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Flight Activity and Offshore Movements of Nano-Tagged Bats on Martha's Vineyard, MA

Final Report

U.S. Department of the Interior
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Flight Activity and Offshore Movements of Nano-Tagged Bats on Martha's Vineyard, MA

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DISCLAIMER

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ABSTRACT

The northern long-eared bat (*Myotis septentrionalis*) was listed as threatened under the federal Endangered Species Act in 2016, following dramatic population declines associated with the spread of the fungal disease known as White-Nose Syndrome (WNS). However, the species continues to persist in the Cape and Islands region of Massachusetts, including Martha's Vineyard. Southern New England waters are likely to be an area of increasing offshore wind development in the coming decades, but the potential threat this development may pose to northern long-eared bats and other bat species remains largely unknown. In 2016, we conducted an automated telemetry study of northern long-eared bats on Martha's Vineyard to monitor flight activity and document any offshore movements.

We tracked four northern long-eared bats for 5-12 nights in July 2016 in our northwest Vineyard study area, and one northern long-eared bat for 39 nights in October 2016. BiodiversityWorks also tagged and manually tracked three northern long-eared bats on other parts of the island in July and August 2016. Our sample size was small, due to low capture rates for this species. In this sample, we did not record any offshore movements by northern long-eared bats. To supplement our data for northern long-eared bats, we also tagged and tracked three little brown bats (*Myotis lucifugus*), two big brown bats (*Eptesicus fuscus*), and three eastern red bats (*Lasiurus borealis*) captured on the island. We detected offshore movements by little brown bats and eastern red bats during the study period, suggesting our automated telemetry network was adequate to detect offshore movements by tagged individuals. Among these detections was the migration of the congeneric little brown bat from Martha's Vineyard in late August. Although northern long-eared bats are capable of accessing the offshore environment during the summer months, our data, as well as data from the literature, indicate they are unlikely to forage over federal waters during the maternity period (June to mid-July). Our data also strongly suggest that some northern long-eared bats are over-wintering on the island, but this does not preclude the possibility that other individuals of this species may migrate to inland hibernacula. Further study is warranted to determine whether northern long-eared bats are making offshore movements, particularly during late summer and early fall when little brown bats appear to depart the island. Unfortunately, research efforts may be hindered by low capture rates, likely associated with the spread of WNS.

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Abbreviations and Acronyms

EPFU – *Eptesicus fuscus*, Big Brown Bat
LABO – *Lasiurus borealis*, Eastern Red Bat
MYLU – *Myotis lucifugus*, Little Brown Bat
MYSE – *Myotis septentrionalis,* Northern Long-Eared Bat
WNS – White-Nose Syndrome

BACKGROUND

The northern long-eared bat (*Myotis septentrionalis*) is a small insectivorous vespertilionid, with a wide distribution across much of the eastern United States and Canada, northwest to British Columbia and the Northwest Territories, west to eastern Montana and Wyoming, and south to Alabama, Georgia, and the Florida Panhandle (Arroyo & Alvarez 2008). The northern long-eared bat was listed as threatened under the federal Endangered Species Act (ESA) in 2016, due to dramatic population declines associated with the spread of the fungal disease known as White-Nose Syndrome (WNS) (USFWS 2016). The species is also state-listed as Endangered in Massachusetts, Maine, and New Hampshire. Northern long-eared bat counts have declined by as much as 95-99% at WNS-affected hibernacula in the Northeast (Turner et al. 2011), and echolocation calls of these species have decreased in their summer range (Brooks et al. 2011, Ford et al. 2011). At these low densities, there is concern that additional loss of individuals - whether through mortality at wind energy facilities, disturbance of hibernacula, or other causes - could affect local population viability.

Large numbers of bats are killed in collisions with wind turbine blades in the United States every year (Hayes 2013). Northern long-eared bats and other hibernating species typically represent only a small fraction of fatalities (Arnett et al. 2008). However, recent analyses suggest mortality associated with wind facilities could have population-scale consequences for the federally endangered Indiana bat (*M. sodalis*) across its range (Erickson et al. 2016), and it is possible that related species, including the northern long-eared bat, face similar risks. Incidental take of northern long-eared bats at wind energy facilities is regulated by a 4(d) rule under the federal ESA (USFWS 2016).

As wind energy development expands into the offshore environment, the question arises of whether offshore development poses a risk to the northern long-eared bat, as well as other bat species. Bats are not traditionally thought of as ocean-going animals, but there is a long anecdotal history of bat sightings off the East Coast (Hatch et al. 2013, Peterson et al. 2014), and bats are known to utilize temporary roost sites on lighthouses and other structures on offshore islands (Miller 1897, Cryan & Brown 2007, Johnson et al. 2011). It is most often long-distance migratory bats that have been observed offshore, but *Myotis* spp. were documented in acoustic surveys 2.8-11.5 km off the coasts of New Jersey and the mid-Atlantic states (Sjollema et al. 2014). Recent acoustic monitoring efforts in the Gulf of Maine detected *Myotis* spp. on eight of nine forested islands surveyed, and on two tree-less rocks located 33 and 42 km from the mainland (Peterson et al. 2014). Overall, hibernating species (*Myotis* spp., *Eptesicus fuscus*, and *Perimyotis subflavus*) were present on 20% of nights surveyed at offshore sites in the Gulf of Maine in the late summer and fall (Omland et al. 2013). There is also a report from 2003 of a flock of *Myotis* bats roosting on a fishing boat 110 km from shore in the Gulf of Maine in late summer (Thompson et al. 2015). The Environmental Impact Statement for the proposed Cape Wind offshore wind facility in Nantucket Sound notes that big brown bats, tricolored bats, little brown bats, and northern long-eared bats must all at least occasionally make over-ocean movements, since they are known to occur on Martha's Vineyard (MMS 2009).

In Scandinavia, bats, including *Myotis* species, have been observed foraging over the ocean, feeding on insects, and even gaffing prey from the water's surface (Ahlen et al. 2009). Bats will forage in the vicinity of offshore wind facilities, and even attempt to roost in turbine nacelles (Ahlen et al. 2009). In North America, we know very little about the offshore behavior of *Myotis* species. It is not clear whether *Myotis* species routinely forage over the ocean during the active season, or in the fall, if hibernating bats on islands move to mainland hibernacula. Certainly, little brown bats (*M. lucifugus*) are capable of making long-distance movements (>500 km) to hibernation sites (Norquay et al. 2013). Movements of northern long-eared bats are less studied. Migratory distances traveled by northern long-eared bats are estimated to range 8-270 km (Griffin 1945). One individual banded at a cave in April was observed at a house roost 56 km away in May of the same year; this was interpreted as a movement from a winter hibernaculum to a summer territory (Caire et al. 1979). Recent genetic analyses suggest northern long-eared bats may be comparable to little brown bats in terms of dispersal and population mixing. In Canada, population-level genetic structuring was similar between little brown bats and northern long-eared bats, and structure was not related to geography (Johnson et al. 2015). Analyses of nuclear DNA at swarming sites did not reveal isolation by distance for northern long-eared bats over the distances examined (up to 309 km) (Johnson et al. 2015). Johnson et al. (2014) found that groups of northern long-eared bats in New York and West Virginia were genetically indistinguishable at multiple spatial scales.

Within the WNS-affected zone, northern long-eared bats appear to be persisting in some coastal areas, including the Cape and Island region of Massachusetts, and Long Island, New York. In 2014, a pilot mist-netting survey on Martha's Vineyard by BiodiversityWorks and the U.S. Fish & Wildlife Service (USFWS) resulted in capture of five northern long-eared bats in nine nights (0.56 bats/night). By contrast, Buresch (1999) documented average capture rates of 1.4-4.2 northern long-eared bats per night in mesic and oak woodlands on the island in 1997-1998. Bat biologists speculated that persistent coastal populations could be hibernating locally, rather than migrating to large inland hibernation sites already infected with WNS.

The continuing presence of northern long-eared bats on Martha's Vineyard offered a unique opportunity to study offshore movements of this rare bat, as well as a chance to learn more about habitat use of persistent northern long-eared bat populations in the face of WNS. In 2015, we assisted local non-profit BiodiversityWorks in a study of northern long-eared bat roosting ecology on the island, identifying maternity colonies, roost trees, and roosting home ranges. Eleven northern long-eared bats were captured and tracked to day roosts between May and September as part of the BiodiversityWorks project. Subsequently, The Bureau of Ocean Energy Management (BOEM) funded the acquisition, installation and removal of three automated telemetry stations, and part-time funding for one year for a researcher to complete this study. In 2016, this funding allowed us to use automated radio-receiving towers and coded transmitters to document activity patterns of tagged bats on Martha's Vineyard, and to detect any offshore movements by bats during the active season. We report here on the results of automated telemetry tracking, and provide context with results of manual tracking, roosting behavior, and acoustic detections, where they are of relevance to bat flight activity. In addition, we report on detections of other tagged bats and birds recorded by the Vineyard and Naushon island automated telemetry stations in 2016. This study is a collaboration among the USFWS, University of Massachusetts Amherst, the USGS Cooperative Units of Virginia Tech and UMass, and BiodiversityWorks.

METHODS

Bat Capture and Radio-Tag Deployment

Bat capture work was conducted collaboratively among the USFWS, University of Massachusetts Amherst, and BiodiversityWorks. Bats were captured using single, double, and triple high set-ups of 2.6, 4, 6, 9, and 12 m mist nets strung across woods roads, trails, wetland areas, and adjacent to identified roost sites on Martha's Vineyard, MA. Trap stations consisted of 2-5 mist-net set-ups, with trapping conducted at a given location for 1-3 nights in succession (almost always 2), from near sunset until 3-5 hours post-sunset, depending on trapping success and weather conditions. On cold and windy nights, nets were occasionally closed earlier (e.g. after 1.5 hours).

All bats were handled in accordance with American Society of Mammalogists standards (Sikes & Gannon 2011). Bats were identified to species, aged as adult or juvenile based on ossification of the wing bones, sexed, and weighed. For a subset of captured bats, a small area was shaved between the scapulae, and a radio-tag was attached using eyelash adhesive. Radio-tags were Lotek NTQB-1 (0.29 g) or NTQB-2 (0.35 g) NanoTag series coded units, with burst intervals of 6.7-19.9 seconds and operating lives of 24-71 days (www.lotek.com). To reduce risk to bats, no transmitter constituted greater than 5% of bat body weight (Aldridge & Brigham 1988). All gear was treated in accordance with USFWS National White-Nose Syndrome Decontamination Protocols (2012, 2016).

Manual Tracking

Tagged bats were tracked manually to daily roost sites using a Lotek SRX-800 receiver, which allows for differentiation among coded nano-tags. Tracking was conducted until bats dropped tags or battery life of the tags expired. BiodiversityWorks conducted the majority of manual tracking as part of a separately-funded roost study, the results of which will be available from this organization.

Automated Tracking

We utilized nano-tags deployed within the Motus network to track bat movements. Nano-tags are coded radio-transmitters operating on a single frequency; in combination with automated radiotelemetry stations, they allow for the simultaneous, long-distance tracking of thousands of individual birds, bats, and large insects. The Motus network consists of over 100 automated telemetry stations in the U.S. and Canada, stretching along the East Coast from Nova Scotia south to Florida, and inland at sites along the Great Lakes, the Connecticut River, and portions of the Midwest (Taylor et al. 2017). Stations consist of yagi or omni-directional antennae, deployed on buildings, lighthouses, pop-up masts, or sectional towers; the antennae are attached via BNC cables to radio receivers, which continuously monitor for nano-tags transmitting at a single frequency. Stations typically are built in one of two styles, either a "Motus-style" arrangement of 3 9-element yagi antennae oriented horizontally on a pop-up mast and connected to a hand-built sensorgnome receiver (www.sensorgnome.org), or a "Lotek-style" arrangement, consisting of 6 9-element yagi antennae oriented horizontally on a sectional tower and connected to a Lotek SRX series receiver (http://www.lotek.com). BOEM funded the purchase and installation of three Lotek-style stations, which were deployed on the coast at Cedar Tree Neck sanctuary (Sheriff's Meadow Foundation property) and at the Nature Conservancy's Hoft Farm Preserve about 1.7 km from the coast, both on Martha's Vineyard, as well as at a coastal site on Naushon Island (Table 1). We also deployed a Motus-style station at a coastal site at Sheriff's Meadow Foundation's Goethals sanctuary on Martha's Vineyard, funded by a Martha's Vineyard Vision Fellowship grant to BiodiversityWorks.

Table 1. Automated telemetry stations deployed on Naushon Island and Martha's Vineyard in 2016 as part of this study.

Site Name	Latitude	Longitude	Installation	Deconstruction	Receiver Type	Installation Type
Goethals	41.4463	-70.6691	6/16/2016	11/27/2016	Sensorgnome	9 m pop-up mast, 3 antennae
Cedar Tree Neck	41.4274	-70.7021	6/14/2016	11/28/2016	Lotek	6 m Rohn tower, 6 antennae
Hoft Farm	41.4466	-70.6482	6/13/2016	11/26/2016	Lotek	12 m Rohn tower, 6 antennae
Naushon Island	41.4694	-70.7573	6/19/2016	12/6/2016	Lotek	12 m lighthouse tower, 6 antennae

Interpretation of Automated Telemetry Data

The Motus network returns data from automated telemetry stations indicating station location, antenna bearing, nano-tag ID number, timestamp, and signal strength of detections of registered nano-tags. Detection power is strongest along the direct beam of a receiving antenna, and falls off to either side of that bearing, such that for the antennae used at our stations, detection power drops below 50% beyond 22.5° to either side of the antenna bearing. The antenna also has some detection power behind the antenna, but this is limited in our antennae by a high front/back ratio for power of detection. Thus, for a station with six equally-spaced antennae, there are six regions of relatively high detection power directly in line with each antenna, and six 15° gaps between each pair of antennae where detection power falls below 50%. Of course, for radio signals transmitted immediately adjacent to the telemetry station, power of detection is high, and there are likely to be no gaps in detection. Conversely, for radio signals transmitted far from the telemetry station, power of detection may be below 50% at all antennae, even if the signal is directly in line with the antenna bearing.

The power of detection of a radio transmission within an antenna beam is sensitive to altitude of the radiotransmitter relative to the ground, orientation of the radiotransmitter antenna in space, noise in the frequency range of interest, topography, other obstructions to signal transmission (such as trees), and additional factors. Previous studies have documented detection ranges of up to 12 km for migrating passerines (Mills et al. 2011, Smetzer et al. 2017, in review), and near-simultaneous detections have been recorded at stations 50 km apart for migrating eastern red bats (unpublished data), indicating a maximum detection range of at least 25 km. However, detection range is expected to be significantly lower for bats foraging at low height above ground, especially under forest canopy. Northern long-eared bats tagged in the vicinity of a "Motus-style" telemetry station at Great Bay NWR were detected ~75% of the time by the near station (~100m from the capture site), but only intermittently recorded by a station 2 km away (Nancy Pau, personal communication), suggesting detection range is significantly lower than 12 km for this species during foraging. Nano-tagged birds at ground level can typically be detected within 0.5-2 km of an automated telemetry station (Taylor et al. 2011). Bat roost sites in houses, tree crevices, and under bark may dampen radio signals relative to bird roosting sites, further decreasing signal detection range during roosting.

In general, we can assume that detections with higher signal strength are likely to represent a radiotransmitter at greater height above ground level, more directly within the center of an antenna beam, and/or closer to the telemetry station where detection occurred. Research efforts funded by BOEM and others are underway to model predicted radiotransmitter location and movement pathways based on signal strength, biangulation between antennae, and other factors. Unfortunately, currently available models are highly simplistic and have error ranges of ~3 km (Jen Smetzer, personal communication). These models are useful for considering long-distance movement pathways of migrating animals, but cannot be practically applied to foraging and roosting bats if detection distance falls below three km. Further, these models are sensitive to input factors including height above ground and the orientation of the radiotransmitter antenna in space. We know little about foraging heights for northern long-eared bats, beyond the fact that they are often captured in mist-nets deployed 0-8 m above ground height, and based on morphology, are unlikely to forage in open spaces above the canopy. In addition, we would expect that antenna orientation would change frequently as bats make multiple foraging passes through an area.

For the purposes of analysis of northern long-eared bat activity, we report roosting and foraging detections by antenna sector, with the assumption that detections by a single antenna likely indicate presence of the bat in a beam within 30° to either side of an antenna bearing, and more likely within 22.5°. Unlike sensorgnome receivers, Lotek receivers cannot provide simultaneous detections from multiple antennae. In our system, Lotek receivers cycled through each of six antennae in turn, "listening" at each antenna for 20.5 seconds. Hence, consecutive detections within a < 3 min period by antennae on a single telemetry station approximate a simultaneous detection. Where there are consecutive detections by more than one antenna, we average signal strength over a 3 min period and assume the bat was within the antenna sector which showed the highest average signal strength. In these cases, the bat is likely closer to the station than at other times, and might more easily pass between adjacent antenna sectors over a short time period while foraging.

Acoustic Data

To increase our chances of successful bat capture, we deployed SM3BAT acoustic detectors for periods of 1-8 nights at potential trapping sites in the summer and fall, with length of deployment dependent on weather conditions, trap site needs, and convenience. We analyzed the full spectrum data collected by these detectors using KaliedoscopePro, which includes auto-classification software to identify bat echolocation calls. Because auto-classification is prone to error, especially in discriminating among members of the *Myotis* genus, we grouped all *Myotis* recordings together, rather than considering only calls identified as northern long-eared bats. BiodiversityWorks collaborated to deploy acoustic detectors and conduct analyses of results. We include results of this analysis where it is deemed relevant to the study questions.

Nantucket Research

As part of a separate pilot study conducted in concert with UMass, the USFWS, and Nantucket Conservation Foundation, we nano-tagged seven northern long-eared bats on the nearby island of Nantucket in 2016. We report on results of this study as well, insofar as they relate to the question of offshore movements.

RESULTS

Year 2015

The information provided for 2015 is included as background for efforts conducted in 2016 under this agreement

Bat Capture and Tagging

In 2015, we trapped for a total of 19 nights in foraging habitats, and six nights at known bat roost locations (based on visual observation of bats or fresh guano). We captured a total of 20 bats, including 12 northern long-eared bats (MYSE), five big brown bats (*Eptesicus fuscus*, EPFU), two little brown bats (MYLU), and one eastern red bat (*Lasiurus borealis*, LABO). The capture rate for free-ranging MYSE at flight corridor locations (not roost sites) was 0.26 bats per night. We tagged the 11 adult MYSE captured. Eight female MYSE were tagged in late May or June during the maternity period, when females are pregnant or lactating, one MYSE was tagged in late July during the volancy period, when juveniles are flying, and two were tagged in September, during the time period when we suspected MYSE would move to hibernation sites.

Manual and Automated Tracking

All eight bats tagged during the maternity period were captured in the northwest part of Martha's Vineyard, in the vicinity of Hoft Farm, and roosted in that vicinity until the tag dropped off the animal (4-17 days) (Table 2). In July, the lone bat tagged was captured at Job's Neck in the south-central part of the island, and also roosted in the same vicinity for three days following capture until its tag was recovered in the State Forest, approximately 3 km north. The two bats captured in September were tracked to roosts in the same vicinity for 15 and 17 days following capture.

Table 2: Bats tagged and tracked in 2015 on Martha's Vineyard. All tagged bats were adult female northern long-eared bats. No bats were recorded by off-island telemetry stations.

	Capture Details					
ID	**Datetime**	**Site Type**	**Latitude**	**Longitude**	**Days Tracked Post-Capture**	**Nearest Automated Telemetry Station (km)**
248	6/2/2015 21:10	Trails, wetland area	41.45024	-70.6438	7	Waquoit, Cape Cod (16)
252	6/2/2015 21:10	Trails, wetland area	41.45024	-70.6438	17	Waquoit, Cape Cod (16)
255	6/2/2015 22:15	Trails, wetland area	41.45024	-70.6438	10	Waquoit, Cape Cod (16)
266	6/18/2015 20:45	House roost	41.45319	-70.6410	17	Waquoit, Cape Cod (16)
253	6/24/2015 20:43	House roost	41.45319	-70.6410	8	Waquoit, Cape Cod (16)
256	6/24/2015 20:41	House roost	41.45319	-70.6410	9	Waquoit, Cape Cod (16)
248B	6/24/2015 20:39	House roost	41.45319	-70.6410	10	Waquoit, Cape Cod (16)
255B	6/24/2015 20:43	House roost	41.45319	-70.6410	4	Waquoit, Cape Cod (16)
256B	7/20/2015 23:00	Forest trails	41.36421	-70.5768	3	Waquoit, Cape Cod (21)
282	9/3/2015 20:25	Forested trails by brook	41.35391	-70.7258	15	Noman's Island (13)
285	9/19/2015 13:32	Bird nest box	41.41166	-70.5719	17	Waquoit, Cape Cod (16)

In 2015, there were no operational telemetry stations on the island. During this time, the closest telemetry stations were at Waquoit Bay on the south shore of Cape Cod, on Noman's Island southwest of Martha's Vineyard, on Muskeget Island, east of the Vineyard, and at Eel Point on the western shore of Nantucket, also to the east of the Vineyard (Figure 1). None of these telemetry stations recorded detections of the tagged bats.

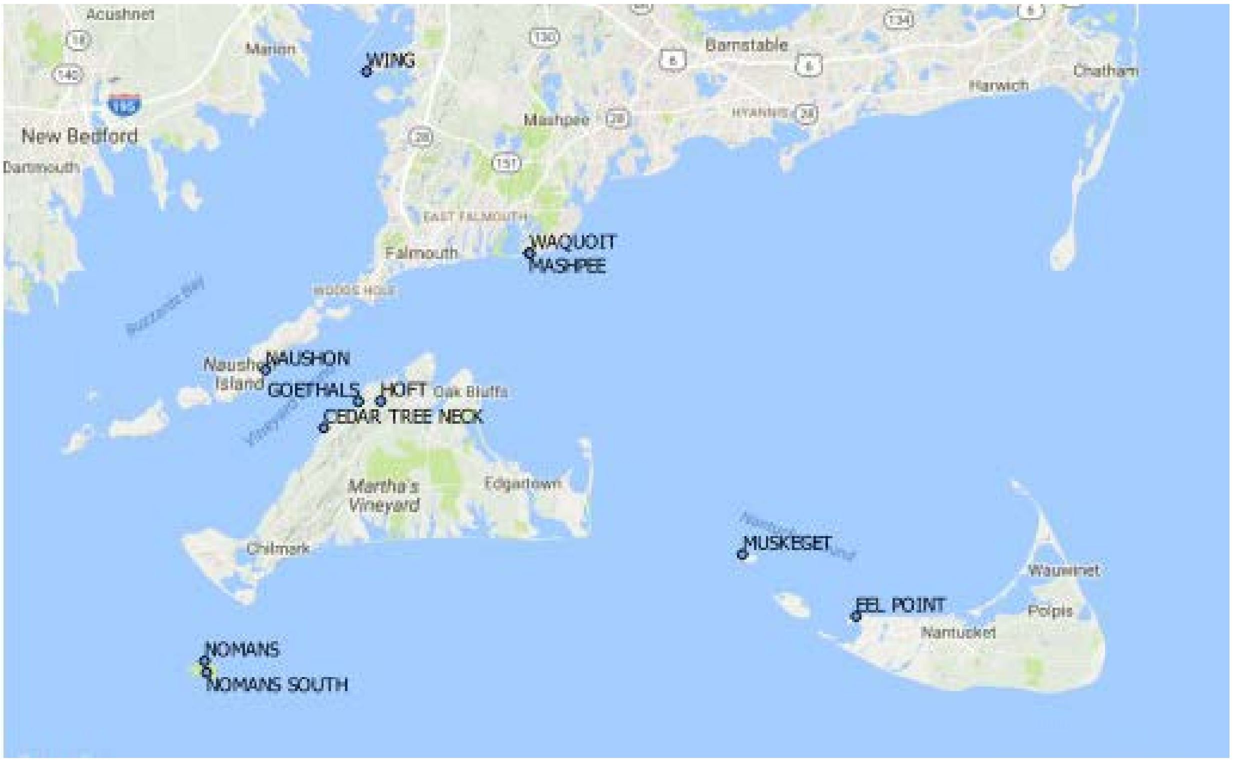


Figure 1. Local and regional telemetry stations in the Martha' Vineyard area. The four stations on Martha's Vineyard and Naushon Island were not deployed in 2015; the other stations were present in both years.

Year 2016

Telemetry Station Deployment

In 2016, we erected three automated telemetry stations on the northwest part of Martha's Vineyard, at the Hoft Farm, Goethals Sanctuary, and Cedar Tree Neck Sanctuary. We also deployed a station on neighboring Naushon Island, 6.5 km to the north of the Cedar Tree Neck station (Figure 2). The three Lotek-style stations had a technical issue which was resolved for the Hoft and Cedar Tree Neck stations on July 6. These stations functioned through the remainder of the season until they were dismantled on November 26 and November 28 respectively, except for a period from October 10 to 25, and again from October 26 to 29, when the Cedar Tree Neck station was non-functional, apparently due to a problem with the software in the receiver. The Naushon station continued to have technical issues through July 21, but then functioned through the remainder of the season until it was dismantled on December 4. As in 2015, a number of other telemetry stations were on-line throughout the Cape and Islands region (Figure 1), as well as along the Atlantic coast, from Nova Scotia as far south as Florida, and in inland Massachusetts along the Connecticut River.

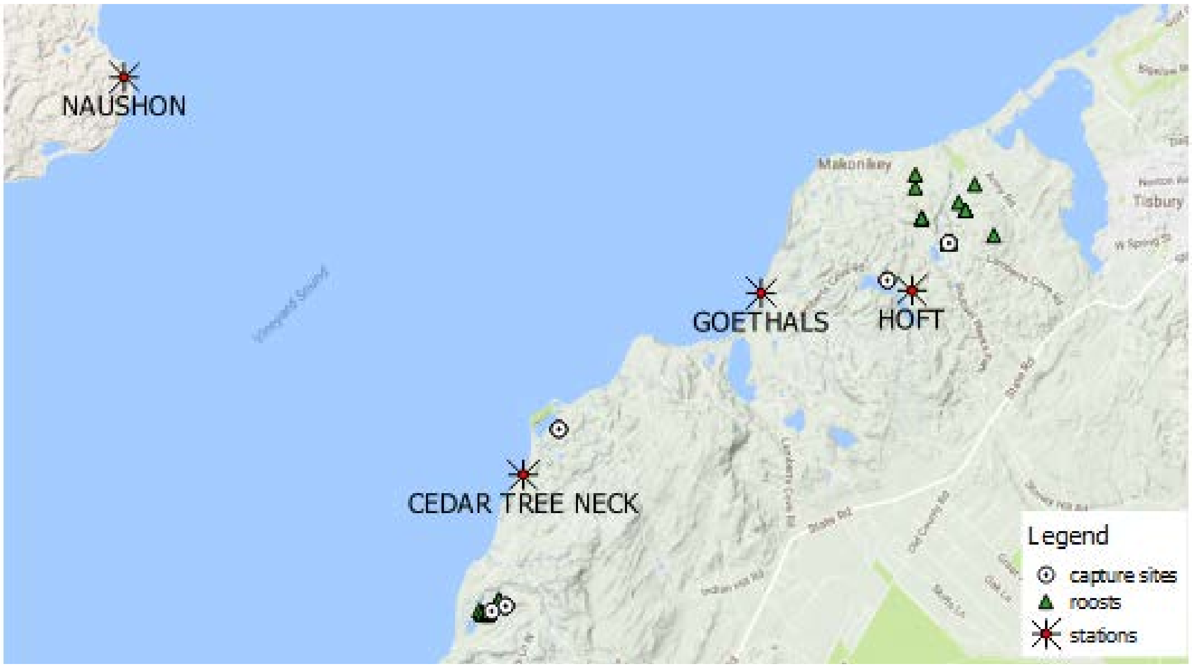


Figure 2. The northwest Martha's Vineyard study area, with local telemetry stations, mist-netting sites, and roost sites of northern long-eared bats in the study area in 2016.

Bat Capture and Tagging

Between June 14 and November 3, we trapped for a total of 43 nights in foraging habitats, and nine nights at roost sites. We conducted 20 nights of mist-netting between mid-June and mid-July, 17 of which were at sites in the northwest Vineyard study area adjacent to telemetry stations. We trapped for four nights in late July and six in August, of which three nights each were in the northwest Vineyard study area. We trapped for two nights in September, outside of the study area. Because the two MYSE tagged in 2015 did not make obvious movements towards a hibernaculum in September, we focused our 2016 migration period efforts in October, trapping for 16 nights during that month, 14 of which we spent at sites within the northwest Vineyard study area. On other nights in October, we were not able to trap, due to cold temperatures, rain, or windy conditions, which rendered capture unlikely or potentially hazardous to bats.

We captured a total of 56 bats in 2016, including 13 MYSE, four MYLU, 30 EPFU, and nine LABO. Five MYSE females were captured at a house roost 0.69 km from the Hoft station on July 6; we tagged four of these individuals (Table 3), the fifth escaped the net during capture. In mid-July, we captured three adult female MYSE and three juveniles at a house roost on the eastern side of the island, 6.69 km from the Hoft station. Because this was outside the area covered by our telemetry stations, we only tagged two of the adults. We also tagged one adult female captured in the south-central part of the island in late August, 9.06 km from the Hoft station. Finally, in October, we tagged an adult MYSE female within the northwest study area. The capture site was 1.62 km from the Cedar Tree Neck station, 4.82 km from the Goethals station, and 6.11 km from the Hoft station.

Due to low capture numbers of MYSE during the maternity period, we decided to expand our tagging to other hibernating species within the northwest Vineyard study area. In July and August, we tagged three MYLU roosting in a barn 1.54 km from the Cedar Tree Neck station and 5.95 km from the Hoft station. In October, we tagged three EPFU, two near the Hoft station (0.31 km from station) and one near the Cedar Tree Neck station (0.67 km from station). As part of a separate project, we also tagged three LABO, one near the Hoft station (0.31 km), and two near the Cedar Tree Neck station (0.67 km), in October.

In summary, we tagged a total of 17 bats, including 8 MYSE (Table 3). Fourteen bats were tagged in the northwest study area within the vicinity of our telemetry stations; three MYSE were tagged on other parts of the island. The capture rate for MYSE in corridor settings (not roost sites) was 0.05 MYSE per night.

Table 3 Bats tagged in 2016 on Martha's Vineyard. All tagged bats were adult females, with the exception of LABO 470 and 473, which were adult males. MYSE=*Myotis septentrionalis*, MYLU=*Myotis lucifugus*, LABO=*Lasiurus borealis*, EPFU=*Eptesicus fuscus*. House roost coordinates are approximate; distance to nearest telemetry station is accurate.

	Capture Details					
ID	**Datetime**	**Site Type**	**Latitude**	**Longitude**	**Days Tracked Post-Capture**	**Nearest Automated Telemetry Station (km)**
MYSE 277	7/6/2016 23:38	House roost	41.45063	-70.6424	12	Hoft (0.7)
MYSE 280	7/6/2016 20:38	House roost	41.45063	-70.6424	5	Hoft (0.7)
MYSE 279	7/6/2016 21:00	House roost	41.45063	-70.6424	9	Hoft (0.7)
MYSE 284	7/6/2016 21:05	House roost	41.45063	-70.6424	5	Hoft (0.7)
MYSE 284B	7/14/2016 20:30	House roost	41.42385	-70.57289	7	Hoft (6.7)
MYSE 280B	7/14/2016 20:32	House roost	41.42385	-70.57289	4	Hoft (6.7)
MYLU 276	7/19/2016 15:15	Barn roost	41.4138	-70.7045	16	Cedar Tree Neck (1.5)
MYLU 286	8/15/2016 20:01	Barn roost	41.4138	-70.7045	16	Cedar Tree Neck (1.5)
MYLU 278	8/15/2016 20:02	Barn roost	41.4138	-70.7045	22	Cedar Tree Neck (1.5)
MYSE 283	8/21/2016 22:45	Forested trails	41.3672	-70.6241	9	Hoft (9.0)
MYSE 281	10/13/2016 18:35	Forested trails	41.4133	-70.7065	39	Cedar Tree Neck (1.6)
LABO 473	10/17/2016 18:40	Woods road, parking area, trails	41.4322	-70.6972	0	Cedar Tree Neck (0.7)
EPFU 271	10/17/2016 19:05	Woods road, parking area, trails	41.4322	-70.6972	0	Cedar Tree Neck (0.7)
LABO 475	10/18/2016 18:10	Woods road, parking area, trails	41.4322	-70.6972	0	Cedar Tree Neck (0.7)
LABO 470	10/21/2016 18:10	Woods road	41.4477	-70.6516	0	Hoft (0.3)
EPFU 275	10/21/2016 18:30	Woods road	41.4477	-70.6516	18	Hoft (0.3)
EPFU 258	10/21/2016 18:30	Woods road	41.4477	-70.6516	18	Hoft (0.3)

Manual and Automated Tracking

Northern Long-eared Bats

Tagged MYSE were manually tracked daily to roost sites through the life of the tag, or until the tag fell off the bat. In July, BiodiversityWorks tracked the four tagged MYSE to the house maternity roost where they were captured, or to additional tree or house roosts within 0.75 km of the capture site and 1.34 km of the Hoft station (Table 4). Tags remained on the bats for 5-12 days following capture. The four tagged northern long-eared bats were only detected by the closest automated station, the Hoft station located 0.69 km from their capture location (Table 4). None of these bats were detected by any of the coastal stations including the Goethals station, which was less than 2.6 km from any identified roost (Figure 2).

These bats were only intermittently detected while roosting, and only detected at the RT09 roost site (Table 5), which was the closest roost to the Hoft station (0.69 km away). They were never detected during daylight hours at other roost sites 0.84-1.42 km away from station. The RT09 roost was at a bearing of 37.5° from the Hoft station. Bats were detected in the roost by the Hoft 2 antenna, bearing 55°, but not by antennae with bearings of 355° or 115°.

Table 4. Roost sites and tower detections for northern long-eared bats tagged near the Hoft station in July 2016. These bats were never detected by the Goethals station. Coordinates listed for RT_09 are approximate.

ID	Date	Roost ID	Latitude	Longitude	Distance to Hoft station (km)	Distance to Goethals station (km)	Detected by Hoft station (hour:min)
MYSE 277	7/6/2016	RT09	41.45063	-70.6424	0.69	2.24	-
	7/7/2016	RT09	41.45063	-70.6424	0.69	2.24	21:04-21:14; 0:01-0:35; 4:25-4:26
	7/8/2016	RT09	41.45063	-70.6424	0.69	2.24	8:03; 8:39-8:40; 11:45; 23:41-2:13
	7/9/2016	RT09	41.45063	-70.6424	0.69	2.24	21:31-21:32; 23:43-3:49
	7/10/2016	RT09	41.45063	-70.6424	0.69	2.24	1:00-2:47
	7/11/2016	RT09	41.45063	-70.6424	0.69	2.24	0:20-4:34
	7/12/2016	RT26	41.45766	-70.6395	1.42	2.77	0:01-0:16, 2:23-2:26
	7/13/2016[a]	-	-	-	-	-	-
	7/14/2016	RT28	41.45578	-70.6418	1.15	2.51	-
	7/15/2016	RT30	41.45497	-70.6408	1.11	2.55	-
	7/16/2016	RT30	41.45497	-70.6408	1.11	2.55	-
	7/17/2016	RT30	41.45497	-70.6408	1.11	2.55	-
	7/18/2016[b]	-	41.45497	-70.6408	1.11	2.55	-
MYSE 279	7/6/2016	RT09	41.45063	-70.6424	0.69	2.24	-
	7/7/2016	RT09	41.45063	-70.6424	0.69	2.24	19:53; 0:22
	7/8/2016	RT09	41.45063	-70.6424	0.69	2.24	10:02; 10:15; 22:10; 23:05-23:14; 2:19; 4:40; 4:44
	7/9/2016	RT09	41.45063	-70.6424	0.69	2.24	21:44; 0:54; 2:02; 3:04-3:26
	7/10/2016	RT09	41.45063	-70.6424	0.69	2.24	15:27-18:02; 19:21-22:27; 1:30-4:02
	7/11/2016	RT09	41.45063	-70.6424	0.69	2.24	11:10-23:18; 0:26-4:47
	7/12/2016	RT09	41.45063	-70.6424	0.69	2.24	20:46-21:10; 0:11-2:20
	7/13/2016	RT27	41.45236	-70.6369	1.14	2.77	22:48-22:54; 2:38
	7/14/2016	RT29	41.45732	-70.6478	1.19	2.16	-
	7/15/2016[b]	-	41.45868	-70.6478	1.34	2.25	-

MYSE 280	7/6/2016	RT09	41.45063	-70.6424	0.69	2.24	-
	7/7/2016	RT09	41.45063	-70.6424	0.69	2.24	20:57-4:21
	7/8/2016	RT09	41.45063	-70.6424	0.69	2.24	20:46-4:46
	7/9/2016	RT09	41.45063	-70.6424	0.69	2.24	-
	7/10/2016	RT09	41.45063	-70.6424	0.69	2.24	-
	7/11/2016	RT09	41.45063	-70.6424	0.69	2.24	-

MYSE 284	7/6/2016	RT09	41.45063	-70.6424	0.69	2.24	-
	7/7/2016	RT25	41.45414	-70.6469	0.84	2.05	22:50-22:53; 3:08-3:26
	7/8/2016	RT09	41.45063	-70.6424	0.69	2.24	21:50-23:44; 2:11
	7/9/2016	RT09	41.45063	-70.6424	0.69	2.24	11:36; 20:46; 23:12-23:57; 3:00-6:29
	7/10/2016	RT09	41.45063	-70.6424	0.69	2.24	20:40-22:42
	7/11/2016	RT09	41.45063	-70.6424	0.69	2.24	8:13-12:59

[a] Roost not found
[b] Dropped tag

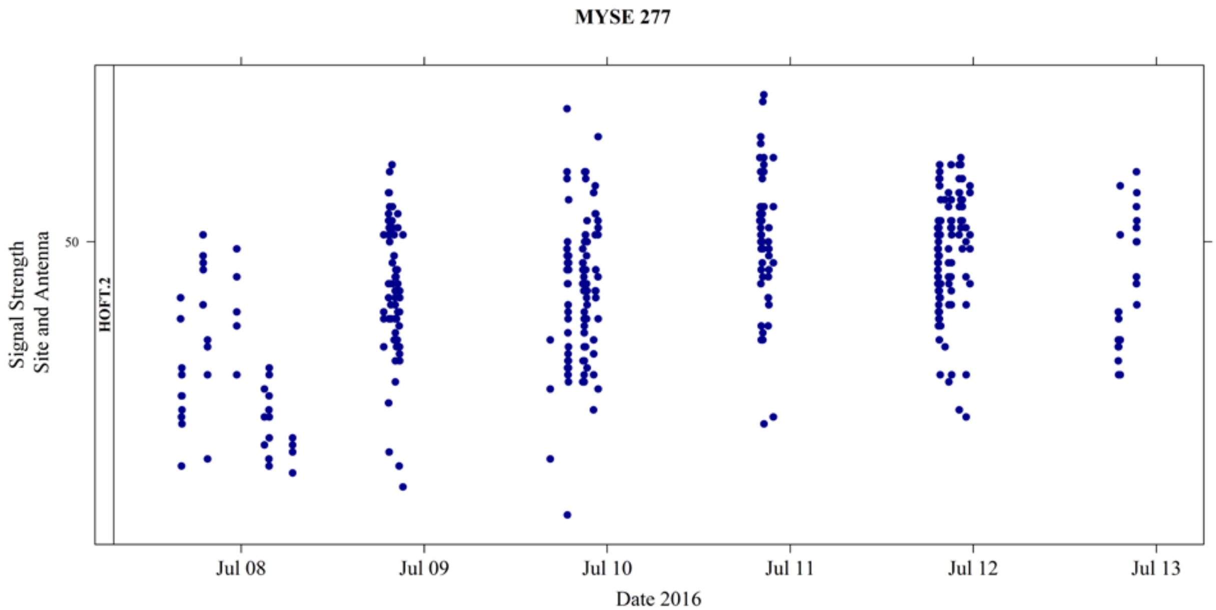
Table 5. Automated detections of tagged bats while in roost (i.e. during daylight hours). Bats were only detected intermittently while in roosts, and only by the telemetry station antenna with the bearing closest to that of the actual bearing from the telemetry station to the roost site. Northern long-eared bats were only detected at the RT09 house roost, 0.69 km from the Hoft station. EPFU 258 was 0.78 km from the Hoft station.

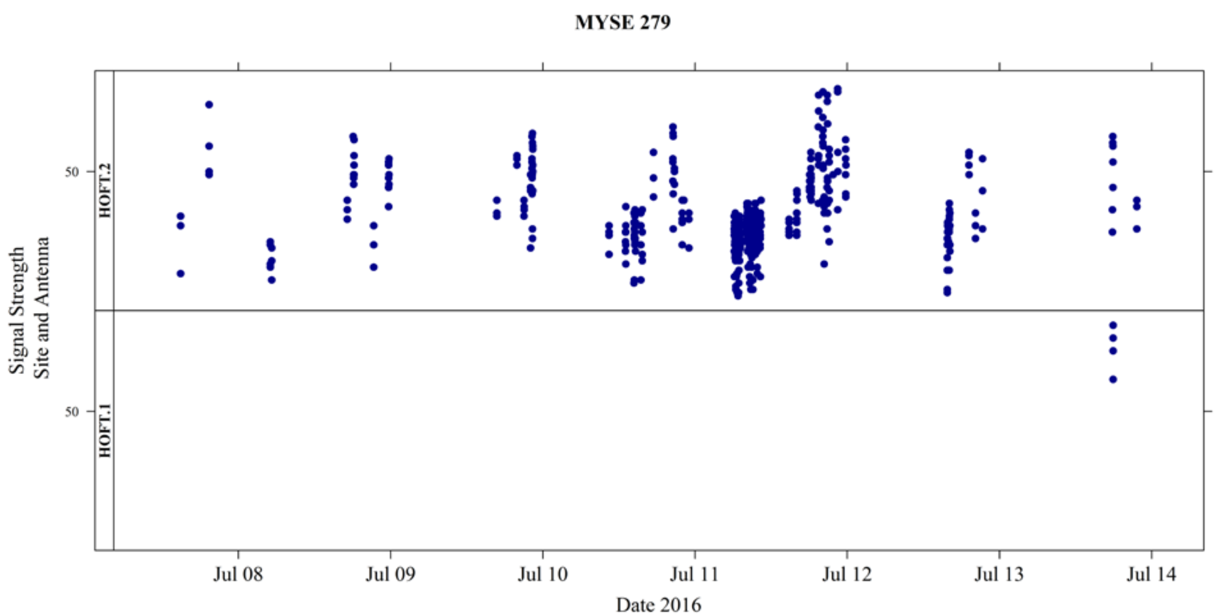
ID	Roost	Latitude	Longitude	Station	Actual Bearing Station to Roost	Datetime detected	Antenna	Antenna Bearing
MYSE 277	RT09	41.45063	-70.6424	Hoft	37.5	7/8/2016 8:03	2	55
	RT09	41.45063	-70.6424	Hoft	37.5	7/8/2016 8:39-8:40	2	55
	RT09	41.45063	-70.6424	Hoft	37.5	7/8/2016 11:45	2	55
MYSE 279	RT09	41.45063	-70.6424	Hoft	37.5	7/8/2016 10:02-10:03	2	55
	RT09	41.45063	-70.6424	Hoft	37.5	7/8/2016 10:15	2	55
	RT09	41.45063	-70.6424	Hoft	37.5	7/10/2016 15:27	2	55
	RT09	41.45063	-70.6424	Hoft	37.5	7/10/2016 18:02-18:05	2	55
	RT09	41.45063	-70.6424	Hoft	37.5	7/10/2016 19:21-19:36	2	55
	RT09	41.45063	-70.6424	Hoft	37.5	7/11/2016 11:10-15:25	2	55
	RT09	41.45063	-70.6424	Hoft	37.5	7/11/2016 19:49	2	55
MYSE 284	RTO9	41.45063	-70.6424	Hoft	37.5	7/9/2016 11:36	2	55
	RT09	41.45063	-70.6424	Hoft	37.5	7/11/2016 8:13-12:59	2	55
EPFU 258	EP2	41.4527	-70.6529	Hoft	330.0	10/22/2016 7:05-13:12	1	355

Given that we never detected these northern long-eared bats at the Goethals station (2-2.8 km from roosts), and did not consistently detect bats exiting roosts within 1.5 km of the Hoft station, our data suggests detection distance was typically less than 2 km, even when the bats were in flight. These bats were likely foraging under the canopy, where tree cover obstructed signal transmission.

When our tagged northern long-eared bats were detected by the Hoft station, they were primarily detected within the range of the Hoft 2 antenna (Figure 3). MYSE 277 was only recorded by this antenna. MYSE 279 was briefly recorded by antenna 1 on July 13, with signal strength higher at this antenna than the preceding detection at antenna 2, suggesting the bat was foraging into Hoft antenna sector 1. MYSE 284 was briefly detected by antenna 5 on July 10, but signal strength was higher at antenna 2, suggesting it remained in the antenna 2 sector. MYSE 280 was frequently detected by multiple antennae consecutively on the nights of July 7 and 8, which indicates it was likely foraging closer to the Hoft telemetry station than other tagged bats, although it also could have been flying higher than the other northern long-eared bats tracked. Variation in the sector with highest signal strength across consecutive detections suggests it flew through multiple sectors over the course of both evenings.

In October, MYSE 281 was tracked to a series of tree roosts located 40-150 m from her capture site, for 39 days following capture. This bat was not detected by any automated telemetry stations. The three MYSE tagged outside of the northwest Vineyard study area were also not detected by automated stations.


MYSE 277
Signal Strength
Site and Antenna
HOFT.2
50
Jul 08
Jul 09
Jul 10
Jul 11
Jul 12
Jul 13
Date 2016


MYSE 279
Signal Strength
Site and Antenna
HOFT.2
HOFT.1
50
50
Jul 08
Jul 09
Jul 10
Jul 11
Jul 12
Jul 13
Jul 14
Date 2016

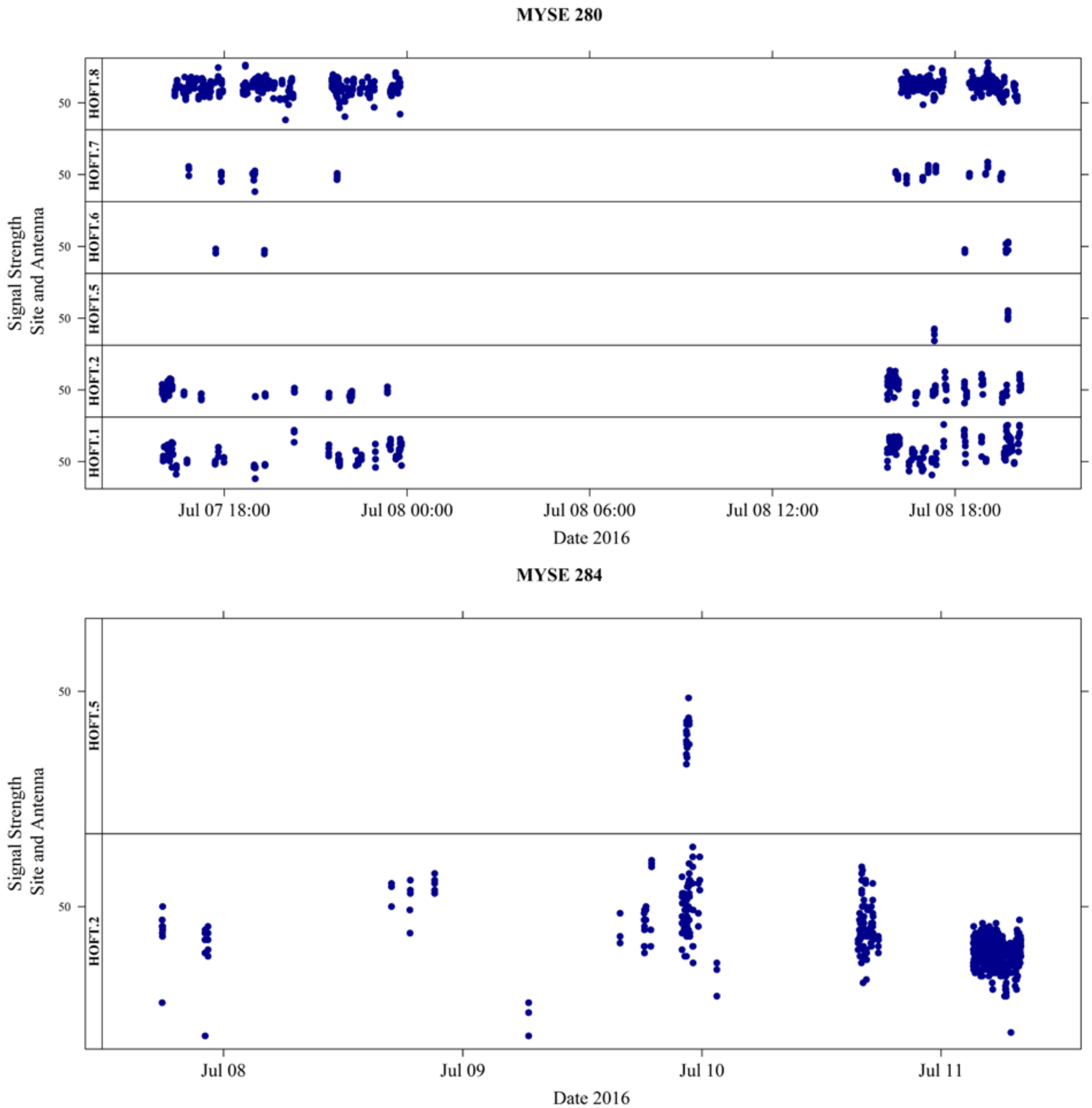


Figure 3. Local detection (signal strength versus time) plots for northern long-eared bats recorded by the Hoft telemetry station in July 2016. Three bats primarily foraged in the antenna 2 sector of the Hoft station. No northern long-eared bats were detected by other stations.

Little Brown Bats

Due to low capture rates for northern long-eared bats, we attached nano-tags to three little brown bats, but because little brown bats were not the focal species for our roost study, we did not track little brown bats to their roost every day. However, BiodiversityWorks re-visited the barn roost where the bats were initially captured to determine if they were still roosting on site.

Following capture of MYLU 276 on July 19, the bat was manually detected at the barn roost site during daylight hours on July 21 and 26 (Table 6). MYLU 276 was not detected by the local automated stations we deployed, but was detected briefly on the night of July 27 by the telemetry station on Noman's Island, 19 km to the southwest (Table 6). Signal strength was low for this detection, but it is likely the bat travelled at least as far as the southern part of Martha's Vineyard to be detected by this station. On August 4, the tag had dropped off the bat and was found at the barn roost site.

Following the capture of MYLU 278 and MYLU 286 on August 15 at the barn roost, the barn was re-visited on August 18, 21, 24, 29, 31, and September 6 (Table 6). On August 29 and 31, there was no longer a signal for MYLU 286, but MYLU 278 was still detected at the roost. On September 6, there was no signal from either bat. Between August 15-September 6, MYLU 278 was detected on one night by the Hoft station, six nights by the Cedar Tree Neck station, and five separate nights by the Naushon station (Figure 4). Between August 19 at 23:02 and August 23 at 20:29, there were no detections of this bat by Vineyard stations, but the bat was picked up by the Naushon station every night. There were near simultaneous detections (1.5 minutes apart) for this bat between the Naushon south-bearing antenna and Hoft south-bearing and south-southwest bearing antenna on August 23. Signal strength was slightly higher for the Hoft station (54 versus 52 dB). There were again near simultaneous detections (1.5 minutes apart) for this bat between the Cedar Tree Neck east-southeast-bearing antenna and the Naushon south-bearing antenna on August 31. Average signal strength was slightly higher at Naushon (56 dB versus 49 dB). The final night of detection for this bat was September 1 by the Cedar Tree Neck station, for the west-northwest-bearing antenna, which suggests the bat may have departed the island at this time. It was not recorded at the barn roost on the subsequent visit (September 6), but was also not detected by off-island stations. Between August 15-August 25, MYLU 286 was detected on four nights by Cedar Tree Neck and five nights by the Hoft station (Figure 4). On the night of August 25, the final night of detection by Hoft, she departed the island. She was next detected in the early hours of August 26 by an automated telemetry station in Falmouth, and ~3:15 in the morning by a station in Wellfleet on the eastern side of Cape Cod (Table 7).

Table 6: Roost sites and local tower detections for little brown bats (MYLU) and big brown bats (EPFU) tagged on Martha's Vineyard in 2016.

ID	Date Tagged	Roost type	Detected at roost	Absent from roost	Hoft	Goethals	Cedar Tree Neck	Naushon
MYLU 276	7/19	Barn, maternity colony	7/21, 7/26	8/4 - dropped tag found	-	-	-	-
MYLU 286	8/15	Barn, maternity colony	8/18, 8/21, 8/24	8/29, 8/31, 9/6	8/16 20:21-21:06; 8/17 20:38-21:29; 8/18 0:54-1:09; 8/24 22:42-22;23; 8:25 20:10-20:12	-	8/17 22:45-23:41; 8/18 1:20-3:15; 8/19 23:36-23:49; 8/23 0:50-5:06; 8/24 1:26-4:39	-
MYLU 278	8/15	Barn, maternity colony	8/18, 8/21, 8/24, 8/29, 8/31	9/6	8/23 20:29-23:11	-	8/17 22:24-23:44; 8/18 2:24; 8/19 4:52, 23:02; 8/31 20:18; 9/1 22:40-22:41	8/19 23:16-23:59; 8/20 0:00-2:48; 8/21 3:50-3:52; 8/22 4:03-4:06; 8/23 20:25-20:26; 8/31 20:16-20:17
EPFU 258	10/21	tree	10/22-10/30, 11/8	-	10/21 22:30-10/22 13:12; 11/3 18:08-20:31; 11/15 21:24-22:01	11/16 2:09-2:12	-	-
EPFU 275	10/21	house	10/22-10/30, 11/8	-	-	-	-	-
EPFU 271	10/17	on sanctuary, not tracked to precise location	10/25, 10/29	-	11/3 19:56-19:58	-	-	-

Table 7: Motus network detections for little brown bats (MYLU) and one eastern red bat (LABO) tagged on Martha's Vineyard that were detected by telemetry stations outside of the study area.

ID	Last Study Area Detection		Network Detection	
	Date Time	**Location**	**Date Time**	**Location**
MYLU 276	7/27/2016, 8/4/2016 (dropped tag)	manual detection at barn roost site	7/27/2016 20:36-20:38	Noman's Island, MA
MYLU 286	8/25/2016 20:12	Hoft	8/26/2016 0:26-0:34	Falmouth, MA
			8/26/2016 3:15-3:16	Welfleet, MA
LABO 473	10/19/2016 21:41	Naushon	10/20/2016 5:09-5:15	Cape May, NJ
			10/24/2016 18:33-18:59	Skidmore Island, VA

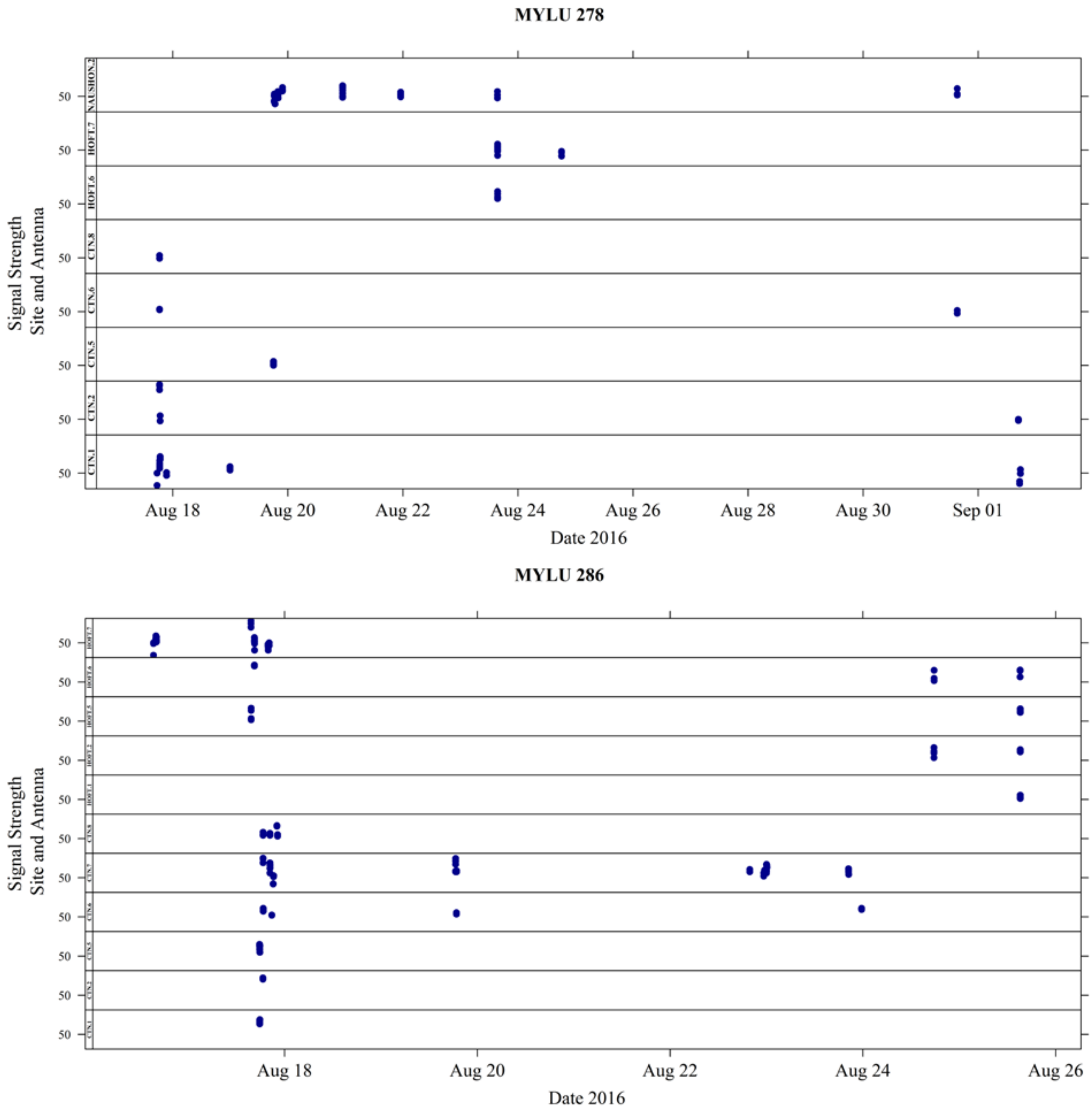


Figure 4. Local detection (signal strength versus time) plots for two little brown bats intermittently recorded by multiple telemetry stations in the northwest Vineyard study area. MYLU 286 migrated off-island and was later recorded by two telemetry stations on Cape Cod.

Big Brown Bats

The EPFU captured at Hoft Farm in October were tracked daily to roost sites from October 22-30, and were again tracked on November 8 (Table 6). Throughout this time period, each bat remained in a single roost. EPFU 275 was located in a house roost 0.55 km from the capture site and 0.84 km from the Hoft station, but was never detected by any telemetry station. This bat roosted in the same location throughout the period it was tracked. It may have dropped its tag immediately, but signal strength at the roost location was stronger in warmer weather and weaker in cooler weather, suggesting the tag remained on the bat as it shifted position in the roost. It is possible this individual entered hibernation and did not emerge in the cold conditions which followed the night of capture. EPFU 258 was located in a hollow tree 0.57 km from the capture site and 0.78 km from the Hoft station. This bat used the EP2 roost at a bearing of 330° relative to the station, and was intermittently detected by the Hoft 1 antenna, bearing 355°, while roosting, but not by antennae with bearings of 295° or 55° (Table 5). EPFU 258 was detected on three nights by the Hoft station, and on the fourth night by the Goethals station (Table 5, Figure 5), at a west-southwest bearing suggestive of offshore movement. EPFU 271, tagged near Cedar Tree Neck, was detected by the Hoft station (Table 6). We were not able to obtain permission to track bats to roost sites at Cedar Tree Neck sanctuary in October, and therefore did not attempt to track EPFU 271 to a defined roost site. However, EPFU 271 was detected from the road to the Cedar Tree Neck sanctuary on October 25 and 29.

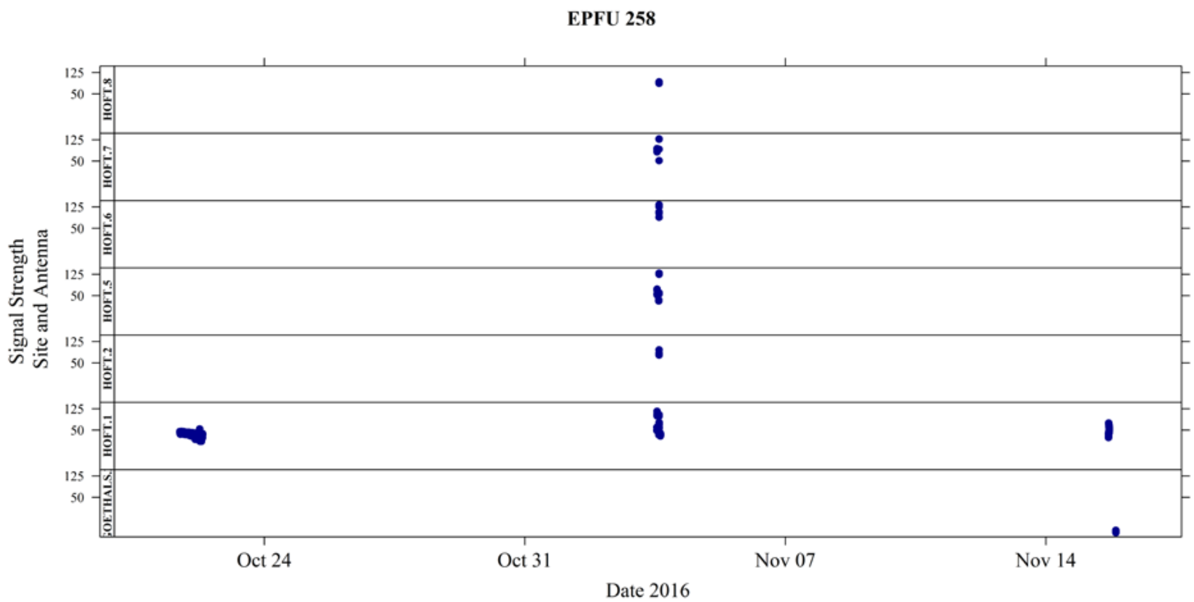


Figure 5. Local detection (signal strength versus time) plot for one big brown bat intermittently recorded by multiple telemetry stations in the northwest Vineyard study area. A second big brown bat was recorded briefly by the Hoft station.

Eastern Red Bats

The tags placed on the three LABO operated with a longer burst interval rate, which allows for a longer tag lifespan. However, the longer burst interval rate is not conducive to manual tracking. We thereforedid not attempt to track these bats to roost sites.

The eastern red bats tagged in October showed wider detectability than our northern long-eared bats. LABO 470, tagged near the Hoft station, was detected by this station on seven nights, but also detected at the Goethals station on eight nights (Figure 6). LABO 475, tagged near the Cedar Tree Neck station, was detected by this station on three nights, but also detected by the

Hoft station on one night, the Goethals station on one night, and the Naushon station on three nights (Figure 6). LABO 473, tagged in the vicinity of the Cedar Tree Neck station, was detected locally by the Hoft station on one night and the Naushon station on two nights. On October 19, the second night it was detected by the Naushon station, the bat departed the island. It was detected the following morning by an automated telemetry station in Cape May, NJ, and several days later by a station off the Eastern Shore of Maryland (Table 7).

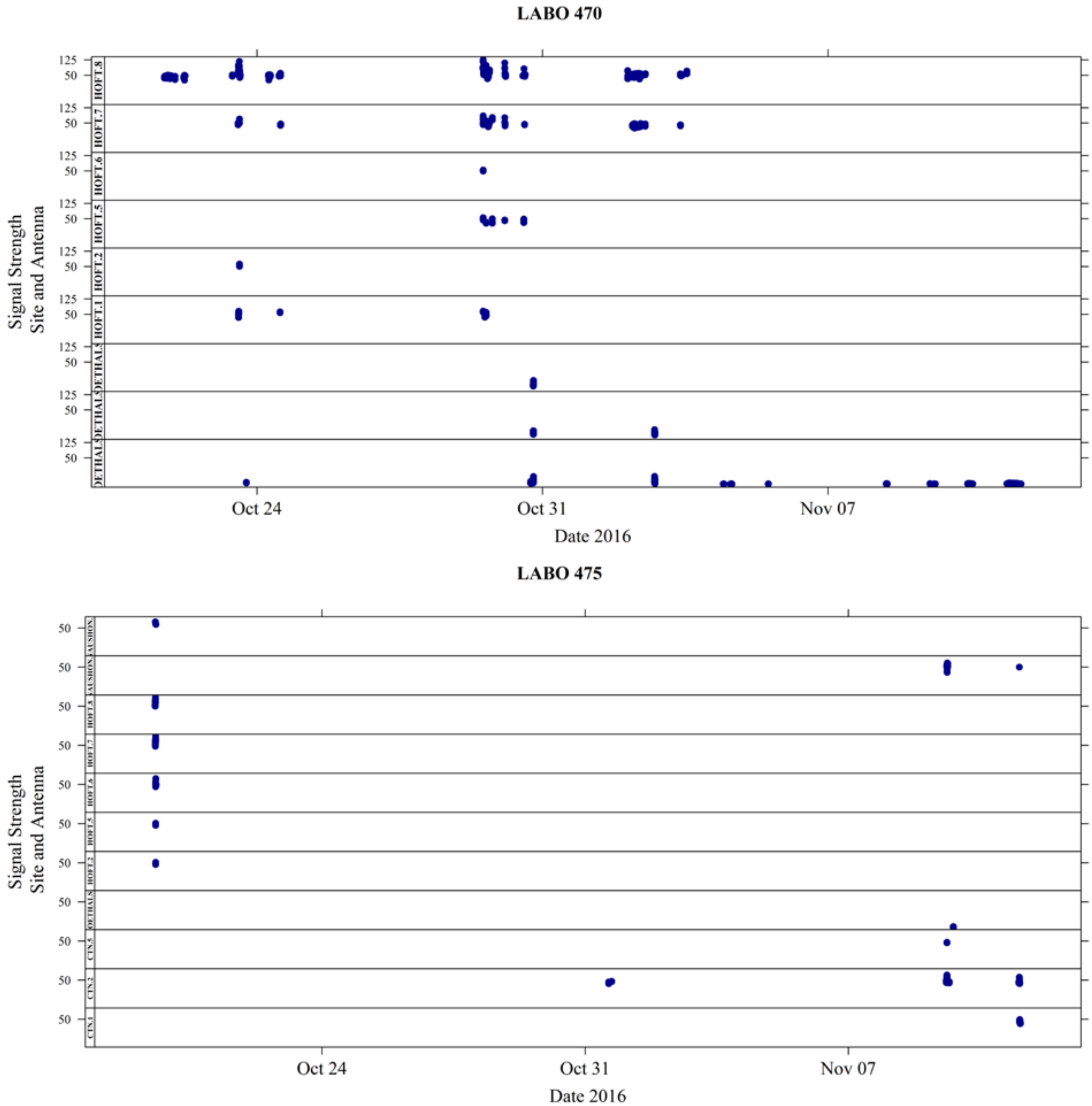


Figure 6 Local detection (signal strength versus time) plots for two eastern red bats intermittently recorded by multiple telemetry stations in the northwest Vineyard study area. LABO 473 was also recorded by a local station before migrating off-island on October 19.

Acoustic Data

We deployed acoustic detectors for a total of 38 site-nights between early June and mid-July, at 11 sites for 2-6 nights each. *Myotis* species were detected on 28 nights (74%), and at all sites except one. *Myotis* calls were recorded throughout the night during this time period, from sunset to sunrise. We again deployed acoustic detectors for four nights in late July at one site, four nights in late August at another site, and 1-6 nights each at four sites in early September. *Myotis* bats were recorded on three of the four nights sampled in July (75%), all four nights sampled in August (100%), and 10 of the 15 nights sampled in September (67%). As in the maternity period, *Myotis* calls were recorded throughout the night hours, from just after sunset until ~5:15 in the morning.

In October, we deployed detectors for a total of 83 site-nights, sampling 20 sites for 1-9 nights each. *Myotis* were recorded on 24 nights (29%). Six sites showed no *Myotis* activity, although most of these sites were only sampled 1-2 nights.

In November, we sampled a total of 27 site-nights, at four sites for 5-8 nights each. *Myotis* were recorded on 3 nights (11%), November 15, 16, and 18. The final detection of a *Myotis* bat was November 18 at 5:38 PM in the forest near where we captured and tagged a northern long-eared bat in October.

Temperature and wind data were obtained from the local airport weather station. A qualitative analysis of these data showed that most fall *Myotis* activity was during periods of low-moderate wind speed (<7 m/s) and warm temperatures (>10°C). It is important to note that weather data may not reflect local conditions experienced by the bats. Local temperatures may be lower or higher; wind speeds are likely lower under the forest canopy where acoustic detectors were deployed, as compared to the open airport environment. Further analysis of these results may be conducted by BiodiversityWorks.

Nantucket Data

In 2016, we mist-netted for bats at three sites on Nantucket. In July, we caught 9 MYSE in one night of trapping, and attached nano-tags to three adult females. One female was tracked to two tree roosts within 200 m of the capture site, another was tracked to a house roost 1.9 km from the capture site. On October 30 at the same site, we captured and tagged one MYSE in two hours of trapping, before a rainstorm interrupted netting efforts. This bat was tracked to a crawl space beneath a house located 2.39 km from the West Gate capture site. We identified the tagged bat and four other *Myotis* roosting in a crawl space beneath a private residence. On November 1, we deployed nano-tags on three additional MYSE roosting in the crawl space. Nantucket Conservation Foundation staff re-entered the space on December 8 and identified at least one individual MYSE hibernating at the site.

The closest automated telemetry stations during our study were on Coatue Point and Great Point on Nantucket, and neighboring Muskeget Island. These stations were 9, 16, and 15 km respectively from the capture site, and 7, 15, and 17 km from the crawl space hibernaculum. No bats tagged on Nantucket were detected by telemetry stations at coastal sites on the island, or anywhere off-island.

Other Tag Detections

Table 8 shows detections of nano-tags from other projects by our telemetry stations during the 2016 deployment period.

Table 8: Detections of nano-tags from other projects by the telemetry stations deployed on Martha's Vineyard and Naushon Island in 2016.

Station	Detection date	ID #	Species	Date deployed	Location deployed
Hoft	7/20/2016	5504	Black-crowned Night-Heron	7/15/2015	Oak Harbor, OH
Hoft	7/24/2016	5504	Black-crowned Night-Heron	7/15/2015	Oak Harbor, OH
Goethals	7/24/2016	6158	Semipalmated Plover	6/25/2016	unknown
Hoft	7/24/2016	6158	Semipalmated Plover	6/25/2016	unknown
Hoft	7/26/2016	8402	Black-crowned Night-Heron	6/14/2016	West Sister Island, OH
Hoft	7/26/2016	8849	Sanderling	5/28/2016	Chaplin Lake, SASK
Naushon	7/26/2016	8849	Sanderling	5/28/2016	Chaplin Lake, SASK
Goethals	7/27/2016	8849	Sanderling	5/28/2016	Chaplin Lake, SASK
Hoft	7/29/2016	8403	Black-crowned Night-Heron	6/14/2016	West Sister Island, OH
Hoft	7/29/2016	8424	Black-crowned Night-Heron	7/5/2016	West Sister Island, OH
Hoft	7/30/2016	5504	Black-crowned Night-Heron	7/15/2015	Oak Harbor, OH
Hoft	7/30/2016	8403	Black-crowned Night-Heron	6/14/2016	West Sister Island, OH
Hoft	7/30/2016	8423	Black-crowned Night-Heron	6/21/2016	West Sister Island, OH
Hoft	7/31/2016	8402	Black-crowned Night-Heron	6/14/2016	West Sister Island, OH
Hoft	8/1/2016	8402	Black-crowned Night-Heron	6/14/2016	West Sister Island, OH
Hoft	8/1/2016	8417	Black-crowned Night-Heron	6/21/2016	West Sister Island, OH
Hoft	8/2/2016	8402	Black-crowned Night-Heron	6/14/2016	West Sister Island, OH
Hoft	8/2/2016	8410	Black-crowned Night-Heron	6/21/2016	West Sister Island, OH
Hoft	8/3/2016	8410	Black-crowned Night-Heron	6/21/2016	West Sister Island, OH
Naushon	8/11/2016	7889	Sanderling	5/22/2016	unknown
Naushon	8/19/2016	10387	Semipalmated Plover	8/8/2016	James Bay, ONT
Naushon	8/29/2016	6198	Sanderling	7/9/2016	Polar Bear Pass, NUN
Naushon	9/1/2016	8935	Semipalmated Sandpiper	8/27/2016	unknown
Naushon	9/4/2016	8602	Semipalmated Sandpiper	8/8/2016	Popham Beach, ME
Naushon	9/5/2016	8939	Semipalmated Sandpiper	8/27/2016	unknown
Naushon	9/23/2016	6162	Semipalmated Plover	9/7/2016	unknown
Naushon	10/11/2016	9526	Red-eyed Vireo	10/8/2016	Block Island, RI
Naushon	10/26/2016	9126	Saltmarsh Sparrow	10/3/2016	Newburyport, MA
Goethals	10/27/2016	9126	Saltmarsh Sparrow	10/3/2016	Newburyport, MA
Goethals	10/31/2016	9490	Saltmarsh Sparrow	10/6/2016	Wells, ME
Goethals	11/12/2016	9133	Sharp-tailed Sparrow	10/13/2016	Newburyport, MA
Goethals	11/19/2016	9557	Hermit Thrush	11/7/2016	Block Island, RI

DISCUSSION

We did not observe offshore movement by northern long-eared bats during our study. In 2016, we nano-tagged four adult female northern long-eared bats in the northwest Vineyard study area during the summer maternity period. In general, individual female northern long-eared bats are known to occupy small home ranges during the maternity period. Roosting home ranges typically are <10 ha in size, and average distances between summer roosts <0.8 km (Silvis et al. 2016). Our tagged bats roosted within 0.75 km of their capture site for the 5-12 days they were tracked. From these roost locations, less than 3 km from the coast, they could easily have accessed the offshore environment. Flight speeds for northern long-eared bats have not been reported in the published literature, but we do have data for congenerics. The Indiana bat has been recorded flying at speeds of 2.5-6.7 m/s (Patterson & Hardin 1969), while the little brown bat has been variously reported traveling at speeds of 2.2-8.5 m/s (Gould 1955, Mueller & Emlen 1957, Patterson & Hardin 1969). Other *Myotis* species reportedly fly at speeds of 4.0-10.8 m/s (Hayward & Davis 1964, LaVal et al. 1977). Even at a moderate 5 m/s, a northern long-eared bat could reach three nautical miles from shore in less than 20 minutes of sustained flight. Lactating females could forage offshore and still return to nurse pups multiple times per night. However, it appears unlikely that this species is foraging far offshore during the summer months, given what is known about northern long-eared bat biology and the limited observations made in this study. Our tagged lactating females were only detected by the inland telemetry station close (0.69 km) to where they were captured, and never by the neighboring coastal station (2.6 km away). Foraging home ranges reported in the literature are somewhat larger than roosting home ranges, but still below 100 ha (Owen et al. 2003, Broders et al. 2006, Silvis et al. 2016), with maximum movements of up to 1.8 km recorded (Broders et al. 2006, Henderson & Broders 2008). While we did not have telemetry stations on the Vineyard in 2015, northern long-eared bats captured on the island during the summer of that year showed similar patterns of behavior to 2016, roosting within a small home range (42-665 m from capture site).

We also did not observe northern long-eared bats leaving the island in the fall. Only one northern was tagged in the northwest study area in fall 2016. This bat was not recorded by any telemetry stations, and roosted in a small area. We anticipated cold temperatures in October would cause the bat to move to a warmer hibernation site, but we saw no evidence of this behavior. The bat switched roost sites through November 3, and we recorded changes in signal strength day-to-day (indicative of the tag remaining on the bat) through November 8. It is possible that the bat entered hibernation within the final tree cavity in which it roosted. Tree cavities can maintain above-freezing temperatures throughout much of the winter, and it has been suggested that *Myotis* species on marine islands could hibernate in cavities in northern climes (Burles et al. 2014). The two northern long-eared bats manually tracked in September and October 2015 remained locally until transmitters dropped (BiodiversityWorks, unpublished data). In 2016, late season deployment of acoustic detectors intermittently picked up northern long-eared bat calls at multiple sites on the island throughout October and into mid-November.

One of our goals in conducting this study was to address the question of whether northern long-eared bats are remaining on Martha's Vineyard throughout the year, or leaving for the winter months. The presence of a WNS-infected northern long-eared bat on the island in February 2017 (BiodiversityWorks, unpublished data, https://vineyardgazette.com/news/2017/03/22/bats) requires that one of two explanations be true – either northern long-eared bats are leaving the island, and becoming infected at mainland hibernation sites, or northern long-eared bats remain on the island, but other species travel between the island and the mainland and have brought WNS to the island, which has since infected local northern long-eared bats. Of course, these alternative explanations are not mutually exclusive. It is possible, and frankly, entirely likely, that these bats exhibit a range of behaviors, with some venturing to mainland hibernation sites, while others remain on-island. Little brown bats in the same maternity colony have been shown to use different hibernation sites 51-554 km away (Norquay et al. 2013). The drop in overall capture rates of northern long-eared bats since the 1990s strongly suggests that WNS has affected populations on the island, but our observations of healthy maternity colonies could lend support to the hypothesis that subpopulations have remained locally on the island in small hibernacula thus far free of WNS. Collectively, our evidence points to the idea that at least some northern long-eared bats are hibernating locally – this is supported by late season residency behavior of tagged individuals, by late-season acoustic data, and perhaps most strongly, by the February occurrence of bats on the island, and the discovery of a hibernaculum on neighboring Nantucket (unpublished data). A number of summer houses on the Vineyard are heated through the colder months, but remain unoccupied; among other locations, these residences could easily be providing habitat to hibernating bats.

Our telemetry system recorded wider-ranging movements of little brown, big brown, and eastern red bats. Off-island movements were detected for at least two individuals, suggesting our system worked to detect these movements when they occurred. Of the eight bats tagged in 2016 that were not northern long-eared bats, seven were detected by stations at least 2.6 km from their capture location. In contrast, none of the northern long-eared bats were detected by stations more than 0.69 km away.

We documented migration of a little brown bat from Martha's Vineyard to the mainland. One of the three little brown bats tagged was recorded departing the island on the night of August 25, and made migratory movements along the south and east sides of Cape Cod. It was last detected by a telemetry station in Wellfleet, 82 km from its initial capture and roost location. We also recorded evidence that the second little brown bat tagged in August appeared to make offshore movements, traveling to Naushon Island or foraging over Vineyard Sound. This bat was last detected at a bearing of west-southwest off the Cedar Tree Neck station on September 1. The detection direction suggests the bat may have migrated off-island at this time, and it was not detected at its roost site or by Vineyard or Naushon stations after this date, although it was also not detected by off-island stations aside from Naushon. The timing for departure of these bats is consistent with results from other studies, which found most little brown bats departing summer roost sites between mid-August and mid-September (Cope 1976, Kunz et al. 1998, Townsend et al. 2008) or describe capture of these species at cave swarming sites in mid-August to early October (Schowalter 1980, Burns et al. 2014). In addition, one of the tagged big brown bats was last detected by an ocean-bearing antenna on the Goethals station in late November, suggesting it was also moving offshore. It may have departed the island at this time, but was not detected by any off-island stations. One of the three tagged eastern red bats departed the island on October

19, and was recorded making migratory movements as far south as Maryland.

While we did not detect offshore migration by northern long-eared bats in our study, we did not track these bats in late August, and therefore cannot rule out the possibility that some northern long-eared bats may depart summer roosts at a comparable time to little brown bats. We could not identify any studies tracking northern long-eared bats as they move from summering grounds to winter hibernacula, and because their maternity colonies are often smaller than those of little brown bats, it is difficult to determine departure dates from summer roost sites for this species. Several studies do report northern long-eared bats arriving at swarming sites from the end of July through mid-October (Carceres & Barclay 2000, Broders & Forbes 2004). Seasonal patterns of bat activity on Martha's Vineyard vary by habitat (Buresch 1999), so it remains unclear whether a population decrease for northern long-eared bats occurs in late summer.

The timing of northern long-eared bat activity on Martha's Vineyard varied by season. During the maternity period, automated stations recorded activity of our tagged northern long-eared bats throughout the night, from shortly after sunset to shortly before sunrise. In a similar manner, acoustic detectors recorded *Myotis* calls throughout the night hours. In the fall, however, we primarily detected *Myotis* acoustic activity in the 2-2.5 hours post-sunset, although occasional calls were recorded throughout the night. The majority of echolocation calls in October were recorded under low-moderate wind speed conditions and in relatively mild temperatures (>10°C). If northern long-eared bats are making offshore forays, we might expect them to be active throughout the night in summer, but likely only active for several hours post-sunset in the late fall.

CONCLUSIONS

The five northern long-eared bats tracked in this study in 2016 were not detected making offshore movements. However, our tracking system was adequate to detect wide-ranging and offshore movements by other bat species tagged as part of these efforts. Data in the published literature suggest female northern long-eared bats occupy small home ranges for foraging and roosting during the maternity season, and these findings are consistent with our limited data from Martha's Vineyard. During the summer months, female northern long-eared bats on the island were active throughout the night and could easily have accessed offshore environments for foraging under calm conditions. However, published reports suggest northern long-eared bat females are unlikely to forage greater than 2 km from roost sites during the maternity season, which would indicate they are unlikely to travel into federal waters (5.6 km offshore) during this time period, and we recorded no movements which exceeded 2 km. The behavior of adult male northern long-eared bats during the maternity season is largely unreported throughout their range, and we did not capture adult males on the Vineyard in 2015 or 2016.

We did not detect off-island movements by the two northern long-eared bats tagged in September 2015, or the single northern tagged in October 2016. Our study strongly suggests that some northern long-eared bats are hibernating locally on Martha's Vineyard. In contrast, our limited data show some little brown bats make offshore movements or depart the island in late August. Given the small number of northern long-eared bats we were able to track in the fall, and the timing of those efforts, we cannot rule out the possibility that some northern long-eared bats may migrate off-island.

Low capture rates due to WNS are likely to be a continuing issue for future studies of northern long-eared bats on the island. We offer the following recommendations regarding future studies:

1. Monitoring known northern long-eared bat maternity roosts and trapping at these sites is likely to be the most efficient means of capture for this species during the maternity season. Efforts to further document offshore bat movements during this time period should focus on capture at identified roosts near the coastline in order to increase the sample size of tagged bats.

2. Off-island migration of northern long-eared bats could be occurring in late August. We did not focus our mist-netting efforts during this time period. It could be highly revealing to nano-tag northern long-eared bats during this time, although capture rates are likely to be low. Capture of little brown bats at their barn roost site was more time-efficient, and it would be informative to tag individuals of this species at known roosts on the Vineyard in late August, to further document timing and locations of offshore movement. If possible, individuals of both sexes should be tagged.

3. Capture rates were high at our Nantucket capture site during pilot mist-netting efforts. If northern long-eared bats continue to persist on this island in 2017, it could be a good location for future studies. However, the dynamics of WNS spread on islands is not well understood, and unfortunately, we could easily find similar declines in northern long-eared bat populations on Nantucket in coming years.

4. Offshore acoustic monitoring could be an effective way to identify timing of offshore movements by *Myotis* spp., relative to season and weather conditions. However, it is important to recognize the inherent difficulties in differentiating among *Myotis* spp. echolocation calls, and the degree of error and uncertainty associated with both manual and automatic classification of these calls.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

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