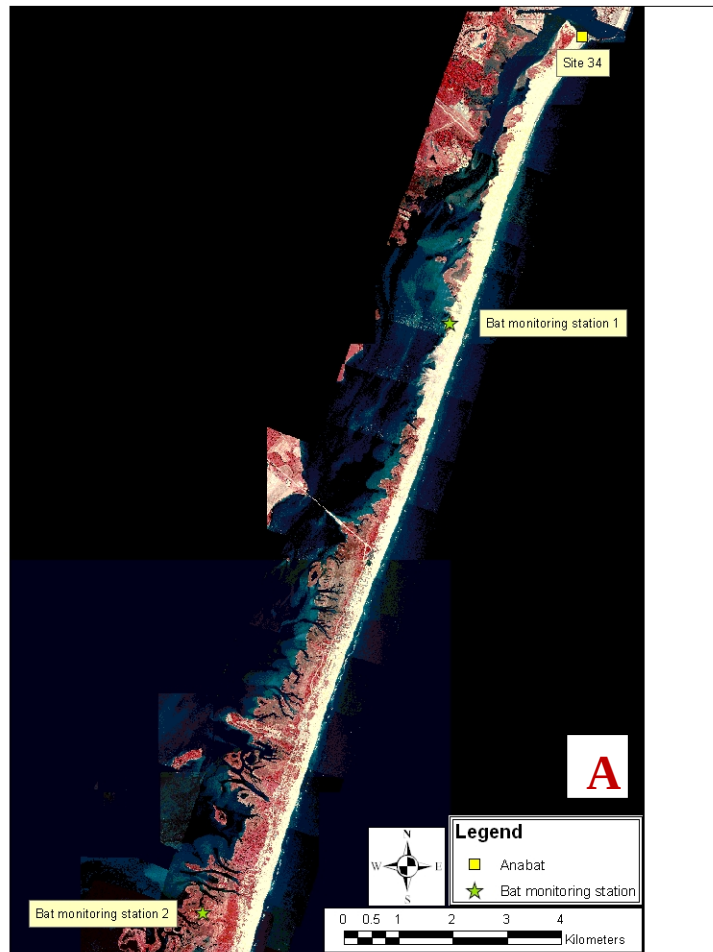






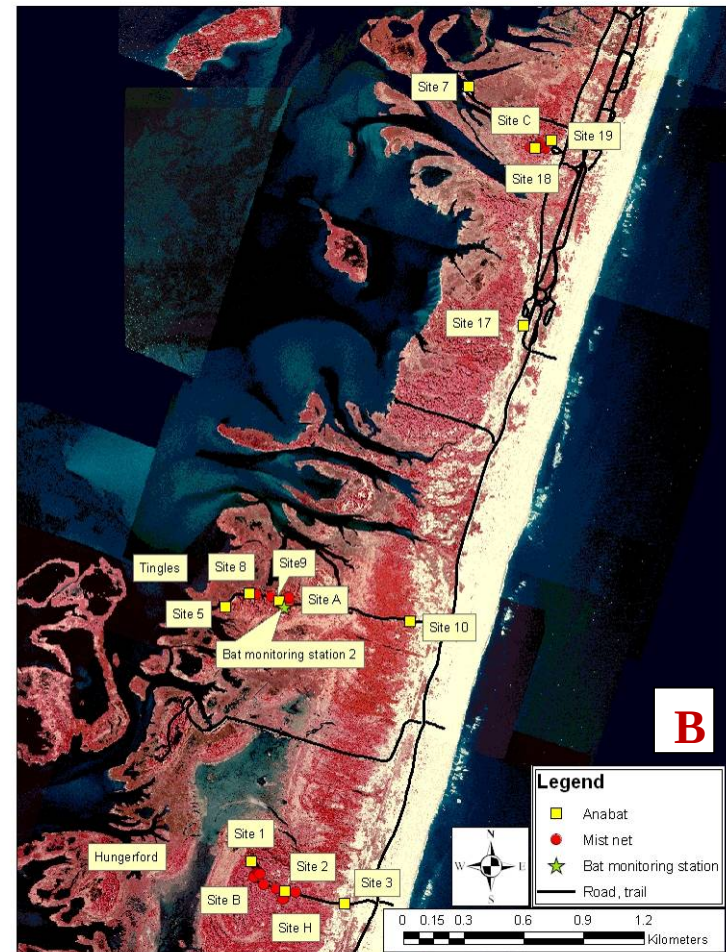
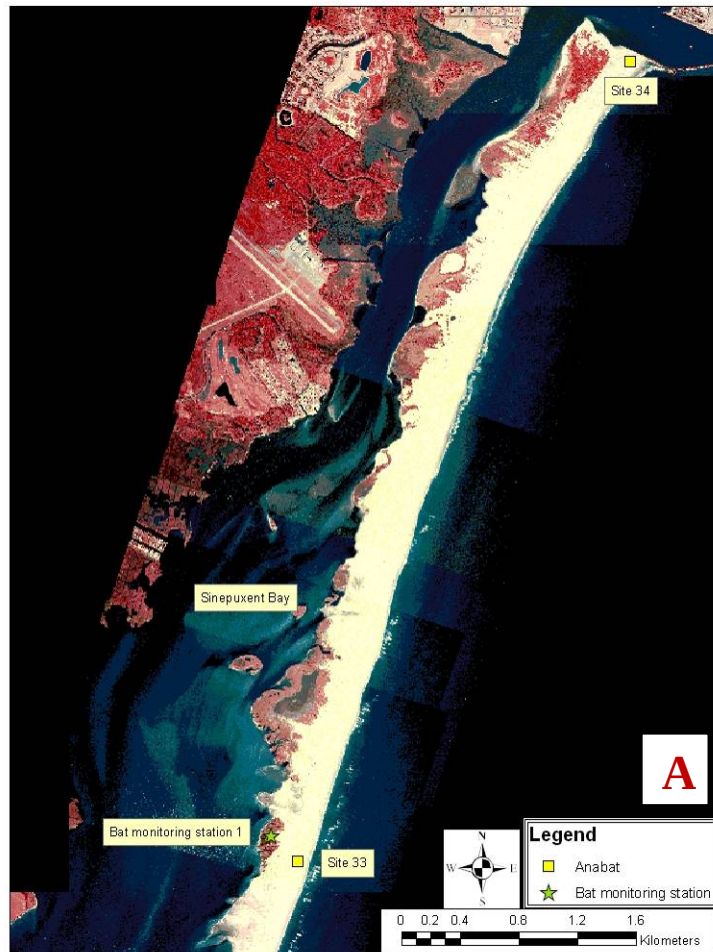
Appendix VII.

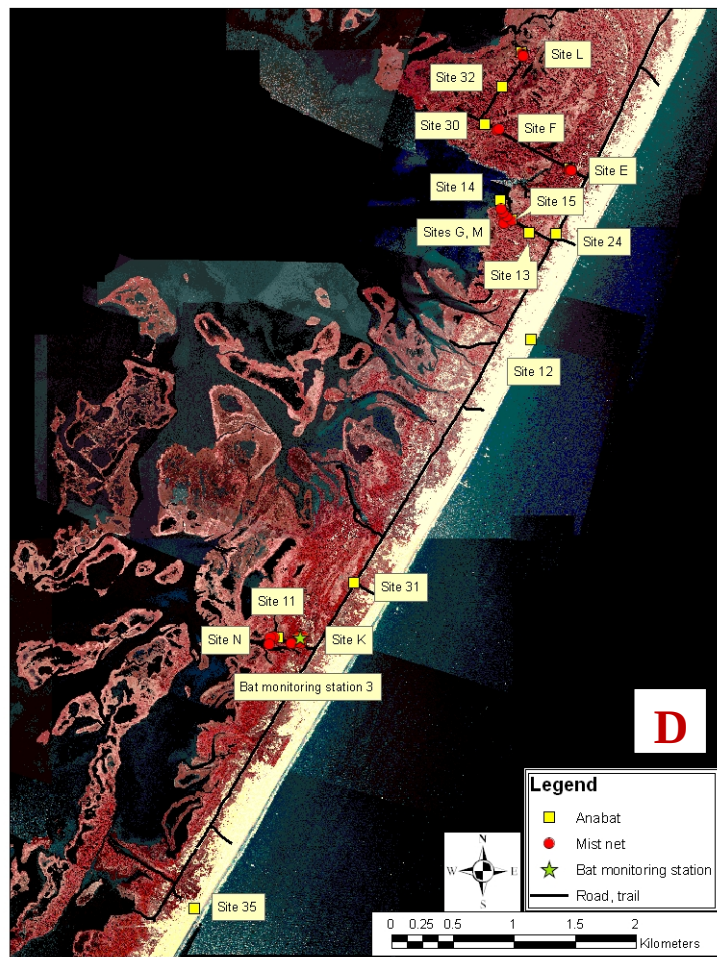
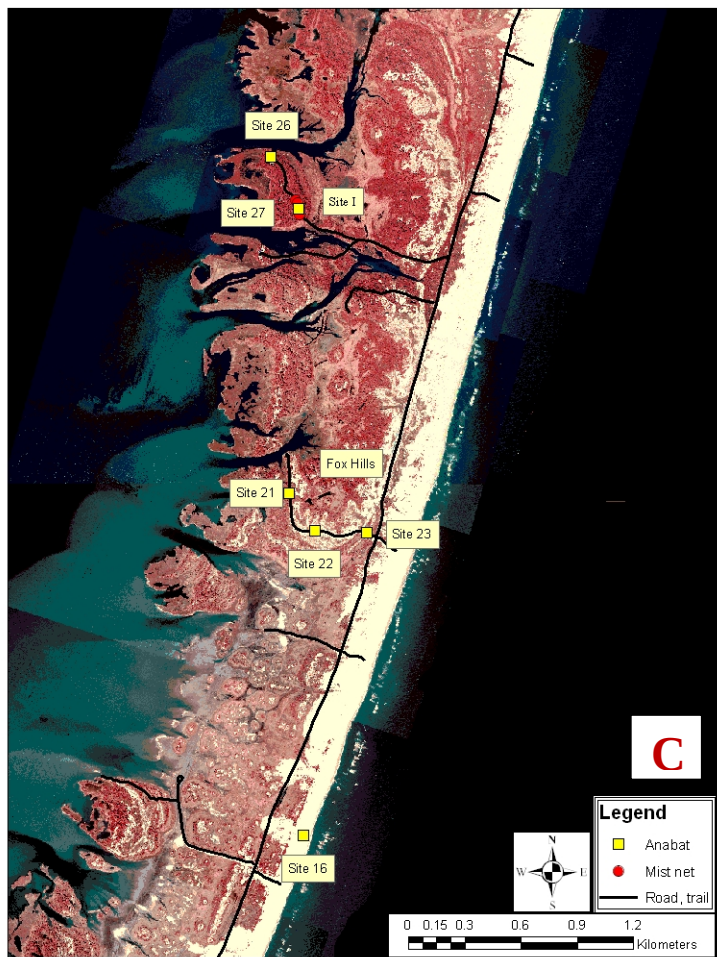
Bat inventory sites where big brown bats (*Eptesicus fuscus*) were documented on the northern (A) and southern (B) portions of Assateague Island National Seashore, 2005–2006.



Appendix VIII.

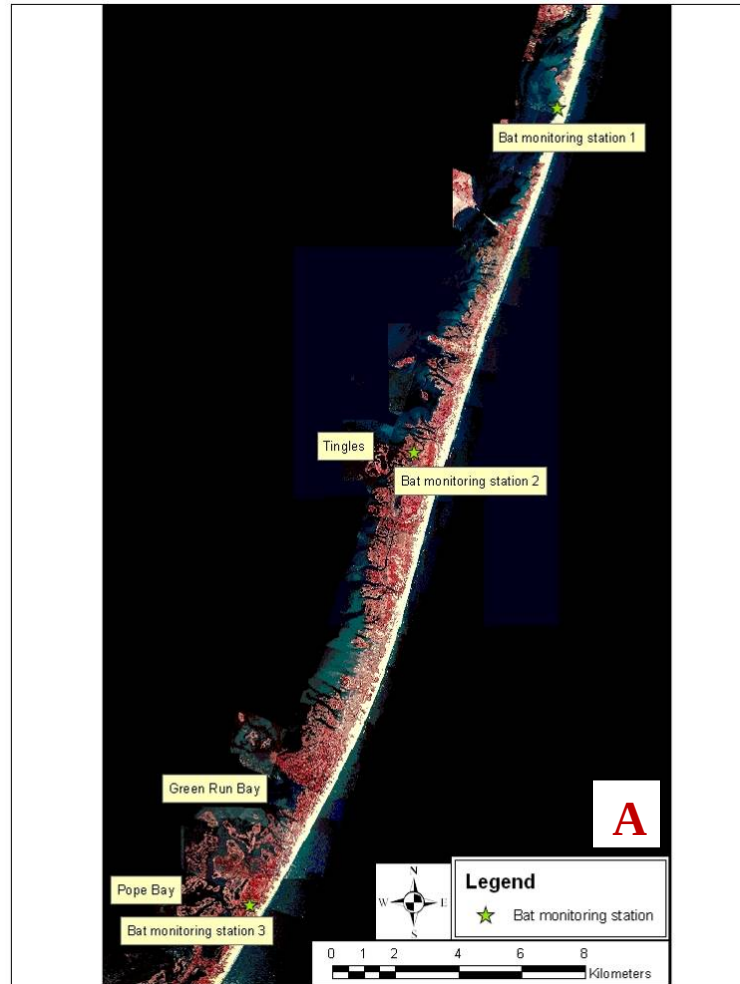
Bat inventory sites where eastern red bats (*Lasiurus borealis*) were documented on the northern portion (A), between kilometer 13–20 (B), between kilometer 20–25 (C), and between kilometer 25–35 (D) on Assateague Island National Seashore, 2005–2006.





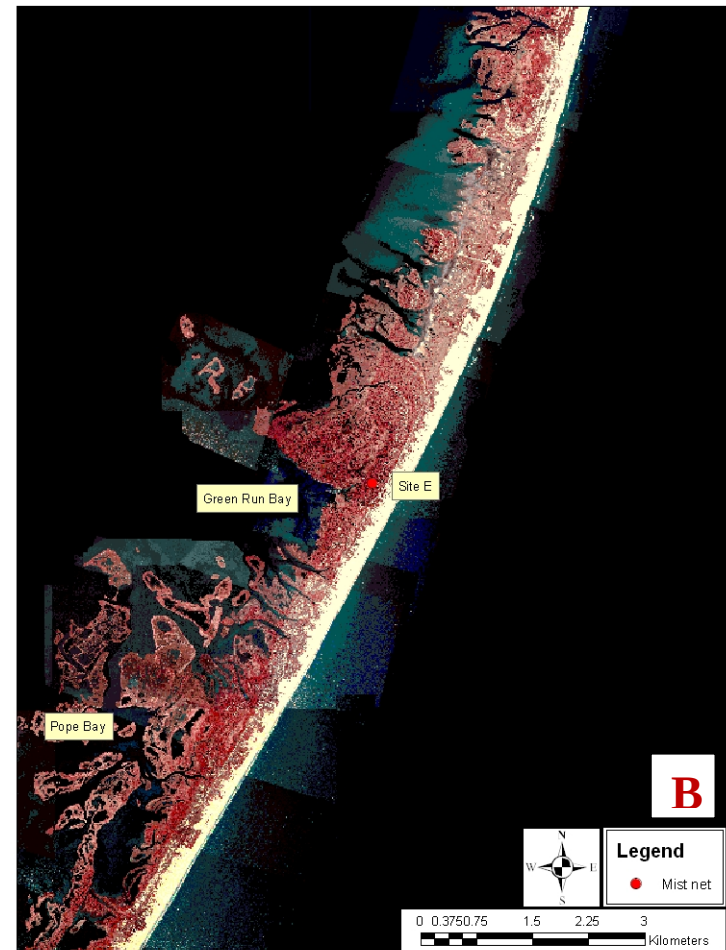
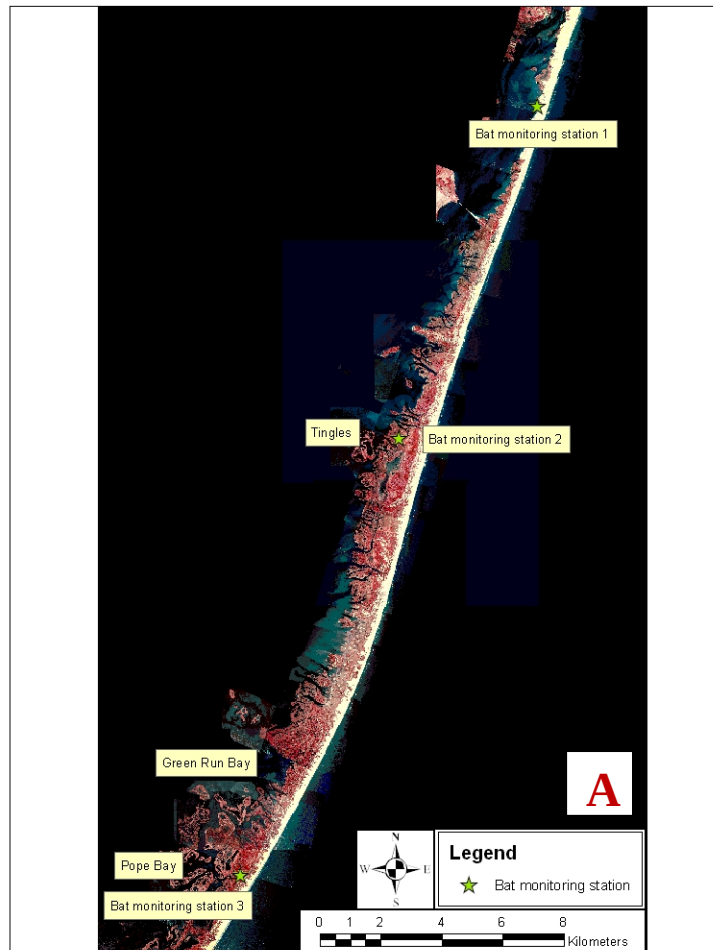
Appendix IX.

Bat inventory sites where (A) hoary bats (*Lasiurus cinereus*) and (B) eastern pipistrelles (*Pipistrellus subflavus*) (B) were documented at Assateague Island National Seashore, 2005–2006.



Appendix X.

Bat inventory sites where (A) silver-haired bats (*Lasionycteris noctivagans*) and (B) Seminole bats (*Lasiurus seminolus*) were documented at Assateague Island National Seashore, 2005–2006.



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
U.S. Department of the Interior



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