INTERIM REPORT

Acoustic monitoring of migrating bats and birds on Rhode Island National Wildlife Refuges

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Coastal New England is an important migratory corridor and contains important stopover habitats for migratory songbirds and bats. For example, many songbird species consume large amounts of seasonally-available fruit in the maritime shrub community of southern New England. Nonetheless, coastal New England remains under constant threat from development and invasive plant species. Additionally, parts of coastal Rhode Island (onshore and offshore) are being explored for wind energy development. All of Rhode Island's five National Wildlife Refuges (NWRs) occur along this coastal flyway and protect significant amounts of maritime shrub community and complex habitat mosaics well-suited for foraging and stopover by migrating birds and bats. However, we know little about the relative use of these refuges by migrating bird and bat species, or the patterns of this relative use during fall migration.

During the fall 2010 migration, we initiated passive acoustic monitoring of the nocturnal activity of migrating birds and bats at three Rhode Island NWR (RINWR) locations: Sachuest Point NWR, and two locations on Block Island NWR, the Kurz and Wash Pond tracts (Figures 1 and 2). Our primary objectives were threefold: to compare among these RINWR locations (1) the relative use by migrating bats and birds; (2) the species composition of migrating bats and birds; and (3) the seasonal and nightly patterns of use by migrating bats and birds.

METHODOLOGY

Acoustic Monitoring

Birds. We recorded nocturnal flight calls (NFCs) with the Wildlife Acoustics SM2BAT and SMX-NFC microphone (Wildlife Acoustics, Inc., Concord, MA; 192 kHz sampling rate, resampled to 22 kHz). The microphone capsule of the SMX-NFC is mounted near a flat horizontal plate creating a pressure zone for sounds originating from above the plate, effectively increasing signal gain by 3 - 6 dB, while attenuating sounds from below the plat. The microphone element possesses a relatively flat frequency response from 2-12 kHz (the range of most nocturnal flight calls). Monitoring was passive at all sites: a SMX-NFC microphone was mounted on U-channel post approximately 5 - 5.5 m above ground level (and above the canopy) in coastal shrub habitat. The signal was relayed through 10 m of SM2 microphone cable to the SM2BAT. The Sachuest Point NWR installation was the exception to this arrangement, with the microphone mounted on the edge of the roof near the north corner of the maintenance building, approximately 6.5 m above ground level, in a mixed lawn and impervious surface mosaic; however, coastal shrub habitat surrounds this location. We recorded continuously from civil sunset to civil sunrise, from 9 September to 9 November, although coverage was not complete during this period owing to occasional equipment or data storage malfunctions. Night length increased from 10.3 to 13.0 hours over the course of the recording season.

Bats. We recorded 12-bit, full-spectrum ultrasonic bat calls with the Wildlife Acoustics SM2BAT and SMX-US microphone (Wildlife Acoustics, Inc., Concord, MA; 192 kHz sampling rate, frequency range 1–96 kHz). As with the nocturnal flight calls, monitoring was conducted passively. The SMX-US microphone was mounted on the U-channel post adjacent to the SMX-NFC microphone. We used triggered recording from civil sunset to civil sunrise, from 9 September to 9 November, although coverage was not complete during this period owing to occasional equipment or data storage malfunctions. Triggered recording with the SM2BAT at high gain (+ 60dB) maximized reception range and reduced the number of recordings attributable to insects. In short, potential bat calls were recorded when a signal exceeded by 6 dB the 0.5 s rolling average power spectrum in the frequency band; recording ceased when no trigger was detected for 1 s.

Analysis

Birds. Analysis of nocturnal flight calls is ongoing and detailed analytical methodology will be provided at a later date.

*Bats***.** Nine bat species inhabit or potentially migrate through Rhode Island: big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*), eastern red bat (*Lasiurus borealis*), hoary bat (*Lasiurus cinereus*), eastern small-footed myotis (*Myotis leibii*), little brown myotis (*M. lucifugus*), northern myotis (*M. septentrionalis*), Indiana bat (*M. sodalis*), and the tri-colored bat (*Perimyotis subflavus*; formerly eastern pipistrelle). The Indiana bat is federally endangered. None of the other species currently possesses special conservation designations at the state or national level, although an initial review by the U.S. Fish & Wildlife Service has recently concluded that the eastern small-footed myotis and northern myotis may warrant federal protection under the Endangered Species Act due primarily to the impacts of white-nose syndrome (WNS). Additionally, big brown bats, little brown myotis, Indiana bats, and tri-colored bats are believed susceptible to WNS, which threatens to devastate bat populations throughout the continent.

Original audio (*.wac4) files recorded with the SM2BAT were decompressed to *.wav files using Wildlife Acoustics' WAC2WAV utility. The WAC2WAV utility split the ultrasonic triggering events into separate *.wav files for analysis, and provided an optional filter to separate potential calls from noise; we elected to apply this built-in noise filter. Recorded files were truncated to a maximum of 8 s in length to facilitate analysis. The maximum file length dictates our definition of a bat pass; in this case, we consider a bat pass as at least one echolocation pulse in each ≤ 8 s recording. We considered each file to have only one pass of a given species, even if long gaps between pulse series suggested multiple flights past the microphone. Occasionally, multiple species were recorded in a single file, in which case a pass was counted once for each of the species represented. We emphasize that while the number of passes is likely correlated with bat abundance at a site, it may not accurately reflect true abundance (Miller 2001). For example, one pass represents at least one individual, whereas ten passes could represent ten individuals, one individual passing the detector ten times, or some intermediate number of bats. The number of bat passes, and any associated pass rate, should therefore be considered reflective only of relative activity (rather than abundance).

The resulting potential bat calls were then analyzed using the automated identification algorithms in SonoBat 3.02 (SonoBat, Arcata, CA). SonoBat uses a hierarchical analysis of full spectrum call characteristics to evaluate the potential identification of the species issuing the call. By default, the identification algorithms are conservative, and we used the default analysis parameters. In most cases (88.6% of all passes across sites), we were unable to reliably assign calls to species. We manually inspected (i.e., vetted) all recordings associated by SonoBat with any species with > 0.75 discriminant probability (DP); however, we did not vet calls associated only with either eastern red bat and silver-haired bat, as both species were very common and not of particular conservation concern. During the vetting process, we made species identifications through detailed inspection of individual pulses and pulse sequences for key features. We assigned species identifications conservatively, and thus we did not confidently assign most passes to a species due to too few pulses or pulses of inadequate quality (e.g., indistinct pulse characteristics, background interference, faint or fragmentary calls, calls lacking structure easily characterized to species, or microphone/SM2BAT limitations). Given our conservatism, it is likely that we did not confirm every species present at each site. However, we vetted all calls associated with any species other than eastern red bat and silver-haired bat. We assert that any species present but unconfirmed is rare or not calling (i.e., not foraging) at these sites. Calls not assigned to a species were classified as follows:

- Myotid (MYSP) – This guild contains the four species of the genus *Myotis*: eastern small-footed myotis, little brown myotis, northern myotis, and Indiana bat. With calls of good quality, myotid calls are relatively distinct from other high-frequency bat calls in Rhode Island (i.e., HFUN, below).

- High-frequency unknown (HFUN) – The category includes all call sequences above 30-35 kHz with too few pulses or pulses of inadequate quality (e.g., indistinct pulse characteristics or background interference). Although calls could have originated from bats included in the MYSP guild, the vast majority of cases likely represented eastern red bats or tri-colored bats;

- Low-frequency unknown (LFUN) – This category includes all call sequences below 30-35 kHz with too few pulses or pulses of inadequate quality (e.g., indistinct pulse characteristics or background interference). Most unknown low frequency calls originated from big-brown or silver-haired bats, as hoary bats are more readily distinguished in most cases.

Once bat passes were identified and categorized, we summarized passes to explore nightly and seasonal patterns of bat activity. First, to explore seasonal phenology, we used a custom script in R (version 2.12.0; R Development Core Team 2010) that tallied bat passes on a nightly basis at each site. Second, we examined bat activity patterns over the course of the night in two ways: we calculated (1) the time since civil sunset of each bat pass and categorized them into half-hour intervals; and (2) the proportion of the night (i.e., civil sunset to civil sunrise) that had transpired when each bat pass occurred. The two metrics are similar, but because night length increased over the course of the season, the second metric (proportion of the night) makes activity patterns directly comparable among nights. This metric assumes, however, that bats adjust their activity patterns based on night length, rather than relative to some fixed event (e.g., sunset). The two metrics provide qualitatively similar patterns (see Results below).

RESULTS

Birds

Analysis of flight calls is ongoing. Results will be provided at a later date.

Bats

Relative activity among sites. Between 8 September and 9 November, 11783 bat passes were recorded among the three Rhode Island NWR sites (Tables 1 and 2). Recording did not occur on 34 nights at Sachuest due primarily to the failure of the ultrasonic microphone element. Apparently, gulls removed the wind screen from the microphone and the element was subsequently compromised by precipitation. Recording did not occur on 7 nights at Kurz and 5 nights at Wash Pond, due primarily to data storage failures. Rates of bat activity were highest at Sachuest (Table 2), although the comparison is complicated by dissimilar recording coverage among sites. The comparison of bat activity rates on the 23 nights in which the three sites recorded simultaneously indicated that Sachuest and Kurz witnessed approximately seven times more bat activity than Wash Pond (Table 2). Although they exhibited similar average activity rates, levels of bat activity at Sachuest and Kurz exhibited little correlation (correlation coefficient of log-transformed counts of bat passes = 0.01).

Seasonal phenology of bat activity. Most bat activity occurred prior to early October, and bat activity occurred quite sporadically throughout the season at all sites (Figure 3). For example, nearly half of all bat activity occurred on just five nights at Sachuest, four nights at Kurz, and three nights at Wash Pond (Figure 3). The occurrence of high and low frequency bat calls also varied throughout the season; low frequency calls were more common earlier in the season than later except at Sachuest, which witness relatively little activity from low frequency bats (Table 2 and Figure 3).

Bat community composition. Sachuest experienced predominantly high frequency bat activity, while the Block Island sites experienced a more even mix of low and high frequency bats (Table 2 and Figure 3). At all sites, eastern red bats and silver-haired bats were the most commonly identified high and low frequency bats, respectively (Table 3). While we believe this represented relative abundance to some extent, it also likely reflected the relative ease of distinguishing eastern red bats and silver-haired bat calls. For example, big brown bats and silver-haired bats possess very similar calls; however, it is much easier to confirm a silver-haired bat than it is a big brown bat, so we expect that big brown bats were more common than Table 3 would suggest. Additionally, when recorded with good quality, distinguishing myotids from other high frequency bats is relatively straightforward; thus, we expect that the vast majority of the unidentified high frequency calls represent eastern red bats or tri-colored bats. Similarly, hoary bats are relatively easy to distinguish from silver-haired and big brown bats, thus the latter likely comprise the majority of the unidentified low frequency calls. Within the myotids, Indiana bats and little brown myotis call are difficult to distinguish, and distant calls (i.e., lacking complete frequency information) can closely resemble those of eastern red bats. Eastern small-footed and northern myotis calls are more distinctive - all myotids identified to species were eastern small-footed myotis, and northern myotis was likely detected on two occasions (once each at Kurz and Wash Pond). We did not "confirm" any northern myotis calls, however, as their calls are necessarily incomplete owing to the frequencies recorded by our version of the SM2BAT (i.e., ≤ 96 kHz; northern myotis calls regularly reach > 110 kHz).

Within-night patterns of bat activity. Bat activity during the course of the night showed relatively similar patterns among sites (Figures 4 and 5). Specifically, bat activity exhibited some degree of periodicity, with alternating intervals of relatively high and low activity. This pattern was most pronounced at Sachuest, and more subtle at the Block Island sites. While the general pattern of nightly bat activity was similar among sites, the specifics of the patterns showed some distinct differences. First, at Sachuest and Kurz, nightly patterns were relatively similar for high- and low-frequency bats, while at Wash Pond low-frequency bats were distinctly more active early in the night. Second, bat activity peaked at or just after sunset at the Block Island sites, while a 1-2 hours delay after sunset before peak activity at Sachuest.

DISCUSSION

Birds

Analysis of flight calls is ongoing. Discussion will be provided at a later date.

Bats

Relative activity among sites. Wash Pond experienced less bat activity than Kurz or Sachuest. The extent to which this difference in activity represents differences in habitat quality (e.g., food availability) or differences in geography (e.g., perhaps bats, like birds, are naturally concentrated at Sachuest and Kurz) is unknown, and is difficult to tease apart. Furthermore, caution should be exercised in using only pass rates among sites as indicators of relative bat activity. For example, the Sachuest site was near artificial lighting, which may have attracted flying insects and thus some bats. Additionally, low-frequency calls are detectable at longer distances. Thus, given the relative abundance of low-frequency bats at Wash Pond and Kurz, these microphones may have sampled an effectively larger area than the Sachuest microphone. What is clear, however, is that the Kurz and Sachuest sites regularly experienced significant bat activity (e.g., > 100 bat passes/night) during the 2010 fall migration, and the Wash Pond site did so on a more sporadic basis, particularly in September.

Seasonal phenology of bat activity. The high variability (in occurrence and intensity) characteristic of documented bat activity suggests climatological factors are involved, and that analysis is ongoing. However, the lack of a correlation between bat activity at Sachuest and Kurz suggests that different factors are at play for the two sites; perhaps island dynamics are involved.

Bat community composition. The relatively low activity of low-frequency bats (but relatively high activity of hoary bats) at Sachuest (Tables 2 and 3) is difficult to explain. Species making low-frequency calls are larger, more powerful flyers than those making high-frequency calls, which may help explain the relatively large contribution of low-frequency bats to the activity at the Block Island sites (i.e., given the water crossing necessity), but it fails to explain the relative low numbers of low-frequency bats at Sachuest.

Within-night patterns of bat activity. The alternating intervals of relatively high and low activity during the night perhaps reflects foraging patterns in which periods of foraging activity are interspersed with periods of rest (e.g., for digestion or as a result of local resource depression). We have no specific explanation for the disproportionate activity of low-frequency bats early in the night at Wash Pond, other than the existence of some local conditions (e.g., food availability, roosting locations) that facilitate activity just after sunset. The 1-2 hour delay after sunset before peak activity at Sachuest may suggest that many bats travel from elsewhere (rather than roosting nearby) to feed in the vicinity of the microphone. Alternatively, we do not know the timing or intensity of artificial lighting near the microphone, which may alter bat foraging activity as well. In subsequent years, it is recommended that the Sachuest microphone be placed in a more natural setting to facilitate comparisons with data from other microphones.

LITERATURE CITED

Miller, B.W. 2001. A method for determining relative activity of free flying bats using a new activity index for acoustic monitoring. Acta chiropterologica 3:93-105.

R Development Core Team. 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Table 1. Operational summary of acoustic and ultrasonic recording at three locations on the Rhode Island National Wildlife Refuge (NWR) Complex during the 2010 fall migration.

		Block Island NWR	
	Sachuest NWR	Kurz	Wash Pond
Start night	10 Sept	8 Sept	11 Sept
# nights operated	61	63	60
# nights recorded			
Acoustic (songbirds)	51	55	55
Ultrasonic (bats)	27	56	55

Table 2. General summary of bat passes and pass rates recorded at three locations on the Rhode Island National Wildlife Refuge (NWR) Complex during the 2010 fall migration.

		Block Island NWR	
Bat pass category	Sachuest NWR	Kurz	Wash Pond
High frequency passes	4239	3529	541
Low frequency passes	382	2565	527
Total passes	4621	6094	1068
Pass rate (passes/night)	171.1	108.8	19.4
Pass rates on shared nights (n=23)			
High frequency	144.7	91.4	16.1
Low frequency	12.0	57.6	7.9
Total	156.7	149.0	24.0

Table 3. Bat community composition derived from bat passes recorded at three locations on the Rhode Island National Wildlife Refuge (NWR) Complex during the 2010 fall migration.

		Block Island NWR	
Bat pass category[1]	Sachuest NWR	Kurz	Wash Pond
High frequency (HF) passes			
Eastern red bat	263	74	44
Tri-colored bat	25	20	1
Eastern small-footed myotis	9	1	2
MYSP	4	7	2
HFUN	3938	3427	492
Low frequency (LF) passes			
Silver-haired bat	83	607	146
Hoary bat	42	9	6
Big brown bat	1	3	0
LFUN	256	1946	375

[1]Classification of bat passes was to species, when possible, but otherwise to a broader classification of MYSP (myotids), HFUN (unknown high frequency), and LFUN (unknown low frequency). See text for more complete description.

FIGURE LEGENDS

Figure 1. Location of acoustic and ultrasonic microphones (red circle) at Sachuest National Wildlife Refuge (NWR) during the 2010 fall migration. The microphones were mounted onto the roof at the northernmost corner of the NWR maintenance building.

Figure 2. Location of acoustic and ultrasonic microphones (red circles) on the Block Island National Wildlife Refuge (NWR) during the 2010 fall migration. The microphones were mounted approximately 18 feet above ground level on u-channel poles placed in maritime coastal shrub habitat. The Kurz microphone is the northernmost microphone.

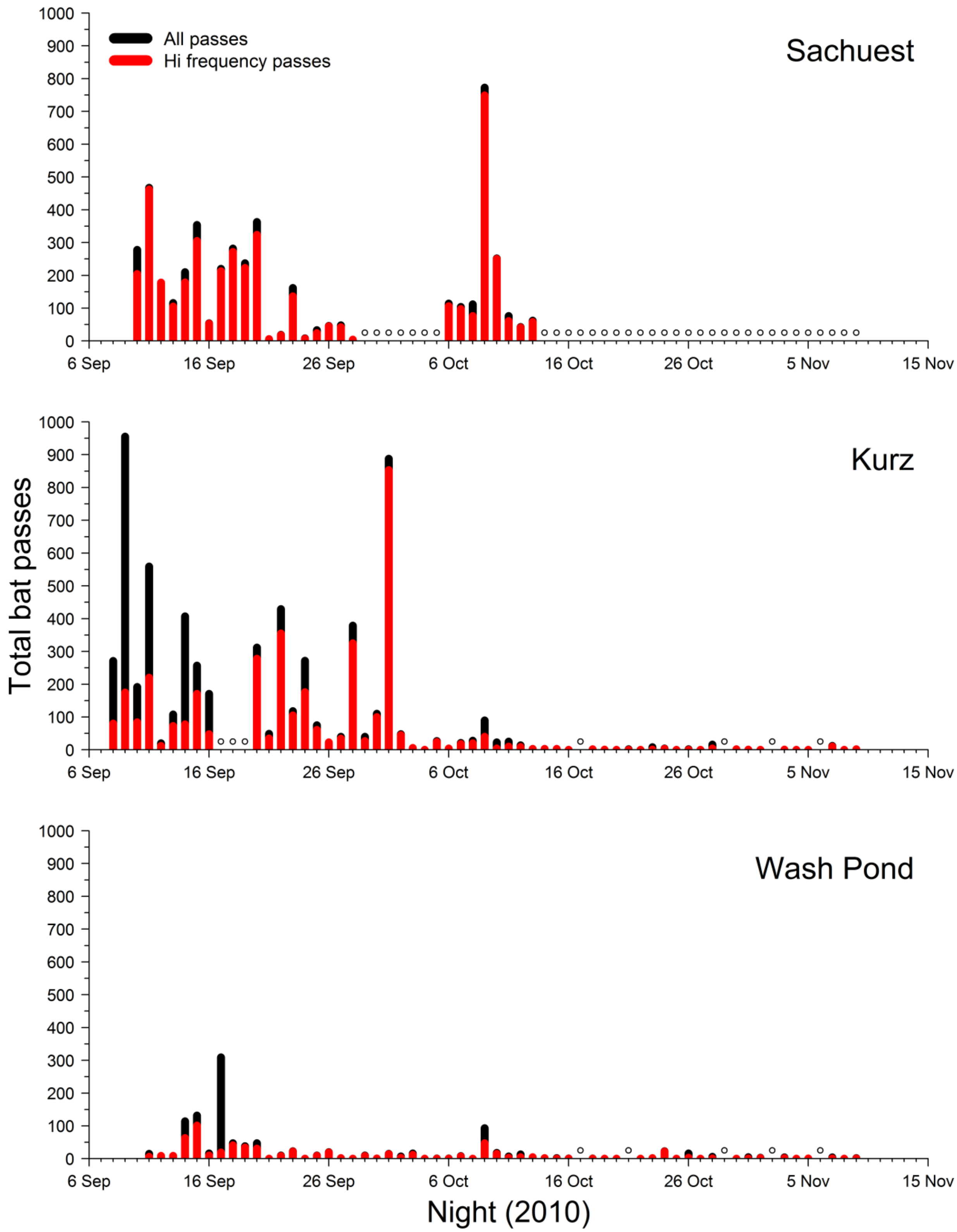
Figure 3. Nightly summary of bat passes recorded at three locations on the Rhode Island National Wildlife Refuge (NWR) Complex during the 2010 fall migration. The height of the black bar indicates the total number of bat passes recorded in a night; the red bar indicates the portion of total bat passes classified as high frequency bat passes. Bats emitting high-frequency calls dominated at Sachuest NWR, while Block Island NWR sites exhibited a more even mixture of high- and low-frequency emitting bats. Low frequency calls were more common earlier in the season. Unfilled circles indicate nights the microphones were deployed but failed to record.

Figure 4. Bat passes in relation to time after civil sunset at three locations on the Rhode Island National Wildlife Refuge (NWR) Complex during the 2010 fall migration. The height of the black bar indicates the proportion of all bat passes recorded at a site that occurred in each half-hour interval between civil sunset and civil sunrise; the red bar indicates the portion comprising high frequency bat passes. Bat activity (calling patterns) exhibited alternating periods of relatively high and low activity throughout the night. Peak activity occurred just after sunset at Block Island NWR sites, but 1-2 hours after sunset at Sachuest NWR. Unfilled circles indicate nights the microphones were deployed but failed to record.

Figure 5. Bat passes in relation to the proportion of night (civil sunset to civil sunrise) that had elapsed at the time of the bat pass at three locations on the Rhode Island National Wildlife Refuge (NWR) Complex during the 2010 fall migration. This metric makes the timing of bat passes comparable among all nights during the entire migration period. The height of the black bar indicates the proportion of all bat passes recorded at a site that occurred in intervals comprising 5% of a given night; the red bar indicates the portion comprising high frequency bat passes. Bat activity (calling patterns) exhibited alternating periods of relatively high and low activity throughout the night. Peak activity occurred just after sunset at Block Island NWR sites, but 1-2 hours after sunset at Sachuest NWR. Unfilled circles indicate nights the microphones were deployed but failed to record

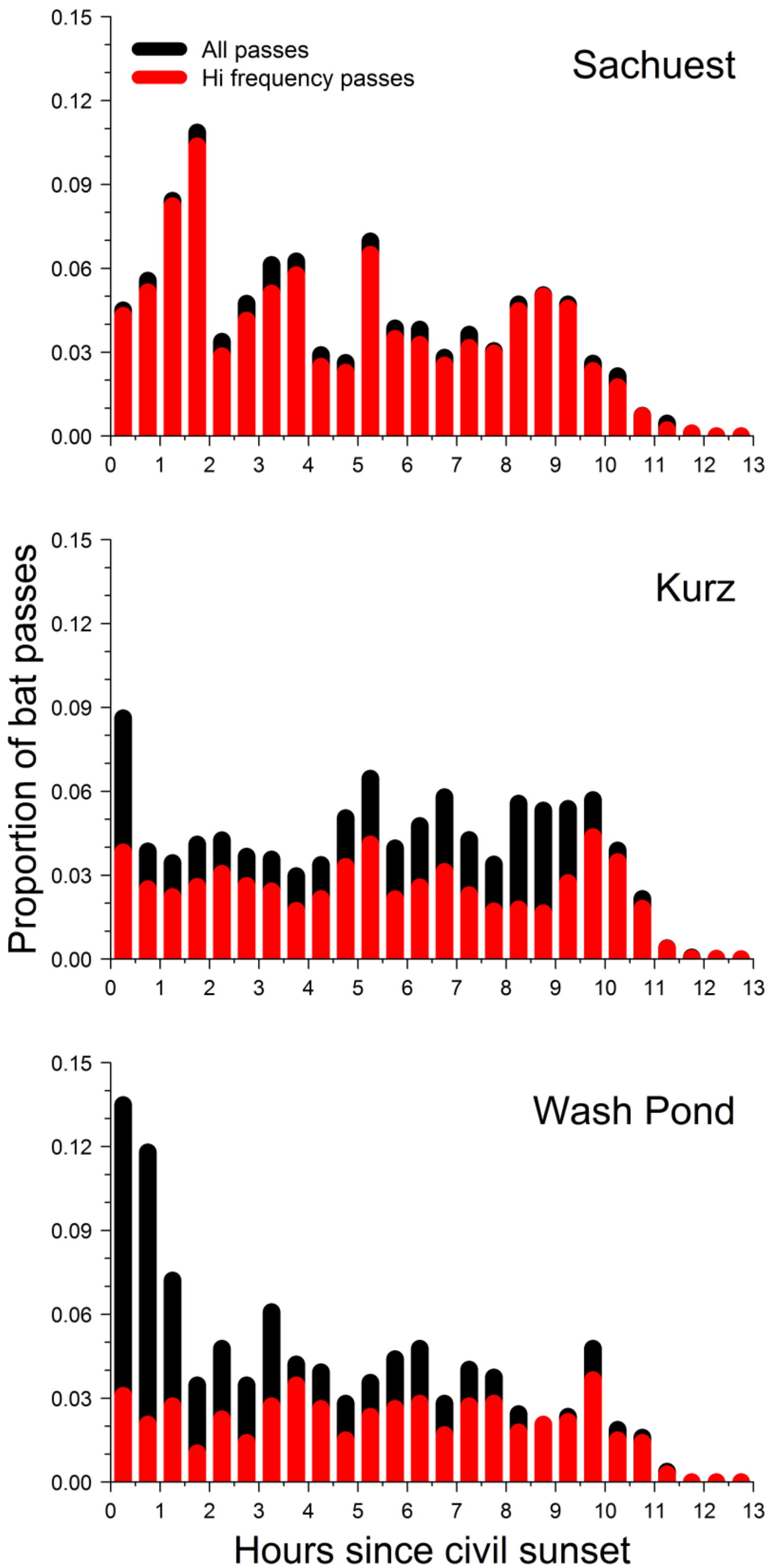
Figure 1.

Figure 2.



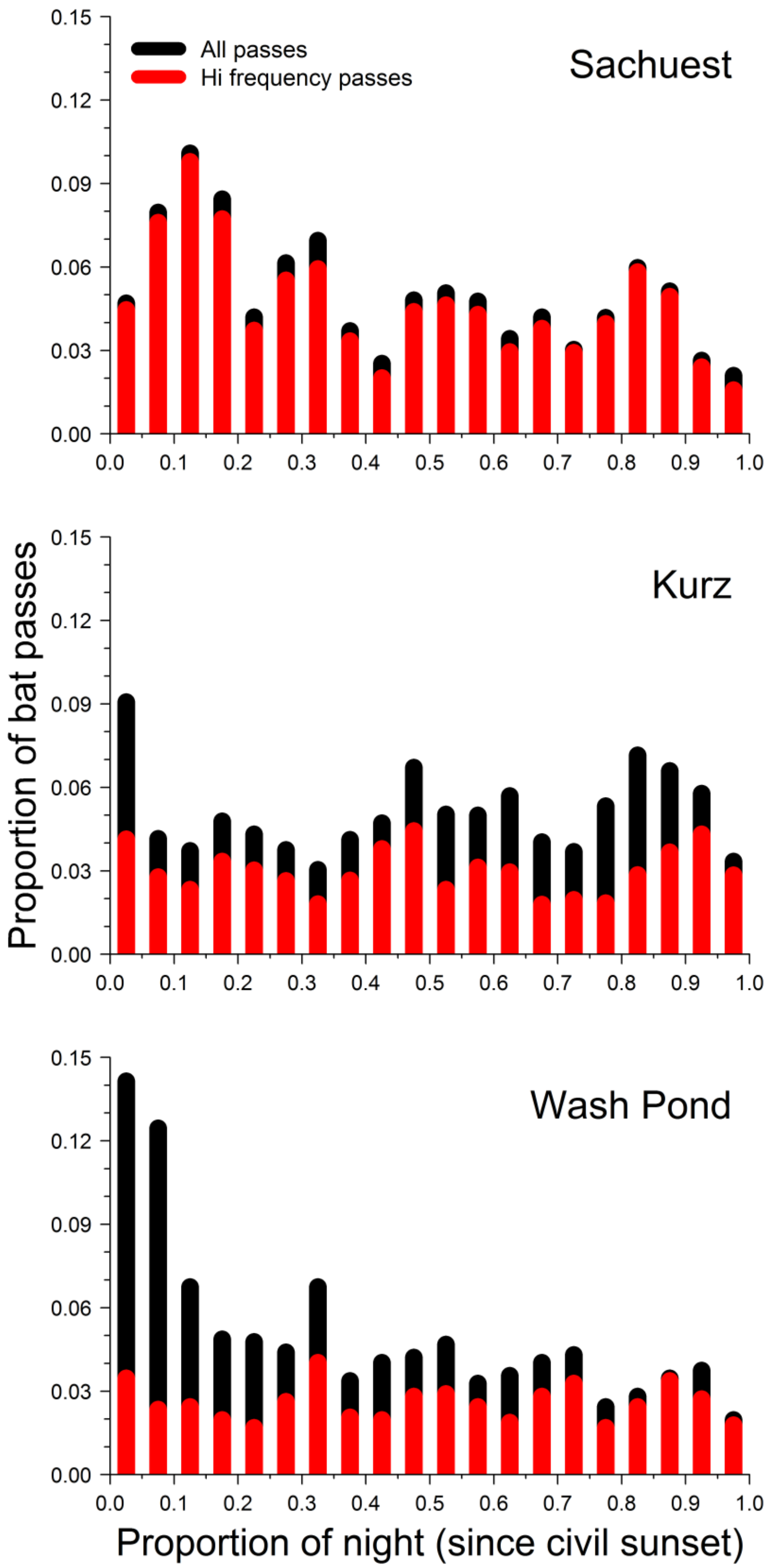
All passes
Hi frequency passes
Sachuest
Kurz
Wash Pond
Total bat passes
Night (2010)
0
100
200
300
400
500
600
700
800
900
1000
6 Sep
16 Sep
26 Sep
6 Oct
16 Oct
26 Oct
5 Nov
15 Nov

Figure 3.



All passes
Hi frequency passes
Sachuest
Kurz
Wash Pond
Proportion of bat passes
Hours since civil sunset

Figure 4.



All passes
Hi frequency passes
Sachuest
Kurz
Wash Pond
Proportion of bat passes
Proportion of night (since civil sunset)
0.00
0.03
0.06
0.09
0.12
0.15
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Figure 5.