

Acoustic survey of bats in the Virgin Islands National Park and adjacent areas, St. John, US Virgin Islands

March 2021



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**Report prepared for:
Virgin Islands National Park
Friends of Virgin Islands National Park**



Friends of
Virgin Islands National Park

Acoustic survey of bats in the Virgin Islands National Park and adjacent areas, St. John, US Virgin Islands

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Summary

Bats are the only extant native mammals of the US Virgin Islands (USVI), and as such, have significant ecological and cultural value. Local bat populations markedly declined as a result of two back-to-back Category-5 hurricanes that struck the USVI in 2017, and the extent of decline and recovery rate are unknown. We conducted an acoustic survey for bats at key locations within and adjacent to the Virgin Islands National Park (VIIS) in St. John, USVI, in the summer of 2019 to evaluate bat presence and activity in associations with different habitat features. Four of five resident bat species were detected using passive ultrasonic acoustic monitoring. *Molossus molossus*, an insectivorous species, was detected in high numbers at all sites sampled, with evidence of robust populations (i.e., high acoustic activity with layers of multiple individuals). *Noctilio leporinus*, a specialist fish-eater, was detected at most sites sampled although was more active in coastal areas and those with major water sources. *Brachyphylla cavernarum*, a fruit-eating bat, was also detected at all sites sampled but at levels insufficient to evaluate habitat use or activity patterns. *Artibeus jamaicensis*, the most abundant fruit-eating bat in the USVI prior to Hurricane Irma, was barely detected at half of the sites sampled, and *Stenoderma rufum*, an endemic fig-eating bat, was not detected at all. A small number of acoustic signals were isolated but were unable to be identified. Activity indices based on bat recordings indicate that bats are both foraging within specific areas and moving rapidly through other areas that may be less resource dense. Data collected in conjunction with a tropical storm/Cat-1 hurricane (Dorian) indicated that bats returned to normal activity within two days of the storm's passing. Recommendations for bat conservation action within the VIIS include increasing survey effort, restoring and protecting historic structures used by bats, planting native pollen- and fruit-producing trees, incorporating bat education into signage, and installing bat houses as allowable by National Park policy.

Contributions and acknowledgements

R Platenberg and S Matthews conducted the field work, with logistical support from D Worthington and L Brannick. Acoustic analysis was conducted by R Platenberg and S Matthews. Report was drafted by R Platenberg. Additional field personnel included C Brewley, D Laplace, and D Bartlett (UVI). NPS Permit Number was VIIS-2019-SCI-021. Cover image: *Molossus molossus* (R Platenberg). Funding support provided by Friends of Virgin Islands National Park.

Introduction

Globally, bats have shown catastrophic responses to natural disasters, emerging diseases, habitat loss, and other environmental changes, with significant consequences for ecosystem function and services. Bat populations in the US Virgin Islands (USVI) showed a significant decline after two category-5 hurricanes that devastated USVI habitats in September 2017 and there has been a critical need to understand how the bats have responded to and are recovering from these major events.

Bioacoustics is the use of audio recording equipment in the field to collect acoustic data on vocalizing species and environmental sounds (such as rain or human activity). Deploying recorders in remote locations allows for collection of species presence (and potentially absence) data with minimal field survey effort, as well as data on timing of vocalizing activities. Other information can be interpreted from recordings, including behavior (feeding, courtship) and response to weather events.

We conducted acoustic surveys at key locations within the Virgin Islands National Park (VIIS) on St. John, USVI, to evaluate presence and activity patterns of VI bats during the summer of 2019. The project had three main goals: to gain information on bat recovery post-hurricane by conducting surveys across geographic regions of the Virgin Islands National Park and surrounding areas; to develop bioacoustic classifiers for local bat species for rapid processing of acoustic data; and to increase capacity for bat research by providing training to personnel from the National Park Service (NPS) and other entities on St. John and raise awareness of bats locally through community outreach.

Methods

Species

There are five resident bat species in the US Virgin Islands. Three are frugivorous: *Artibeus jamaicensis* (Jamaican Fruit-eating Bat), *Brachyphylla cavernarum* (Antillean Fruit-eating Bat), and *Stenoderma rufum* (Red Fig-eating Bat). One species is insectivorous: Pallas' Mastiff Bat (*Molossus molossus*); one is a specialized fish-eater: *Noctilio leporinus* (Greater Bulldog Bat). They will be referred to throughout this document by their genus name.

Artibeus roosts in the forest canopy, in leaves or hanging palm fronds, although they also readily occupy large open cave-like cavities where they can hang from the ceiling, which on St. John take the form of Danish plantation ruins with intact roofs. *Brachyphylla* prefer dark enclosed spaces, such as caves and rock cavities, where they cling to the walls; colonies often consist of several hundred individuals. They occupy plantation towers and wells that are well-enclosed on St. Croix although these structures are largely missing from St. John. *Stenoderma* is believed to roost alone in the forest canopy, although little is known about their roosting behavior. All three fruit-eating species were severely affected by the 2017 hurricanes because of habitat and roost site loss and unavailability of fruit, pollen, and nectar for several months after the storms.

Molossus roosts in tree and rock cavities and commonly occupy roof spaces of occupied homes. Colony sizes in the USVI tend to be small (typically up to 20-30 individuals, although larger colonies are known; pers. obs.) and widespread. *Noctilio* also roosts in tree and rock cavities, with individual roosts or sets of near-by roosts supporting significant populations of wide-ranging individuals. Both these species appear to have been minimally affected by the 2017 hurricanes because of their diverse diet and abundance of insects after the storms.

Site selection

Sites for acoustic sampling were selected to maximize opportunities for detection of *Artibeus* as a priority, while also sampling major habitat types represented within the national park. We focused on known roost sites (Reef Bay Factory Ruins and Great House) and sites with similar features (Annaberg, Catherineberg, and Cinnamon Bay Ruins, Peace Hill, Murphy Great House), which also allowed sampling of coastal shrubland and dry forest habitats. We sampled areas with previous bat survey activity (VIERS road) and targeted water sources (Petroglyph Pools, Fish Bay Gut, and Francis Bay Pond) and potential movement corridors (Cinnamon Bay Gut) as potential important bat resources. We also sampled adjacent to a sea cliff crevice with an active *Brachyphylla cavernarum* roost. Site metadata is contained in Appendix A.1.

Acoustic recording

Three ultrasonic acoustic recorders (Wildlife Acoustics SM4BAT FS) were used to collect acoustic data across the sites (Fig.1). All three units were deployed at a set of sites for a minimum of 1 week, then collected, maintained (SD cards and battery replacement), and redeployed at a different set of sites, such that sampling occurred continuously from the end of May through October 2019. Duration of sampling varied across recorders due to battery life and SD card space. The units were scheduled to turn on at 5pm and off at 7am and programed to record on detection of an ultrasonic signal (i.e., any sound above audible frequency). Recorders were positioned to optimize detections of bats by placing them on trees at the edges of clearings with the microphone positioned around 3m above ground.



Figure 1. Acoustic recorders deployed in the field.

Acoustic processing

Recordings were processed using Kaleidoscope Pro 5.9.3 (Wildlife Acoustics) bioacoustic analysis program that plots patterns of sound into spectrograms, which are visual representations of audio signals. The vocalizations of each species can be visually distinguished according to shape, frequency range, duration, and interval between signals, and unique markers can be used to develop classifiers for automatic identification to allow batch processing.

Species Identification

Each recording set was processed using the Auto ID function in Kaleidoscope (Bats of the Neotropics classifier v. 5.2.1) for the Virgin Islands and/or Puerto Rico, using the “more accurate (conservative)” setting. The software assigns each recording a species ID; recordings containing vocalizations from multiple species are not separately distinguished. The VI classifier only identifies *Molossus molossus* and *Noctilio leporinus*, while the PR classifier includes species that not typically found in the VI, including *Tadarida brasiliensis*; the fruit-eating bats are separated into “no ID” or “noise” categories that are then visually inspected (note that accurate classifiers have not yet been developed for Caribbean fruit-eating bats).

The recording sets were also processed using cluster analysis, which sorts fragments of recordings into groupings with similar sound patterns. The resulting clusters can be manually identified through visual inspection; this allows identification of multiple species in single recordings, and it also reveals cryptic or unusual sound patterns that are useful for finding the fruit-eating bats. Adjusting the signal detection parameters to limit the analysis to a range of frequencies that matches the species of interest allows a quick detection search. Each recording set was processed using three frequency settings: a broad range frequency filter to cluster vocalizations between 15 – 120 kHz; a high frequency filter (70 – 120 kHz) to isolate *Artibeus*; and a low frequency filter (10-25 kHz) to isolate *Brachyphylla*. Frequency ranges and call visualizations are shown in Appendix A.2.

Classifiers for automatic identification were built using the resultant clusters by naming clusters that were most representative of each species and training the software to recognize and isolate these patterns in subsequent clustering runs. These classifiers can be used to cluster new recording sets into species groupings.

Activity Indices

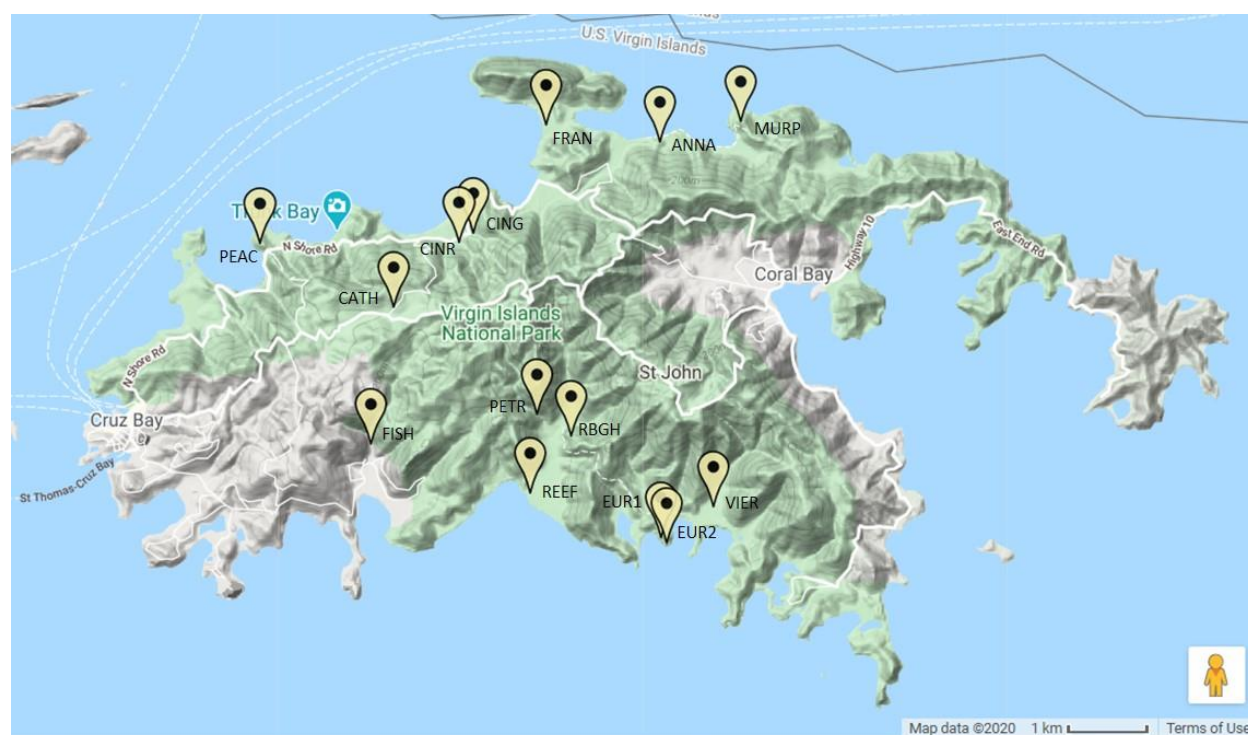
Each recording can be considered a “bat pass”, that is, a single vocalizing bat passing the microphone. The recorder is designed to “listen” for ultrasonic signals and start recording when a signal is detected (as the bat approaches the area) and stop recording when the signal fades (as the bat leaves the area). Bat passes cannot be used to evaluate species abundances, because passes could represent multiple bats flying and echolocating in the vicinity of the recorder or a single bat circling around the area (a typical behavior of *Molossus*). Areas with high bat activity will have vocalizations from multiple bats layered into the recordings, further confounding the use of bat passes as a proxy for abundance. Bat passes can, however, be used as a proxy for activity within the area, which can provide clues to the resource value of the area to bats. We evaluated nightly activity at each site by creating histograms of the relative number of bat passes (number divided by total) within each hour bin.

Results

Graphs and tables that are important for interpreting narrative are shown in the text. Additional material and metadata are included in the Appendix.

Sampling Summary

Twelve sites were sampled (Fig. 2, Table 1; metadata A.1). We conducted five sampling sessions each lasting from 3 to 5 weeks (average 27.4 days) from 29 May to 13 October 2019. Data for each site ranged from 8 to 29 days (average 22.3 days across sites), with the variation due to battery life and SD card space. Additional recordings were collected in October at a *Brachyphylla* roost site (Europa Bat Roost) to collect species-specific recordings. The recordings collected at the two Europa sites were used to help identify *Brachyphylla* vocalizations but were not included in subsequent analyses due to the high volume and variability of the vocalizations.



ANNA = Annaberg Tower
CATH = Catherineberg Ruins
CING = Cinnamon Bay Gut
CINR = Cinnamon Bay Ruins
EUR1 = Europa Point

EUR2 = Europa Bat Roost
FISH = Fish Bay Gut
FRAN = Francis Bay Pond
MURP = Murphy Great House
PEAC = Peace Hill

PETR = Petroglyph Pools
RBGH = Reef Bay Great House
REEF = Reef Bay Factory Ruins
VIER = VIERS Road

Figure 2. Sites sampled for bat activity in 2019 in the Virgin Islands National Park.

The number of recordings collected at each site ranged from 3500 (across 29 days; Francis Bay Pond) to 17,235 (across 26 days; Petroglyph Pools). Three sites showed high bat activity: Petroglyph Pools, Reef Bay Great House, and Fish Bay Gut (Table 1).

Table 1. Sites sampled for bat activity in 2019 in Virgin Islands National Park.

Location	Map Notation	Dates Sampled (2019)	No. Days	No. Recordings
Annaberg Tower	ANNA	24 Jun - 2 Jul	8	8370
Catharineberg Ruins	CATH	24 Jun - 17 Jul	23	6559
Cinnamon Bay Gut	CING	17 Jul - 15 Aug	29	9948
Cinnamon Bay Ruins	CINR	24 Jun - 7 Jul	13	8559
Europa Point	EUR1	22 Sep - 13 Oct	21	7766
Europa Bat Roost	EUR2	13 - 16 Oct	3	7335
Fish Bay Gut	FISH	17 Jul - 12 Aug	26	16,937
Francis Bay Pond	FRAN	17 Jul - 15 Aug	29	3500
Murphy Great House	MURP	15 Aug - 2 Sep	18	6205
Peace Hill	PEAC	15 Aug - 8 Sep	24	8363
Petroglyph Pools	PETR	29 May - 24 Jun	26	17,235
Reef Bay Factory Ruins	REEF	29 May - 24 Jun	26	5109
Reef Bay Great House	RBGH	29 May - 24 Jun	26	15,772
VIERS Road	VIER	22 Sep - 13 Oct	21	5130

Bioacoustic Processing

Each set of recordings was processed multiple times to optimize detection of the frugivorous bats. We used the AutoID function to create a spreadsheet that provides metadata (e.g., frequency, number of pulses, duration, etc.) for each recording and labels each recording with a species ID; output identified *Molossus*, *Noctilio*, NoID, Noise, and species of bats not resident in the VI (e.g., *Tadarida brasiliensis*). We manually vetted each of the *Noctilio*, NoID, and non-VI species recordings and random samples of Noise and *Molossus* recordings. We found that all the *Molossus*-tagged recordings vetted were accurately identified, while the *Noctilio*-tagged ones were also accurate at identifying *Noctilio* but tended to also include other species (primarily *Molossus*). Most of the non-VI bat IDs were identified as either *Molossus* or insects. *Brachyphylla* and *Artibeus* signals were found within both the NoID- and Noise-tagged recordings. Ultrasonic signatures belonging to insects, frogs, birds, and rain were commonly found within the recordings.

Sets of recordings were clustered based on similarity of sound patterns; each cluster analysis resulted in multiple fragments of single recordings that are aligned into numbered clusters according to similarities of each syllable found in each recording. Each recording set produced between 10,000 to 20,000 fragments grouped into anywhere from 10 to 56 clusters. Each cluster was evaluated and labeled for species ID.

We used the labeled clusters to create classifiers by tagging sound patterns of interest and training the software to recognize these specific patterns; these proved to be not particularly effective or time-efficient at automating species identification, plus each fragment within clusters needed to be realigned with the original recording for activity analyses. In the end we used AutoID with manual vetting to process each recording set for species ID. Clustering did reveal recordings with multiple species but proved to be less useful for locating rarely detected species (e.g., *Artibeus*) because rare sound signatures are often not numerically represented in the sample sufficient to form a cluster. Manual

processing found more *Artibeus* than selected-frequency clustering. We also could not create classifiers for *Brachyphylla* due to high variation in vocalization patterns.

Site-Specific Results

Bats were detected at each site sampled (Table 2). *Molossus* was dominant across sites, with between 93-99% of recordings at each site attributed to *Molossus* except at VIERS, where *Molossus* occupied 78% of the recordings and *Noctilio* was present in 19%, with *Brachyphylla* and *Artibeus* detected in 2% and <1% of recordings, respectfully (Appendix A.3.).

Table 2. Bat species detected at each site sampled (Europa Point sites excluded)

Site	<i>Artibeus</i>	<i>Brachyphylla</i>	<i>Molossus</i>	<i>Noctilio</i>
Annaberg	x	x	x	x
Catherineberg	x	x	x	x
Cinnamon Bay Gut	x	x	x	x
Cinnamon Bay Ruins		x	x	x
Fish Bay		x	x	x
Francis Bay		x	x	x
Murphy Great House		x	x	x
Peace Hill	x	x	x	
Petroglyph Pools		x	x	x
Reef Bay Great House	x	x	x	x
Reef Bay Factory Ruins		x	x	x
VIERS entrance road	x	x	x	x

Many of the recordings specifically containing *Molossus* indicate overlapping individuals with no clear amplification of signal, i.e., multiple bats flying around in the same area. Using bat passes as a proxy for activity, we found that diel activity patterns varied across sites, presumably due to resource availability (e.g., roost sites, presence of fruit/flowers or water) offered by each location (Fig.3). Site-specific activity patterns are included with the site accounts.

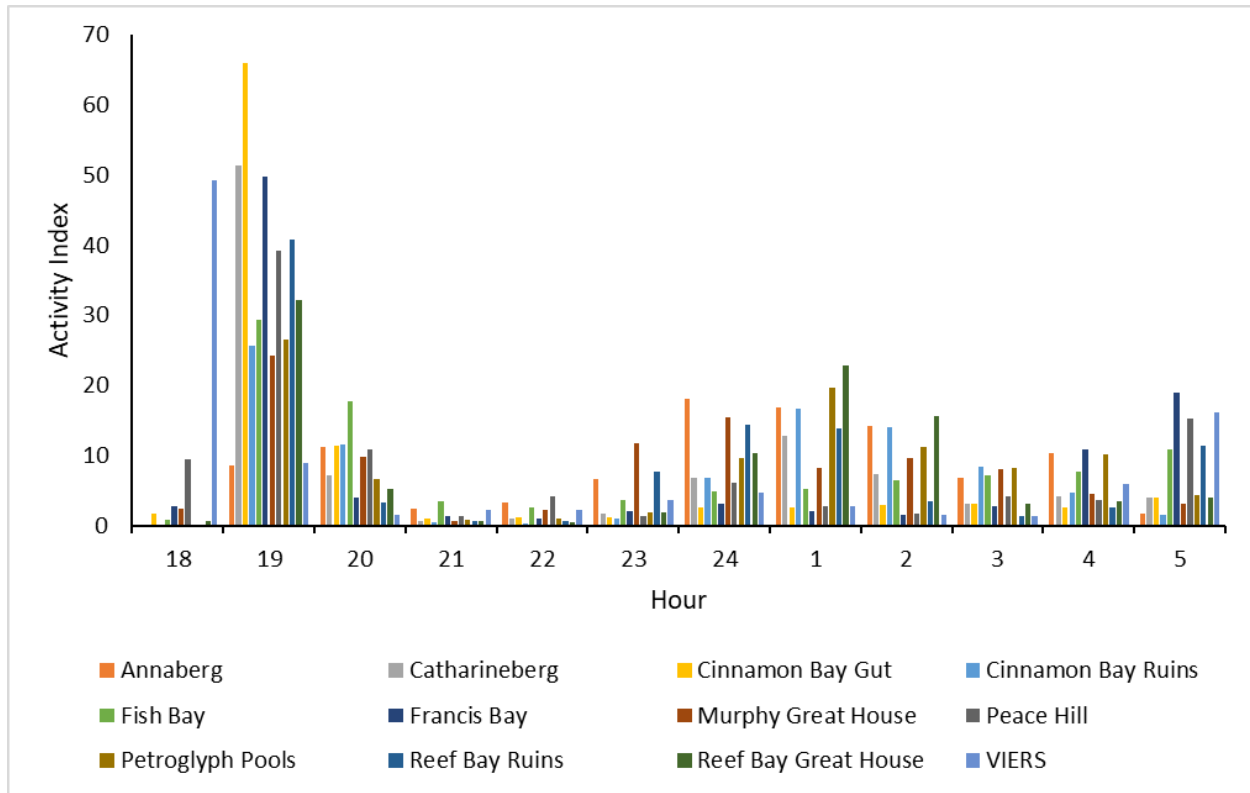


Figure 3. Diel activity of all bats across sites sampled. Activity Index is proportional number of bat passes (=recordings) each hour per total passes at each site, pooled across the sampling period.

Annaberg Tower

Site Description: Highly modified open habitat with manicured lawns surrounded by upland dry forest on a bluff overlooking the ocean. Site contains multiple Danish-era structures that may offer roost sites for bats. Non-native fruit trees may be present. Site does not offer significant source of water.

This site was surveyed across 8 days in late June, with 8268 recordings attributed to bats. All four bat species were detected at this site, with *Molossus* occupying 99.6% of the recordings; only one *Artibeus* signal was detected. Bat activity was high throughout the night, with peak activity occurring in the middle of the night rather than at dusk (Fig. 4). The sustained post-emergence activity suggests that the site offers significant resources of interest to bats.

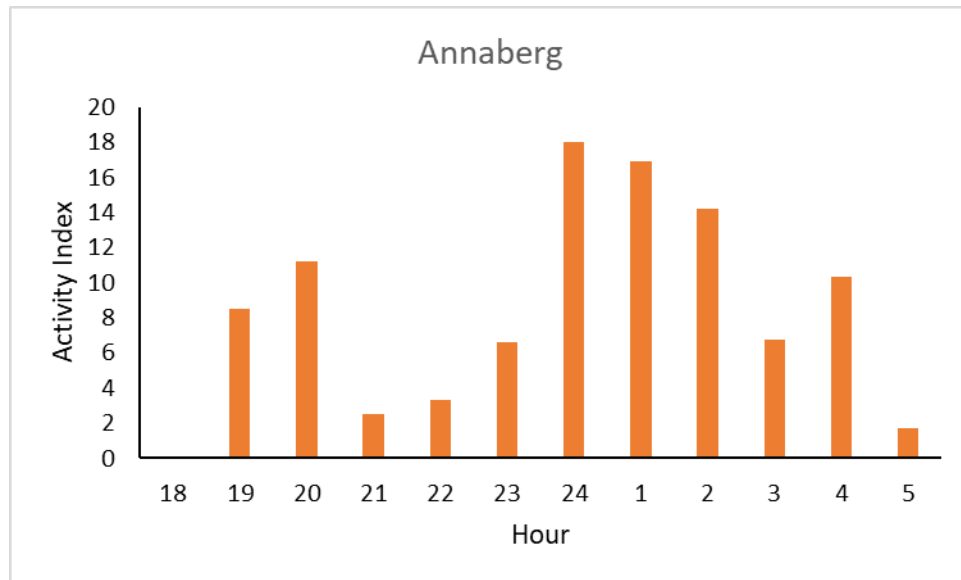


Figure 4. Diel activity pattern of bats at Annaberg Tower; data pooled across sampling period.

Catherineberg Ruins

Site Description: Modified open area bisected by a public roadway, with several Danish-era structures that may offer roost sites for bats. The site is surrounded by upland dry forest. Site does not offer significant source of water, although water may pond seasonally.

This site was surveyed across 23 days in late June and early July, with 5560 recordings attributed to bats. All four bat species were detected at this site, with *Molossus* occupying 93.2% of the recording. Two *Artibeus* signals were detected, along with 46 signals that we were unable to identify. Bat activity was highest around dusk, with some limited activity pre-dawn (Fig.5). The reduced activity post-emergence without a pre-return peak suggests that the site is not a major resource for bats, and likely does not offer roosting opportunities.

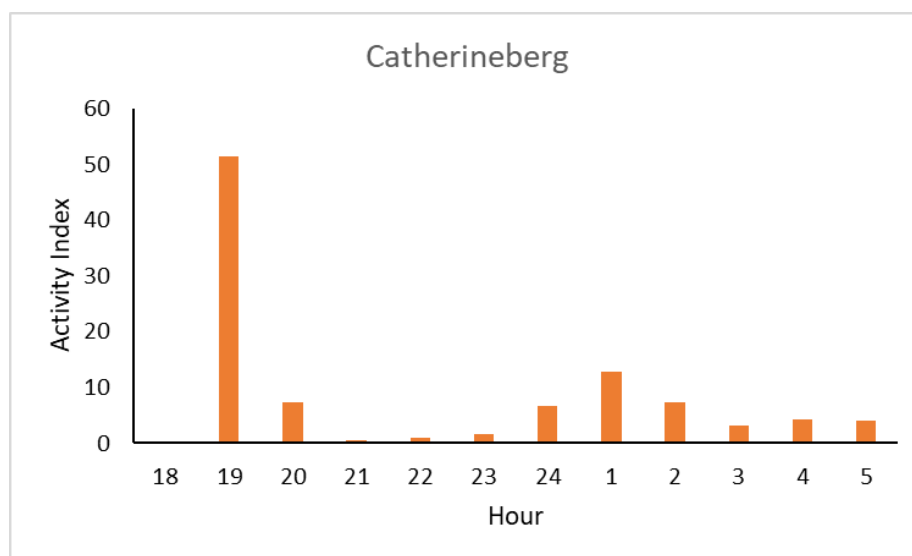


Figure 5. Diel activity pattern of bats at Catherineberg Ruins; data pooled across sampling period.

Cinnamon Bay Gut

Site Description: Narrow stream channel lined with gallery forest, surrounded by upland dry forest. Stream channel at sampling site characterized by steep topography with large boulders. Water pools are a seasonal resource, but site was dry during the survey period.

This site was surveyed across 29 days from mid-July through mid-August, with 6472 recordings attributed to bats. All four bat species were detected at this site, with *Molossus* occupying 97.1% of the recordings; *Brachyphylla* represented the second most frequently detected species, at 2.6% of the recordings. Almost all of the bat activity was around dusk (Fig.6). Reduced activity post-emergence without a pre-return peak suggests that the site is not a major resource for bats and likely does not offer roosting opportunities (Fig. 6). The gut may act as a migration corridor (see species-specific accounts).

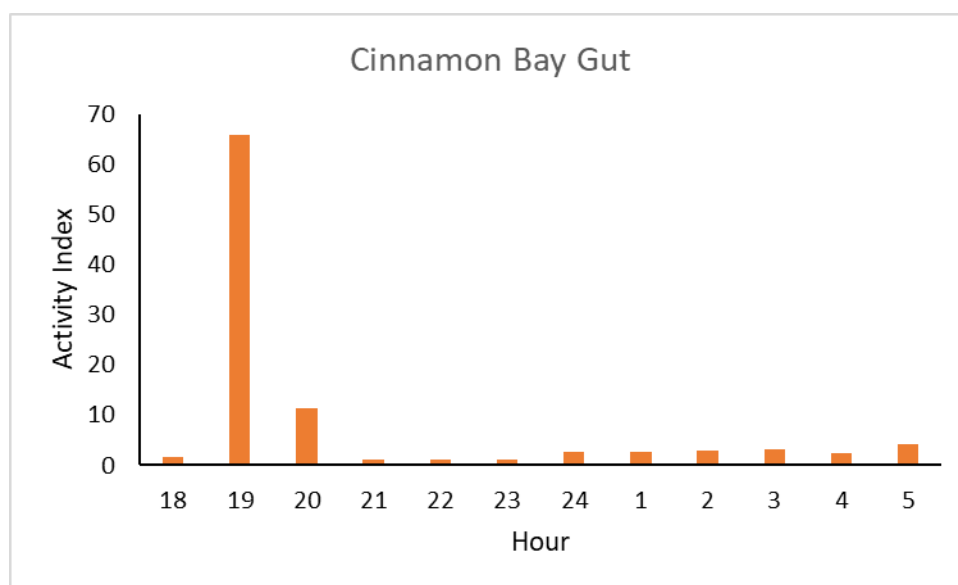


Figure 6. Diel activity pattern of bats at Cinnamon Bay Gut; data pooled across sampling period.

Cinnamon Bay Ruins

Site Description: Highly modified open area with multiple Danish-era structures that may offer roost sites for bats. Site is positioned in basin woodland in close proximity to a seasonal freshwater source (gut pools) and is within 500 m of coastal waters. Freshwater may pond seasonally, although at the time of survey freshwater was not available.

This site was surveyed across 13 days in late June through early July, with 7086 recordings attributed to bats. Three bat species were detected at this site, with *Molossus* occupying 94.2% of the recordings; *Noctilio* were detected in 5.5% of the recordings with sporadic detections of *Brachyphylla*. *Artibeus* was not detected at this site. Bat activity was high at dusk and one hour after dusk, with sustained activity between midnight and dawn, suggesting that the site offers beneficial resources for foraging bats (Fig. 7). Roosting opportunities may be limited.

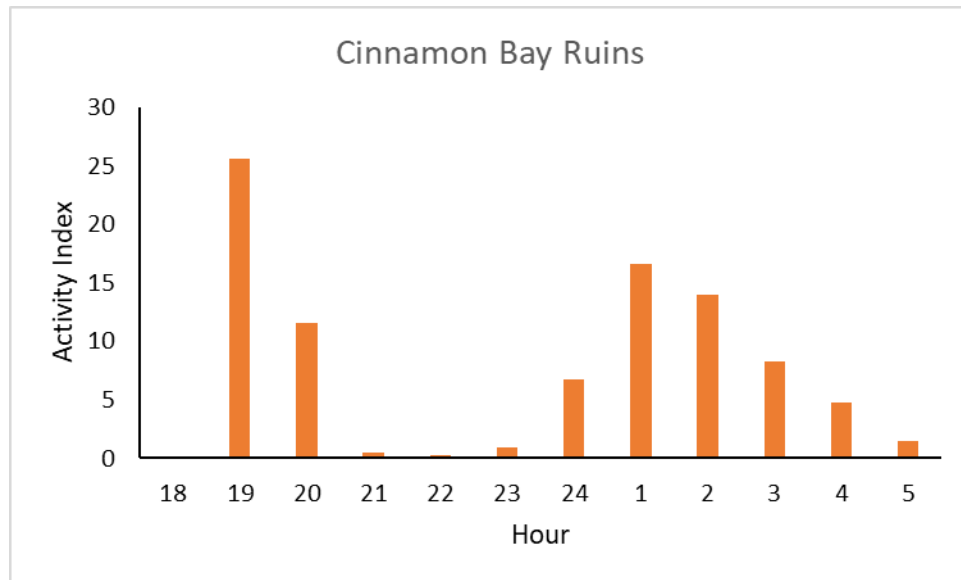


Figure 7. Diel activity pattern of bats at Cinnamon Bay Ruins; data pooled across sampling period.

Fish Bay Gut

Site Description: Wetland site with reliable year-round freshwater pools. Sampling site was along edge of large pool in wide stream channel characterized by low topographic relief and rocky to gravelly substrate. Surrounding habitat is combination of dry forest and gallery woodland.

This site was surveyed across 26 days from mid-July to mid-August, with 15,936 recordings attributed to bats. Three bat species were detected at this site, with *Molossus* occupying 96.4% of the recordings; *Noctilio* and *Brachyphylla* were detected in 2.8% and 0.6% of recordings, respectively. *Artibeus* was not detected. Bat activity peaked around dusk, with low levels of sustained activity throughout the night (Fig. 8). Activity patterns suggest that this is a high value site for short visits, but likely offers limited roosting opportunities.

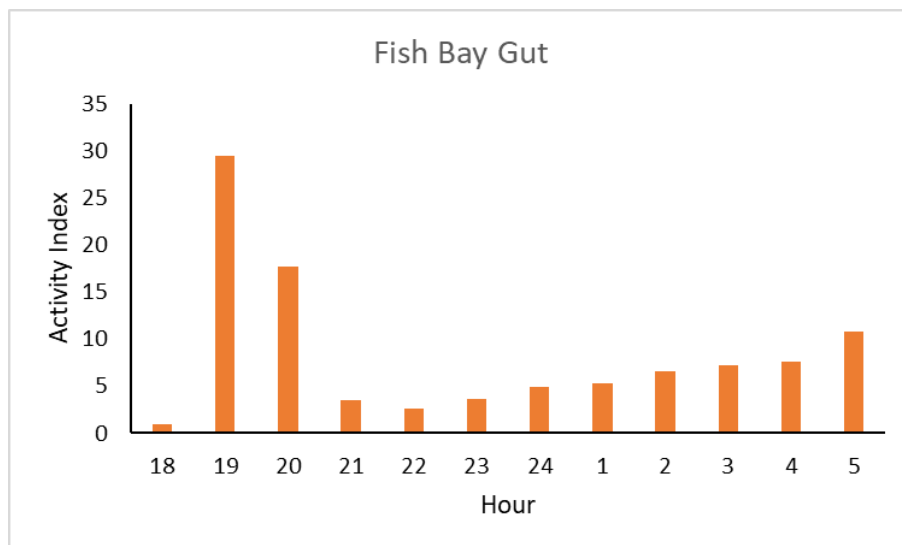


Figure 8. Diel activity pattern of bats at Fish Bay Gut; data pooled across sampling period.

Francis Bay Pond

Site Description: Saline coastal pond surrounded by mangrove and basin woodland, within 500m of shoreline. Pond exhibited seasonal drying during survey period. Site offers valuable foraging resources (e.g., fiddler crabs) for shore and waterbirds that may also be used by *Noctilio*, although freshwater is absent.

This site was surveyed across 29 days from mid-July to mid-August, with 2110 recordings attributed to bats. Three bat species were detected at this site, with *Molossus* occupying 93.1% of the recordings; *Noctilio* was present in 6.8% of the recordings while only 3 *Brachyphylla* signals were detected. *Artibeus* was not detected at this site. Bat activity was bimodal, with a peak around dusk and a second smaller peak pre-dawn (Fig. 9). This pattern suggests that this site does not offer significant foraging resources for bats.

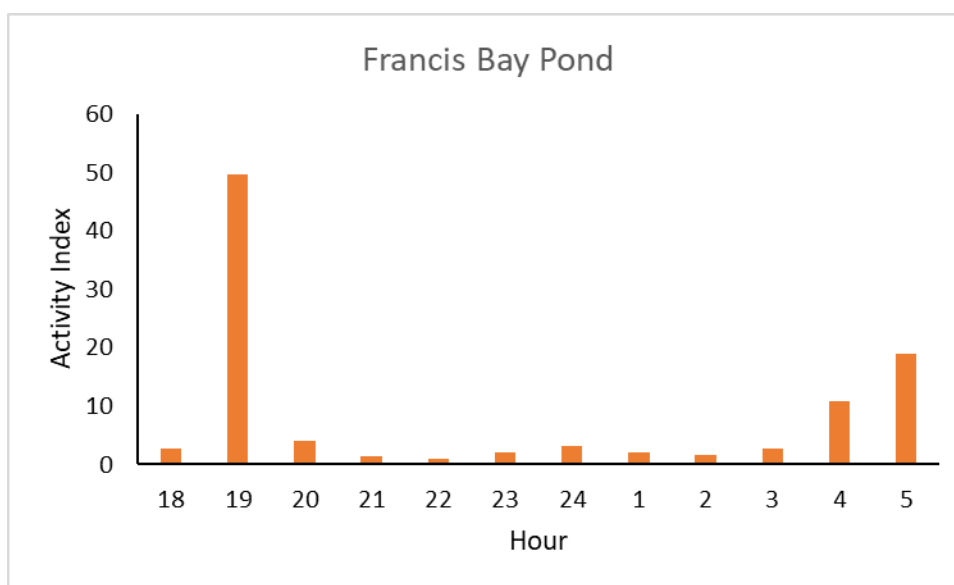


Figure 9. Diel activity pattern of bats at Francis Bay Pond; data pooled across sampling period.

Murphy Great House

Site Description: Highly modified open habitat surrounded by upland dry forest and coastal shrublands located on a bluff overlooking the ocean. Site contains scattered Danish-era structural remnants that may offer roost sites for bats. Site does not offer significant source of water.

This site was surveyed across 18 days in August, with 5464 recordings attributed to bats. Although three bat species were detected at this site, *Molossus* occupied 99.8% of the recordings; *Artibeus* was not positively identified in the recordings, although 2 signals were unidentified. Bat activity occurred throughout the night, with a peak at dusk and a lull from two to three hours after dusk (Fig. 10). This activity pattern suggest that the site offers important foraging resources. Category-1 Hurricane Dorian passed close by during the sampling period.

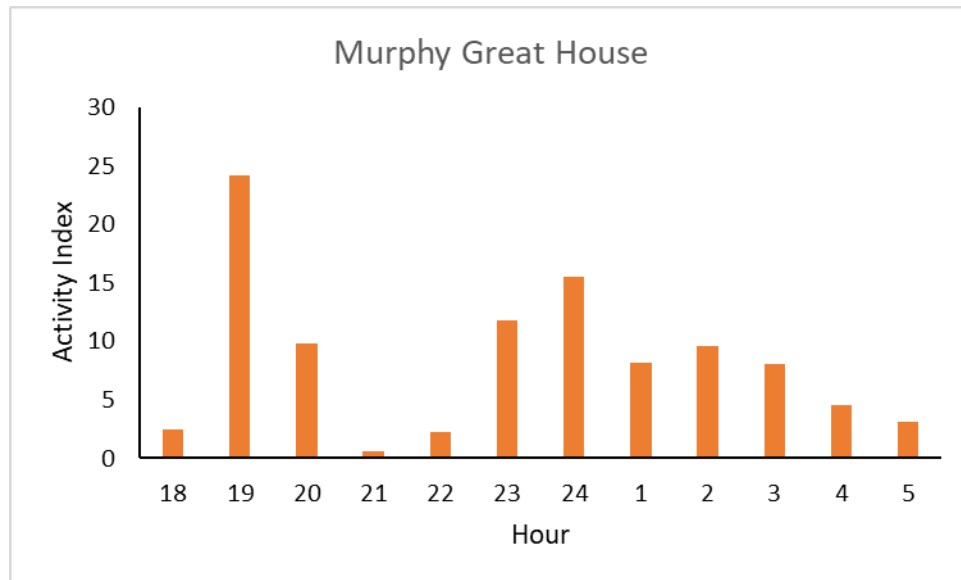


Figure 10. Diel activity pattern of bats at Murphy Great House; data pooled across sampling period.

Peace Hill

Site Description: Small open area located on a bluff overlooking the ocean, surrounded by dry forest and coastal shrubland. A Danish-era tower may offer a roost site. The site does not offer water resources but is close to beach/shoreline.

This site was surveyed across 24 days from mid-August to early September, with 7248 recordings attributed to bats. Three bat species were detected at this site, with *Molossus* occupying 98.7% of the recordings; *Brachyphylla* was present in 1.2% of the recordings, and *Artibeus* was detected in 6 recordings. Six acoustic signals were identified as unknown. Bat activity was concentrated at dusk and, to a lesser extent, dawn, indicating minor value for foraging resources (Fig. 11). Category-1 Hurricane Dorian passed close by during the sampling period.

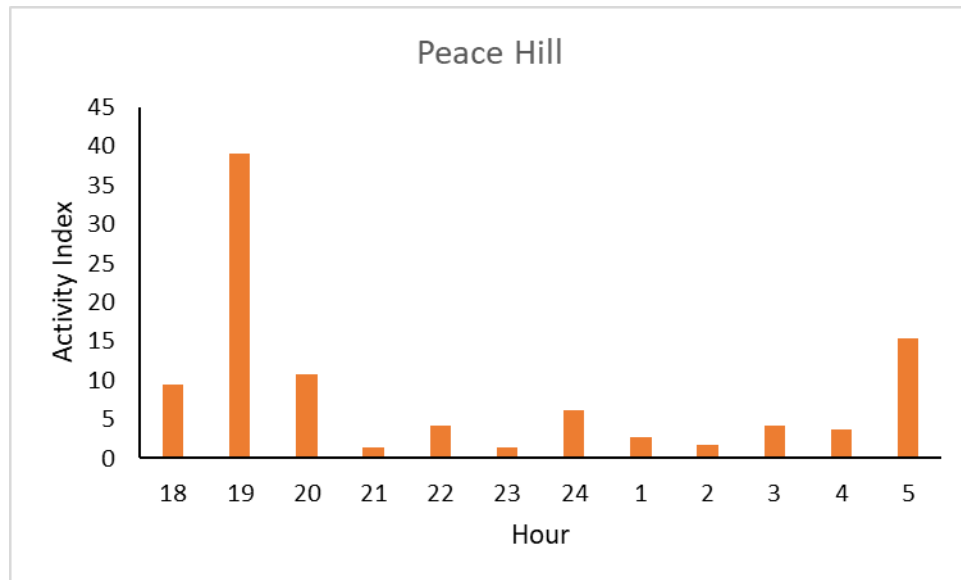


Figure 11. Diel activity pattern of bats at Peace Hill; data pooled across sampling period.

Petroglyph Pools

Site Description: Series of freshwater pools in otherwise dry stream channel surrounded by basin and dry forest. We sampled the lower pool (rather than the permanent upper pool known for the presence of pre-Colombian petroglyphs), which held water at the start of the survey and dried up before we collected the recorder.

This site was surveyed across 26 days in June, with 15,829 recordings attributed to bats. Three bat species were detected at this site, with *Molossus* occupying 96.1% of the recordings and *Brachyphylla* and *Noctilio* detected in 2.4% and 1.6% of recordings, respectively. *Artibeus* was not detected. Nine acoustic signals were identified as unknown. Bat activity was relatively high throughout the night, with a 3-hour lull after the dusk peak (Fig. 12). This pattern indicates the presence of important foraging resources.

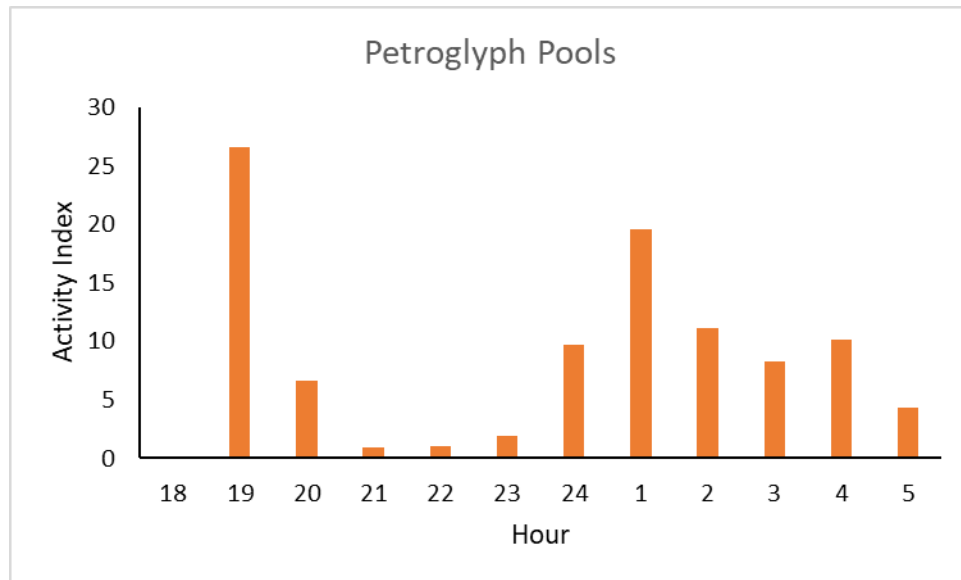


Figure 12. Diel activity pattern of bats at Petroglyph Pools; data pooled across sampling period.

Reef Bay Factory Ruins

Site Description: Highly modified open habitat with multiple Danish-era structures that may offer roost sites for bats; several rooms in the factory building harbored a substantial *Artibeus* colony prior to Hurricane Irma, when the roof was lost. Non-native fruit trees are present. Site does not offer a significant source of freshwater but is within 200m of coastal waters and relatively close to the freshwater Petroglyph Pools. We did not find any evidence of roost use by bats during our visits.

This site was surveyed across 26 days in June, with 3651 recordings attributed to bats. All four bat species were detected at this site, with *Molossus* occupying 93.4% of the recordings and *Noctilio* and *Brachyphylla* each detected in around 3% of the recordings; only one *Artibeus* signal was detected. Peak bat activity occurred at dusk with additional activity surges mid-night and pre-dawn (Fig. 13). The site likely offers resources of moderate value to foraging bats and possibly still offers roosting opportunities.

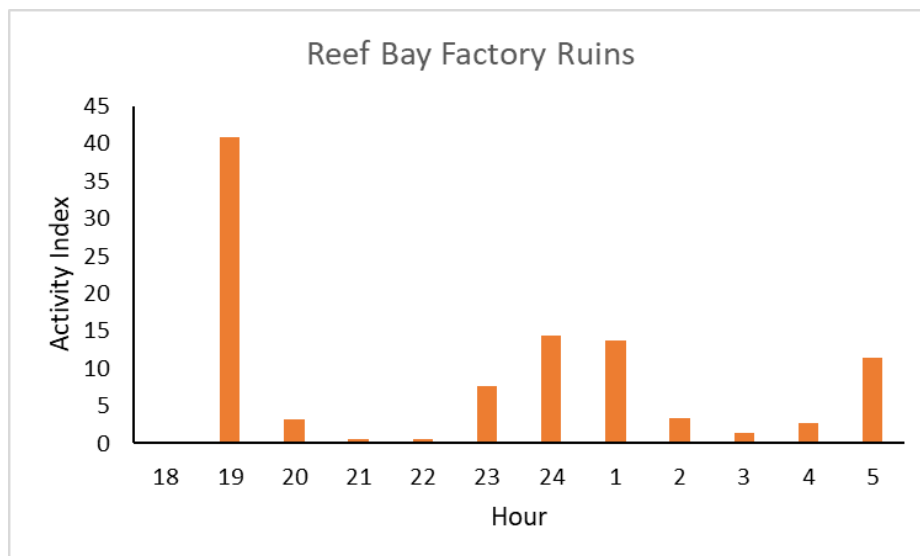


Figure 13. Diel activity pattern of bats at the Reef Bay Factory Ruins; data pooled across sampling period.

Reef Bay Great House

Site Description: Modified open area with one significant Danish-era building with an intact roof. This building has several roofed rooms that harbor a roosting *Artibeus* colony. The site is surrounded by upland dry forest, with a freshwater source at the nearby Petroglyph Pools.

This site was surveyed across 26 days in June, with 14,790 recordings attributed to bats. All four bat species were detected at this site, with *Molossus* occupying 96.2% of the recordings, with *Brachyphylla* and *Noctilio* attributing for 1.7% and 0.7%, respectively; despite the presence of vocalizing *Artibeus* individuals in close proximity of the recorder, only 1% of the recordings contained *Artibeus* signals. There were several signals that likely belong to *Artibeus* but were identified as unknown. Bat activity peaked around dusk, with a second sustained peak from midnight to 3am, indicating resource value for foraging bats (Fig. 14). Indicators for value for roosting are missing, likely because of the difficulty in recording *Artibeus*.

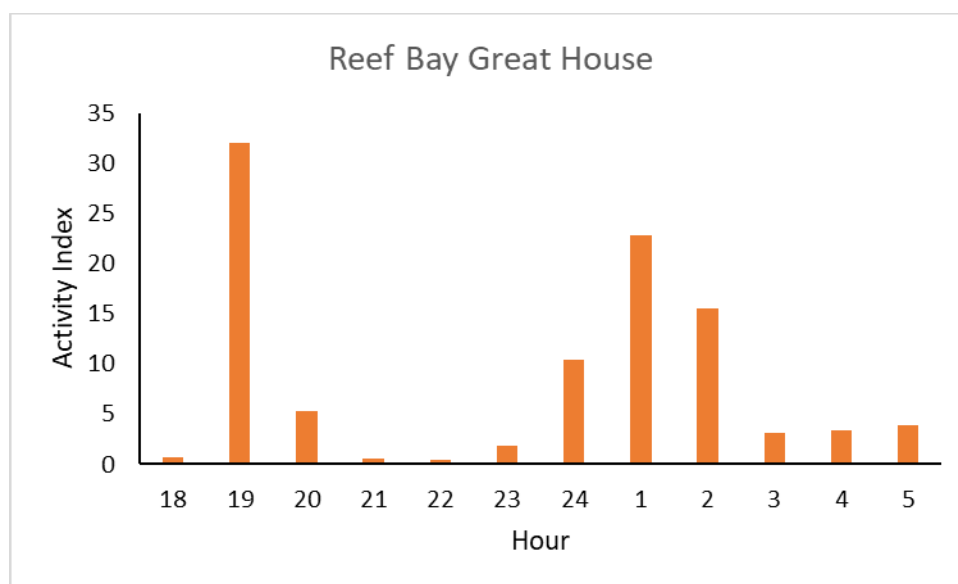


Figure 14. Diel activity pattern of bats at the Reef Bay Great House; data pooled across sampling period.

VIERS (Virgin Islands Environmental Resource Station) Road

Site Description: Unpaved rutted road running perpendicular to nearby coastline (<100m distant), bisecting basin woodland. Research station was unoccupied at time of survey.

This site was surveyed across 21 days in September and October, with 3447 recordings attributed to bats. All four bat species were detected at this site, with *Molossus* occupying 78.5% and *Noctilio* present in 19.1% of the recordings; *Brachyphylla* was detected in 2% of the recordings. *Artibeus* and an unknown signal together represented under 1% of total. There were low levels of bat activity throughout the night with a main peak at dusk and a second smaller peak pre-dawn (Fig. 15). This pattern suggests that the site may not offer significant foraging resources but likely offers migration and/or roosting opportunities.

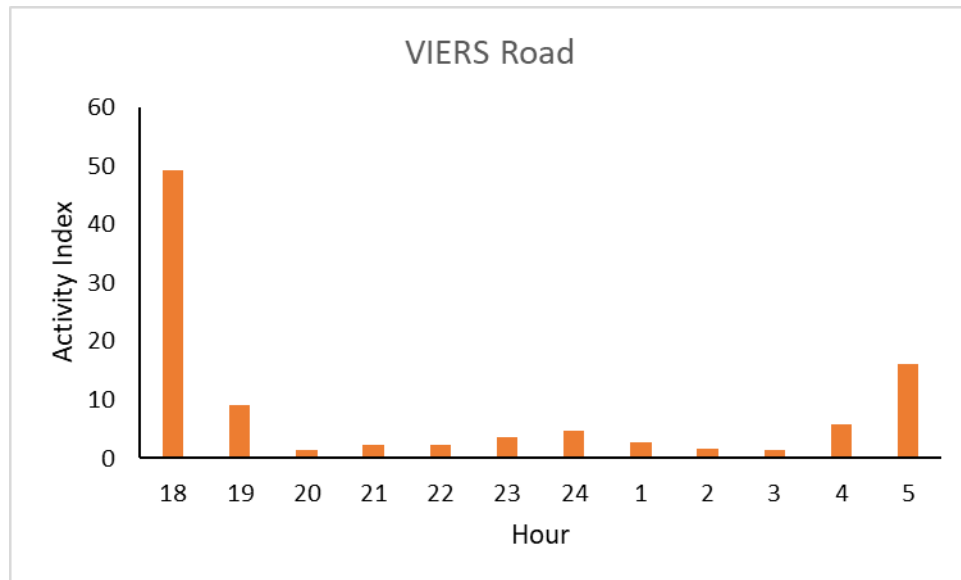


Figure 15. Diel activity pattern of bats at VIERS Road; data pooled across sampling period.

Europa Point

Site Description: Site is a bluff overlooking Europa Bay with steep cliff drop-offs. Habitat is coastal shrub characterized by the presence of *Melocactus intortus*. A rock fissure in the cliff is occupied by a substantial *Brachyphylla* colony.

This site was surveyed at two locations across 24 days in September and October, resulting in over 15,000 recordings (7294 recordings were collected over 3 days adjacent to the bat roost), with 11,960 recordings potentially attributed to bats. Due to the high volume of *Brachyphylla* roost signals, which are highly variable in both acoustic frequency and duration, processing using clustering and auto ID did not produce meaningful results and manual processing was precluded by time and capacity limitations. The vocal parameters were used as reference to confirm *Brachyphylla* presence at other sites.

Species Specific Activity

Molossus molossus dominated the acoustic space attributed to bats across all sites. Excluding *Molossus* from site results allows evaluation of site use and activity patterns of other species (Fig. 16, Appendix A.3). Sites with water resources were proportionately preferred by *Noctilio*, while sites without water were proportionately preferred by *Artibeus*. *Brachyphylla* appeared to favor drier sites over those with water.

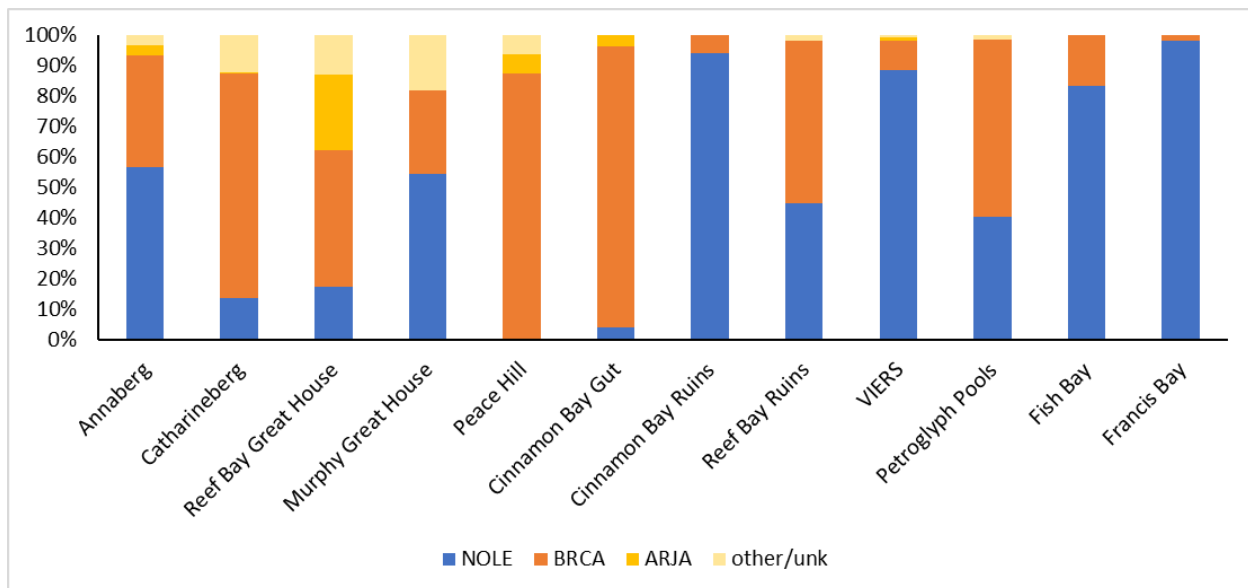


Figure 16. Proportional representation of species (excluding *Molossus molossus*) at each site sampled. Sites arranged according to water resources (left: no significant source of water; right: wetlands). NOLE = *Noctilio leporinus*; BRCA = *Brachyphylla cavernarum*; ARJA = *Artibeus jamaicensis*

Molossus molossus was the dominant species detected at all sites, accounting for over 90% of bat detections, except for at VIERS where *Noctilio* was also detected in a significant number of recordings. Most of the activity attributed to *Molossus* occurred during the first hour after dusk, often with a second smaller peak in activity in the middle of the night and towards dawn (data pooled across all sites, Fig. 17). This corresponds with typical activity for this species, which shows an emergence of the majority of the colony prior to dusk, with individuals foraging within an area for 45-60 minutes before returning to the roost (based on observations at known roost sites; pers. obs.). Individuals may or may not make additional foraging forays throughout the night.

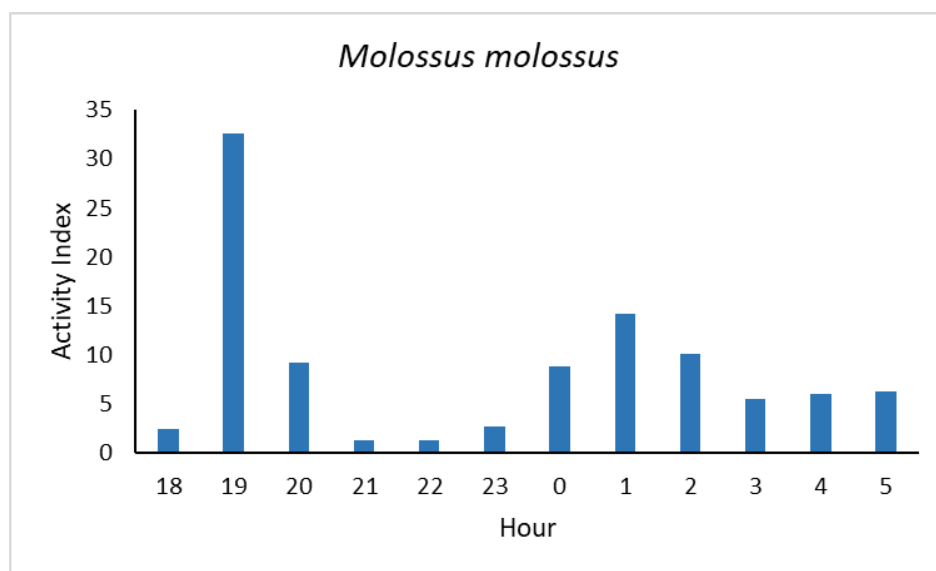


Figure 17. *Molossus molossus* diel activity pattern, pooled across sampling period and all sites. Activity indices represent proportion of total.

Noctilio leporinus was detected at all but one site (Peace Hill) and was more active at coastal sites (Cinnamon Bay Ruins and VIERS road) and those with significant water resources (Petroglyph Pools, Fish Bay, Francis Bay) (Fig. 16). Activity indices show high activity on emergence at dusk with low levels of sustained activity through the night, and a small peak around the dawn return (Fig. 18). This pattern corresponds with typical *Noctilio* behavior of leaving the roost just after dark, flying around the local area for a short time, then heading off for foraging areas further afield. They return in dribs and drabs prior to dawn. While in an area, individuals conduct long low straight circling flights while “looking around”, and moderate sustained activity in an area in relatively short periods of time could represent one or more individuals conducting reconnaissance before moving out of the area. Areas with standing water show high overlap in acoustic signals within individual recordings. Limited-resource sites (Cinnamon Bay Gut, Annaberg, and Catherineberg) show activity occurring close to emergence, suggesting *Noctilio* travelling through, rather than using, the site. Activity patterns (limited to dusk and pre-dawn) at the Reef Bay Great House, a site ecologically similar to Annaberg and Catherineberg in distance to coastal resources, suggest the species may be roosting nearby (Fig. 19).

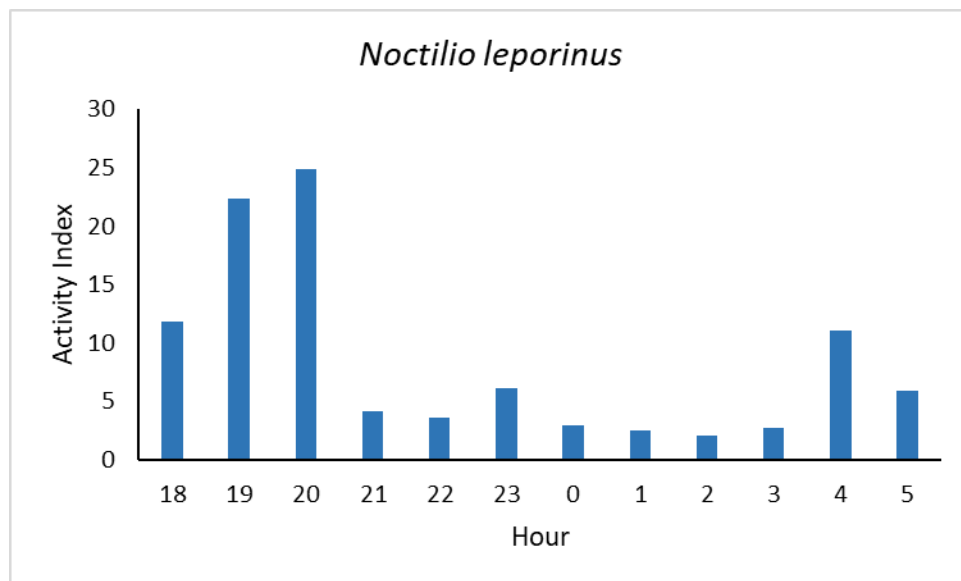


Figure 18. *Noctilio leporinus* diel activity pattern, pooled across sampling period and all sites. Activity indices represent proportion of total.

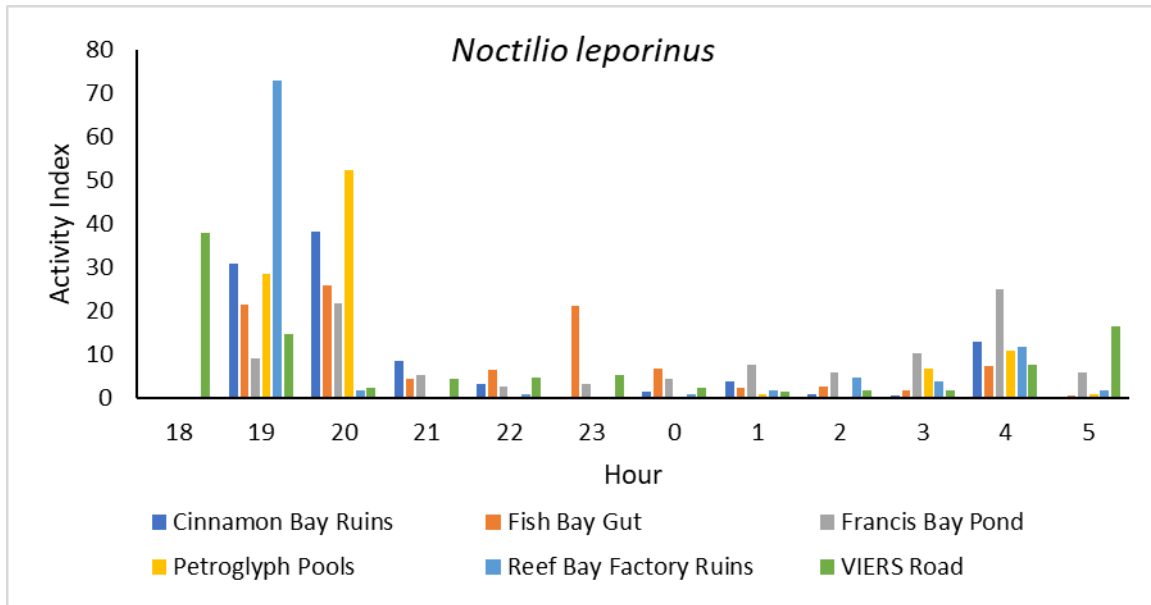


Figure 19. *Noctilio leporinus* diel activity pattern at each site sampled, pooled across sampling period. Only sites with >100 individuals are represented. Activity indices represent proportion of total.

Brachyphylla cavernarum were detected at all sites surveyed. Activity indices show highest activity pre-dawn, with sustained low-level activity (pooled across all sites sampled) starting around 2 hours after dusk (Fig. 20). There did not seem to be a pattern of habitat use, as there were abundant signals in some sites with and without resources (water present: Petroglyph Pools; water absent: Cinnamon Bay Gut; ruins: Catherineberg, Reef Bay Great House), while there were relatively few signals in analogous sites (water present: Fish Bay Gut; ruins: Annaberg, Murphy Great House)(Fig. 16). There was also no clear site-specific activity pattern, with acoustic signals detected across the night-time period at sites with higher (>100) *Brachyphylla* detections (Fig. 21). This species tends to cover great distances during a nighttime foraging foray, and low-frequency echolocation signals may represent individuals traveling through an area. Roost site acoustic signals range from audible chattering and screeches to high frequency multiple harmonic patterns.

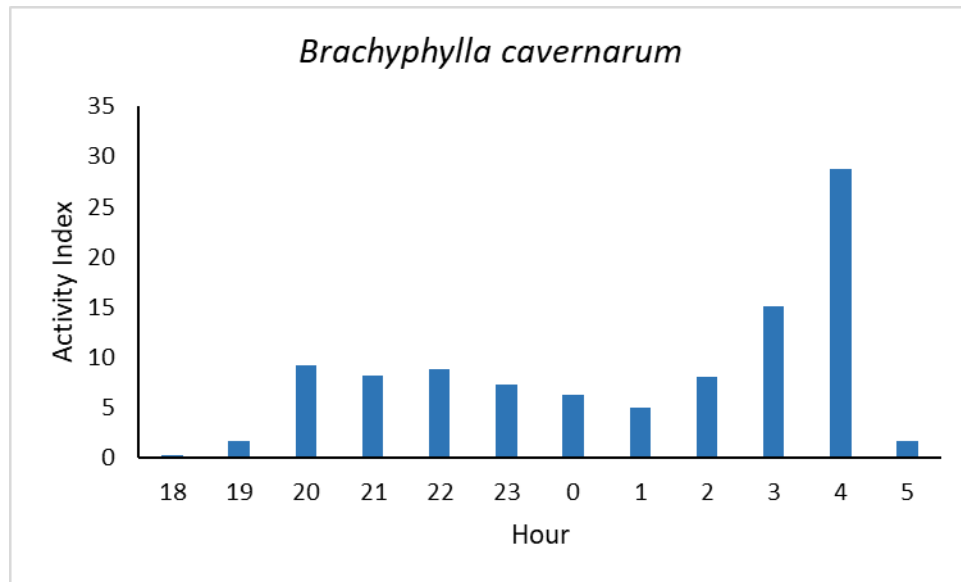


Figure 20. *Brachyphylla cavernarum* diel activity pattern, pooled across sampling period and all sites. Activity indices represent proportion of total.

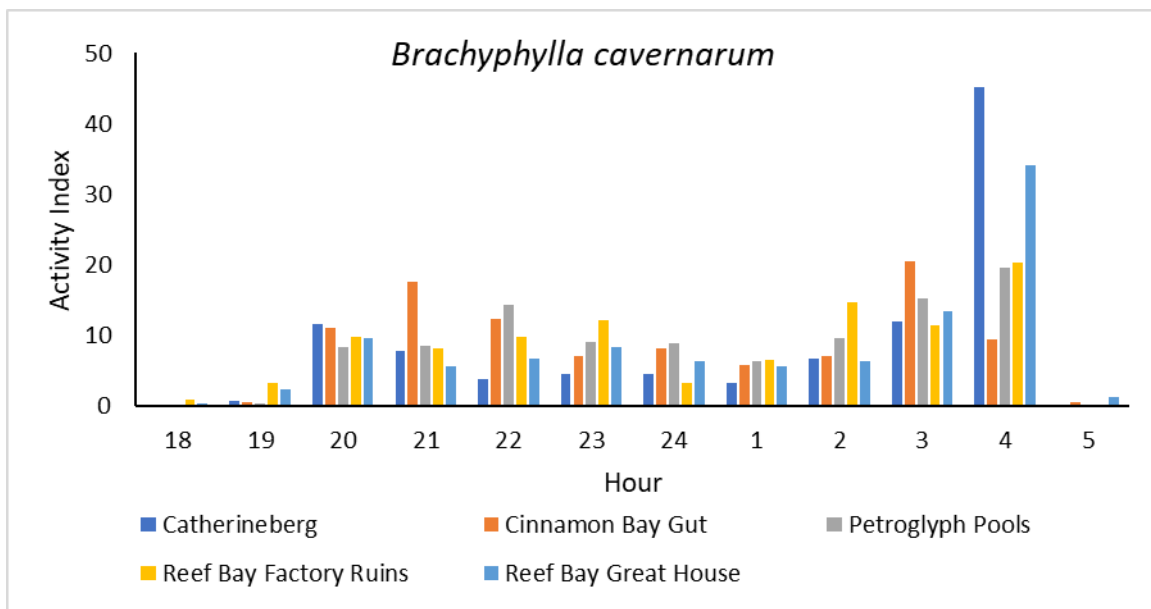


Figure 21. *Brachyphylla cavernarum* diel activity pattern at each site sampled, pooled across sampling period. Only sites with >100 individuals are represented. Activity indices represent proportion of total.

Artibeus jamaicensis was the species of interest for this study because it was adversely affected by Hurricanes Irma and Maria and had largely disappeared from monitoring samples in the initial two years since the hurricanes (pers. obs. and unpubl. data). *Artibeus* was detected across most sites but was not detected at sites with water (Petroglyph Pools, Fish Bay Gut, Francis Bay Pond)(Fig. 16). The site with the

most detections (25% of non-*Molossus* acoustic activity) was the Reef Bay Great House, which was occupied by an *Artibeus* colony at the time of the survey; *Artibeus* emits low-intensity echolocation calls that are difficult to detect using passive recording devices. Activity patterns recorded at the Reef Bay Great House indicated that the bats were active throughout the night, with a peak pre-dawn (Fig. 22).

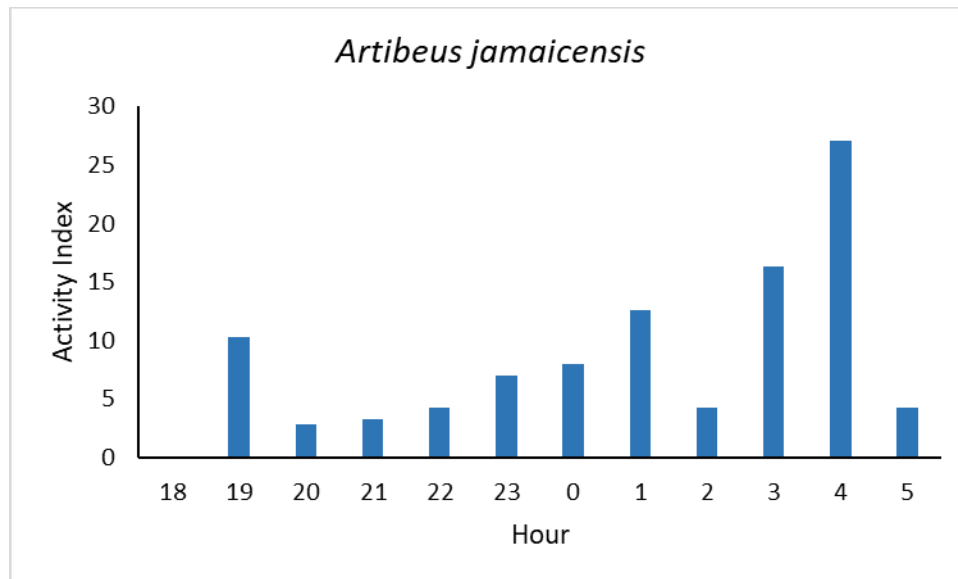


Figure 22. *Artibeus jamaicensis* diel activity pattern at the Reef Bay Great House, pooled across sampling period. Activity indices represent proportion of total.

Stenoderma rufum was not detected. This does not mean the species does not occur at any of the sites sampled, but that none of the vocalizations evaluated matched known acoustic signatures for this species. Likewise, we were unable to detect other non-resident species, such as *Tadarida brasiliensis*. Additional work is needed to collect *Stenoderma* recordings and to verify the identity of the unknown call patterns.

Hurricane Dorian

Hurricane Dorian strengthened from a Tropical Storm to Category 1 during the morning of 28 August 2019 as it approached the US Virgin Islands. While the track of the storm was west of the island of St. John, passing directly over the western side of St. Thomas, storm-force winds affected St. John during the day. Two sites, Peace Hill and Murphy Great House, were being sampled at the time, resulting in acoustic data from 13 days pre- and 11 and 4 day (respectively) post-storm. Bat activity (all species detected pooled for both sites) showed a decline in activity on the night after the storm (28-29 August), with a rapid return to near-previous levels in subsequent days (Fig. 23).

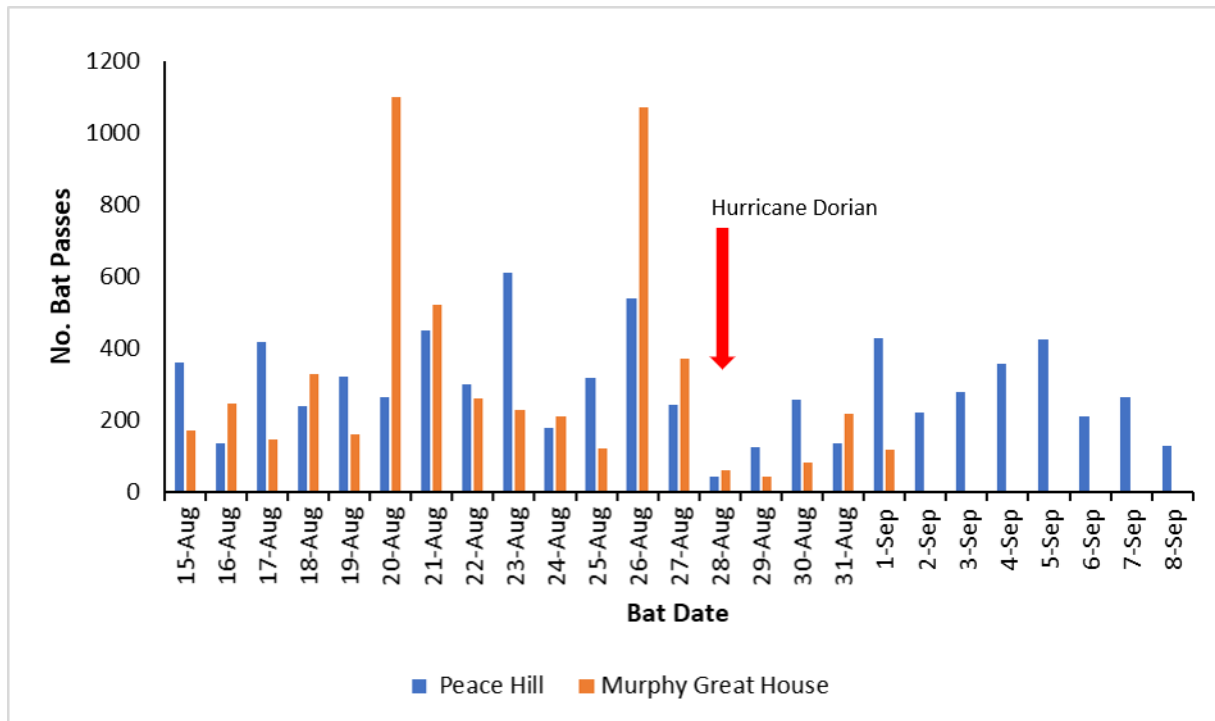


Figure 23. Bat activity (number of recordings) at two sites sampled pre-and post-Hurricane Dorian on 28 August 2019. The recorder at Murphy Great House stopped functioning after 1 September. “Bat Date” represents data collected from 5pm on the date shown to 6am the following day.

Discussion

Hurricanes Irma and Maria in September 2017 left habitats on St. John ravaged, with large swaths of broken trees and the entire island denuded of leafy vegetation. The loss of food resources was acute for the fruit-eating bats; it was three months after Irma before trees started flowering, and fruit/berry production was severely reduced through 2018 (pers. obs.). In the months post-hurricane, *Artibeus jamaicensis* disappeared from mist-net surveys on St. Thomas, while *Brachyphylla cavernarum* was reported “breaking into” houses to access human food, and dead and dying individuals were being reported from St. Croix. *Stenoderma rufum* has also not been observed since Irma (however, this species is uncommon and are rarely observed even under intensive survey effort; pers. obs.). *Molossus molossus*, an insectivore, was also affected: no individuals tagged at a routinely monitored site on St. Thomas prior to Irma were ever captured again. On St. John many *Molossus* likely were lost with the loss of roofs in the storm, as a common roost site for this species is roof spaces in houses.

Although influences of the storm were still apparent in 2019, the bats appeared to be recovering. Acoustic surveys indicated that *Molossus* was widespread and abundant, and that *Noctilio* and *Brachyphylla* were confirmed at multiple sites across the island. The *Brachyphylla* roost at Europa Point was active on visitation in October 2019, with similar acoustic output as a pre-storm survey at a similar roost on St. Croix. Although *Artibeus* was hardly detected in the acoustic surveys, the roost at the Reef Bay Great House was occupied by individuals of different size classes, indicating successful reproduction and recruitment post-hurricane.

As luck would have it, a storm (Dorian) swept through the island while we had sampling equipment in place, and we were able to capture pre- and post-storm data, although at only two sites and only for four days after the storm (one recorder stopped functioning at four days, the other continued recording for a total of 11 days). Bat activity across that time period showed high variation night-to-night, but there was a significant decline in activity on the night of the storm that continued into the second night. By the third night, however, bat activity resumed at both sites at levels similar to those pre-storm. This was not a major hurricane and habitat damage was minimal, and it appears that bats are resistant to these minor disturbances. That bats, particularly the fruit-eaters, are slowly recovering from Hurricane Irma indicates that they are somewhat resilient to major disturbances.

Despite their resiliency to natural disasters, bats are still declining due to anthropogenic influences such as habitat loss, forest conversion, pesticide use, encroachment, and influences of climate change. There are a range of conservation actions that can be implemented to offer support to declining populations.

Recommendations for Bat Conservation

There are a range of conservation actions that will benefit bats. While it is recognized that certain opportunities for conservation action may be limited within the park due to restrictions on allowable activities (e.g., construction) or access to funding, some actions are simple and cost-effective for implementation.

Survey and Monitoring

Survey effort should be expanded to include mist-net surveys across the national park on an annual or semi-annual basis in spring (March/April/May) and fall (Sept/Oct). Dry season (April-May) surveys may be productive at sites with reliable water sources, while wet season surveys should be targeted around food resources such as fruiting trees. Surveys from dusk to 2-3 hours after dark are likely sufficient to capture all four species, with the caveat that in certain sites species other than *Molossus* may be more active during the second half of the night. Regular monitoring of key sites using capture methods is highly recommended to detect changes in population structure and reproduction and health condition of individuals. Acoustic monitoring is beneficial for determining species presence (although not effective at determining absence). Processing acoustic data is extremely time consuming but effort can be reduced with the use of cluster analysis of sound patterns according to acoustic parameters for each species.

Education and outreach

Educating the public about bats is a powerful conservation action. While the bats at the Reef Bay Factory Ruins provided a valuable wildlife experience to visitors, there was a missed opportunity to allow the bats to serve as ambassadors because of a lack of information about them. Bat information, including what species we have, why they are important, how they use habitat features, biological needs and parameters, echolocation, and conservation measures such as avoiding roosts during the breeding season, should be included on signage. Good locations for bat signage include the Reef Bay Trail, Cinnamon Bay Ruins and campground/beach, Visitor Center, and other locations. A leaflet containing this information could be available at the Visitor Center and included on a website. A bat experience would be a great addition to the Friends of the Park Seminar Series.

Roost site protection

Artibeus, *Noctilio*, and *Molossus* are tolerant of some degree of roost site disturbance, but *Brachyphylla* does not tolerate any level of disturbance. Individuals are quick to take flight on intruder approach, which can prove lethal to dislodged juveniles in a maternity colony (pers. obs.). All known *Brachyphylla* roosts (sea caves, rock fissures, occupied structures) should be protected against visitation disturbance. This is particularly important for caves and fissures on cays, which tend to be known by boaters.

Restoration and protection of structures used as roosts

The **Reef Bay Factory Ruins** has had *Artibeus* hanging from the roof for as long as anyone can remember, until the roof was lost in Irma (Fig. 24). *Artibeus* is extremely tolerant of human intrusion, and as such the experience of observing these bats was unique and cherished by visitors, offering a remarkable public relations exercise in bat conservation. This experience should be restored as a visitor attraction by replacing the roof to recreate the roost. The visitor experience can be enhanced by installing signage about the bats and their biology and ecological and cultural significance.

With the loss of the roost at the factory, the structure at the **Reef Bay Great House** has taken on enormous value to *Artibeus*. The building is open to entry, and the floor is unstable and likely very prone to collapse. This site should be protected from human intrusion by installing gates or other structures that allow visitors visual access to the inside of the building while preventing entry. Any boarding up of windows should allow free movement of bats. The site should be cleaned up of debris and construction material such that the public can safely move around the building. A bat observation platform or kiosk can be installed, with educational signage. A “bat cam” with a feed to the Visitor Center or website would be a tremendous resource for education and public relations.



Figure 24. Reef Bay Factory Ruins bat roost pre- and post-Hurricane Irma. Photo: R. Platenberg

Artificial Refugia

Natural roosts for *Artibeus* include collapsed palm fronds and other forest canopy structures. *Noctilio* uses cavities in large trees (e.g., *Terminalia catappa*, pers. obs), as well as rock fissures and human structures. *Brachyphylla* are cave dwellers and will occupy any spacious yet dark cavity with sheer rough walls for clinging. The needs of all three of these species can be met with the use of appropriately designed artificial refugia. Small bat houses typically occupied by *Molossus* can be wall-mounted in appropriate locations, such as the Visitor Center or Cinnamon Bay Campground (there was one on the Maho Bay cafeteria building that was occupied by bats, pers. obs.). Larger structures, such as those at the University of Florida at Gainesville (Fig. 25) can offer roosting habitat for multiple bat species and can offer great potential for wildlife viewing and educational opportunities. Information on Bat Condos is included in the Appendix (A4).



Figure 25. Bat houses at the University of Florida, Gainesville campus. Photo credit: betterwander.com

Support and augment native forest

The fruit-eating bats are vulnerable to aberrant shifts in seasonal patterns of precipitation, and a severe drought (characterized by higher temperatures and higher rates of evaporation) during the typical January to May dry season or an extension of the end of the dry season to mid or late summer can have lasting impacts on populations. Adults with reduced access to resources usually present during these times will lose body condition leading to delayed or suppressed reproduction, increased juvenile mortality, and reduced recruitment. Adult survival is also reduced. Supporting native forest communities is an important conservation measure to mitigate these seasonal stressors. Native trees that provide a broad temporal range of services should be planted throughout the park, and culturally important non-native fruit trees (such as banana and mango) can be planted within or peripheral to cultural sites (e.g., Annaberg). Valuable species for birds and bats are listed in the Appendix (A4).

Appendices

Metadata and Supplemental Information

Appendix 1. Site Metadata



Table A1.1. Sites sampled for acoustic activity of bats in the Virgin Islands National Park, St. John, US Virgin Islands.

Location	Habitat	Structure	Map Notation	Latitude	Longitude	Dates Sampled (2019)	No. Days	No. Recordings
Annaberg Tower	Upland dry forest, altered	Open	ANNA	18.363063	-64.729495	24 Jun - 2 Jul	8	8370
Catharineberg Ruins	Upland dry forest, altered	Open	CATH	18.344132	-64.761424	24 Jun - 17 Jul	23	6559
Cinnamon Bay Gut	Gallery forest, dry forest	Closed	CING	18.352571	-64.751928	17 Jul - 15 Aug	29	9948
Cinnamon Bay Ruins	Basin woodland, altered	Open	CINR	18.35156	-64.753675	24 Jun - 7 Jul	13	8559
Europa Point	Coastal shrubland	Open	EUR1	18.317841	-64.72923	22 Sep - 13 Oct	21	7766
Europa Bat Roost	Coastal shrubland	Open	EUR2	18.317133	-64.728568	13 - 16 Oct	3	7335
Fish Bay Gut*	Gallery forest	Open	FISH	18.32848	-64.76418	17 Jul - 12 Aug	26	16,937
Francis Bay Pond*	Salt pond coastal wetland, mangrove woodland	Open	FRAN	18.364906	-64.743064	17 Jul - 15 Aug	29	3500
Murphy Great House	Coastal shrubland, dry woodland, altered	Open	MURP	18.365408	-64.719536	15 Aug - 2 Sep	18	6205
Peace Hill	Coastal shrubland, dry forest, altered	Open	PEAC	18.351416	-64.777544	15 Aug - 8 Sep	24	8363
Petroglyph Pools*	Gallery forest	Open	PETR	18.331923	-64.744175	29 May - 24 Jun	26	17,235
Reef Bay Factory Ruins	Basin woodland, altered	Open	REEF	18.322938	-64.745055	29 May - 24 Jun	26	5109
Reef Bay Great House	Upland dry forest, altered	Open	RBGH	18.32936	-64.740036	29 May - 24 Jun	26	15,772
VIERS Road	Gallery forest	Closed	VIER	18.321339	-64.722808	22 Sep - 13 Oct	21	5130

*water present at time of survey

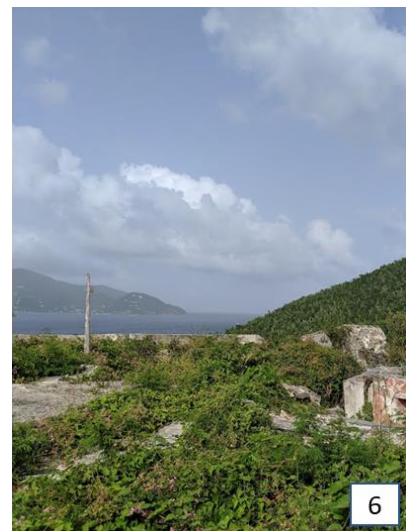
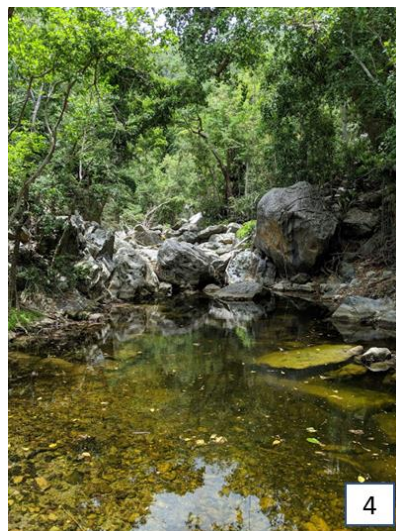
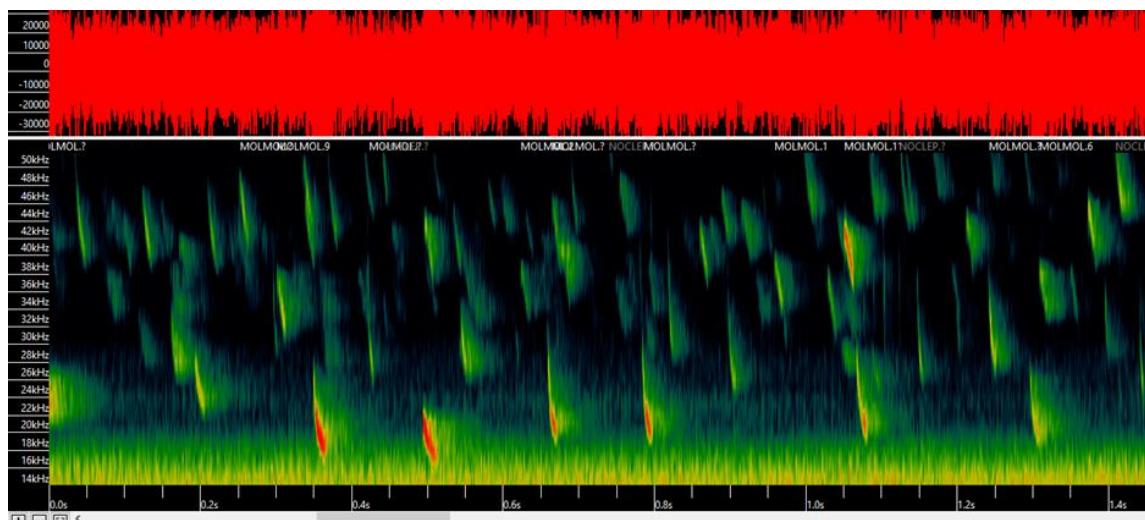


Figure A1.1. Photos of selected sampling sites. 1-Cinnamon Bay Gut; 2-Cinnamon Bay Ruins; 3-Catherineberg Ruins; 4-Fish Bay Gut; 5-Francis Bay Pond; 6-Murphy Great House; 7-Petroglyph Pools; 8-Reef Bay Factory Ruins; 9-Reef Bay Great House.

Appendix 2. Acoustic Metadata



Species Frequency Ranges

The bulk processing of sets of recordings can be better targeted for individual species by establishing frequency range (Table A2.1) constraints in the processing parameters for auto ID or clustering in Kaleidoscope. While there is considerable overlap in frequency range, applying these parameter constraints improves the accuracy of the processing output and reduces the volume of recordings needing to be manually evaluated.

Table A2.1. Typical frequency range of USVI bat species. Asterisk denotes published range from Jennings et al. 2004.

Species	Frequency Range kHz
<i>Artibeus jamaicensis</i>	50-110*
<i>Brachyphylla cavernarum</i>	17-40*
<i>Molossus molossus</i>	25-60
<i>Noctilio leporinus</i>	20-56
<i>Stenoderma rufum</i>	26-95*

Jennings, N.V., S. Parsons, K.E. Barlow, and M.R. Gannon. 2004. Echolocation calls and wing morphology of bats from the West Indies. *Acta Chiropterologica* 6:75-90.

Selected Spectrograms

Spectrograms are visual representations of sound, with the frequency range (kHz) of an acoustic signature depicted across time (duration of recording in seconds). In these spectrograms, sound amplitude is represented by the oscillogram (waveform) above, in red. All spectrograms were produced using Kaleidoscope Pro (wildlifeacoustics.com). Species are distinguished by frequency range of acoustic output, duration of call signature, interval between pulses, and general shape of the vocalization. Species identifications were made using a combination of roost site recordings, published vocalization parameters, auto-ID references in Kaleidoscope, reference recordings donated by other researchers, and process of elimination.

Molossus molossus have highly variable call signatures that vary in shape, duration, and frequency range. A typical *Molossus* spectrogram shows a series of pulses (Fig. A2.1). This species emerges at dusk and forages in groups, resulting in extremely cluttered spectrograms (Fig. A2.2) within the first hour post-dusk. Once the mass emergence has dissipated, individuals can be better distinguished in the spectrograms (Fig. A2.3). Feeding buzzes are commonly captured in the recordings (Fig. A2.4).

Molossus vocalization pattern ranges from inverted v-shaped echolocation pulses to long club-shaped pulses of approximately 15 kHz range at a slightly higher frequency. Feeding buzzes tend to follow the long club-shaped pulses and show a drop in frequency and decreased interval between pulses. Automatic classifiers show high accuracy at detecting and identifying strong *Molossus* signals.

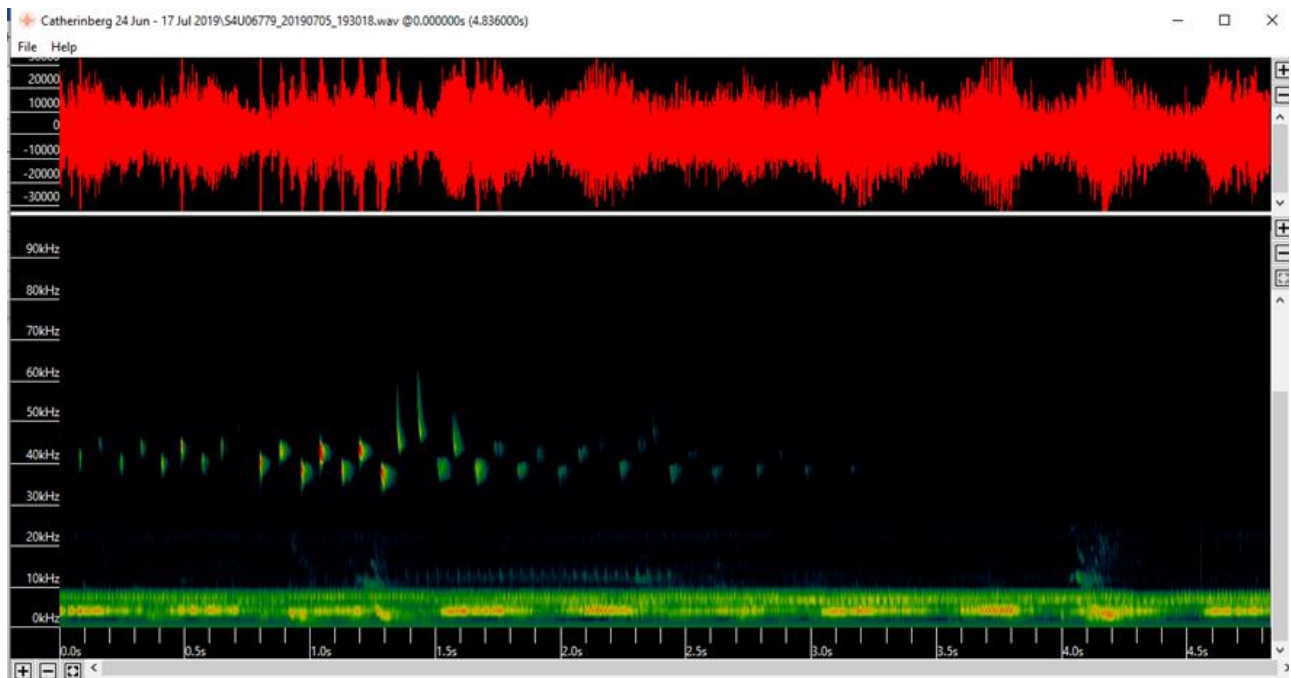


Figure A2.1. Spectrogram of *Molossus molossus* individual (timestamped at 7:30pm). This spectrogram represents a “bat pass”: note the fading of the acoustic signature as the bat moves away from the microphone.

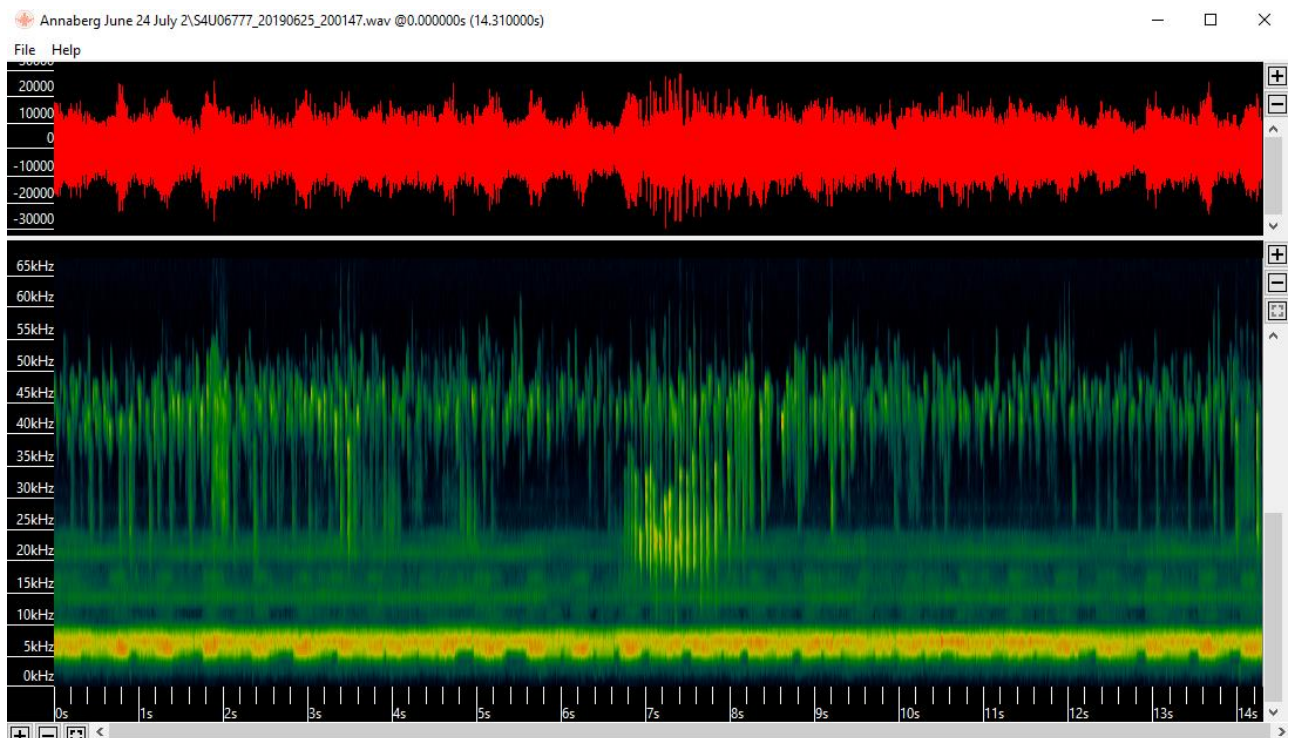


Figure A2.2. Spectrogram of *Molossus molossus* (timestamped at 8:01pm). Many of the recordings appear as above: cluttered with multiple individuals and potentially multiple species. A prominent insect signature is visible between 5-10kHz, with residual harmonics registered up to 25kHz. A feeding buzz is

apparent at 7-8 seconds. Note the absence of an “approach” and “retreat”; this recording cannot accurately be considered a “bat pass”, although we considered these cluttered recordings as proxy for bat activity.

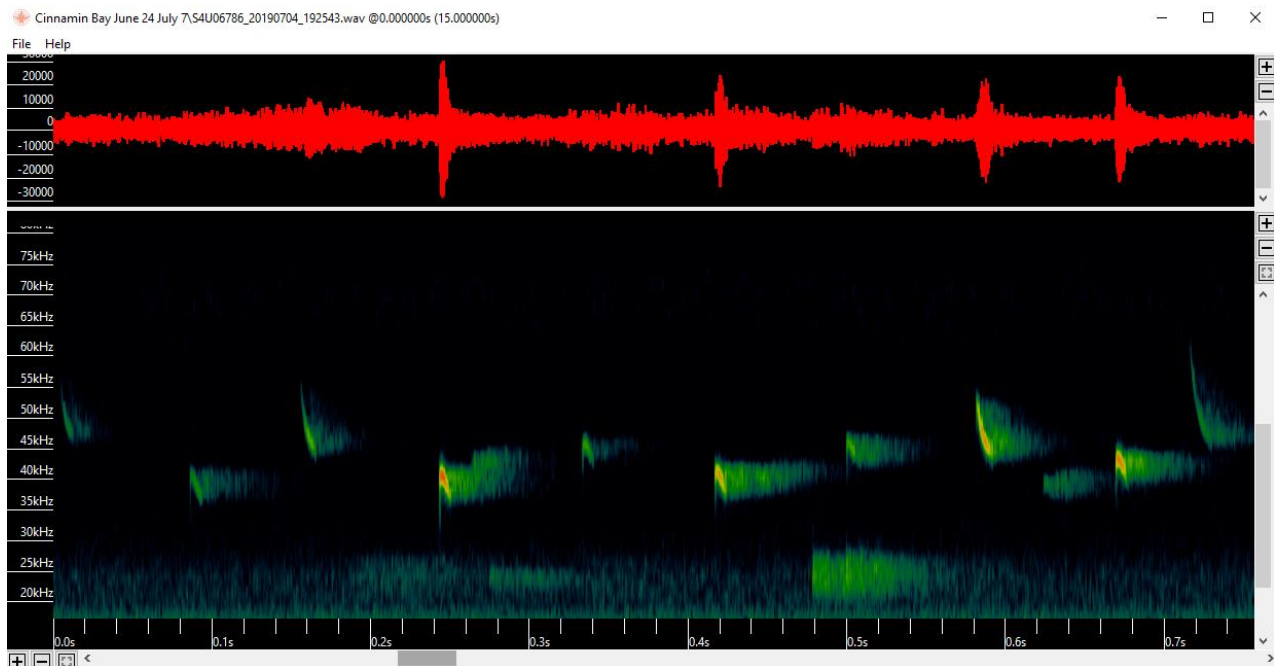


Figure A2.3. Spectrogram of *Molossus molossus* echolocating individual (timestamped at 7:25pm). Note the variation in signal shape and frequency.

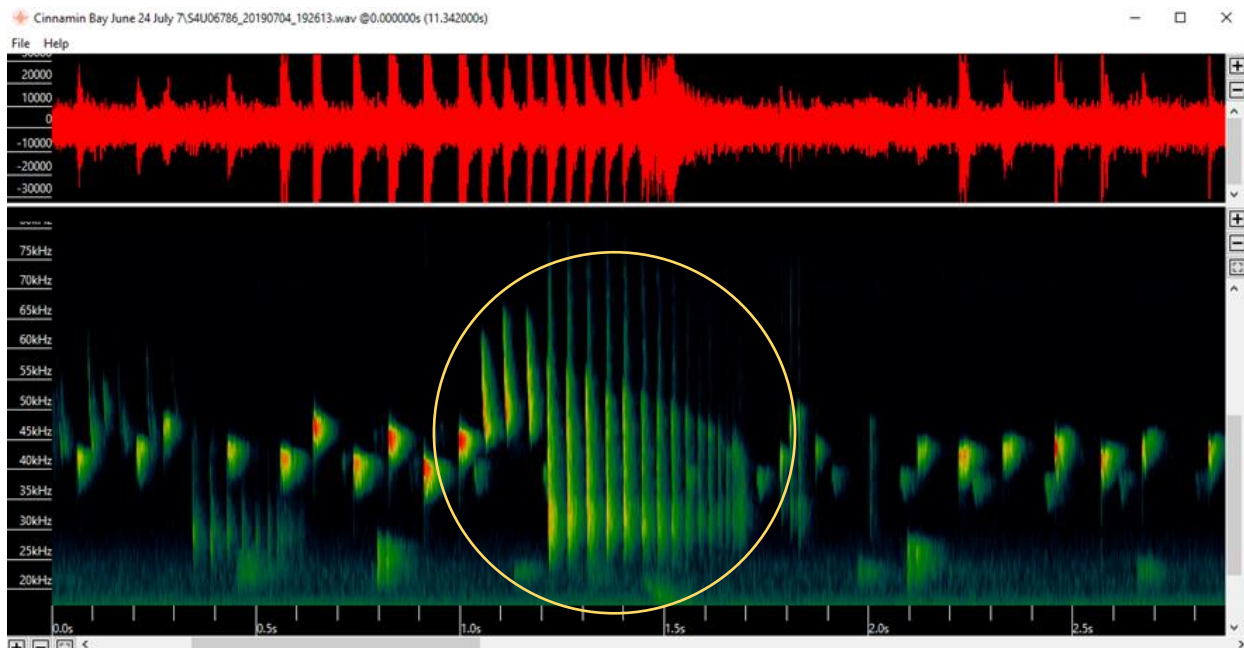


Figure A2.4. *Molossus molossus* feeding buzz (circled)(timestamped at 7:26pm). Note upper and lower frequency changes and overlap with at least one other individual.

Noctilio leporinus show little variation in call structure. Pulses are cane-shaped with a intensity flair toward the lower range of the pattern (Fig. A2.5). Automatic classifiers show high accuracy at detecting and identifying *Noctilio* call signatures. Classifiers created to detect both *Noctilio* and *Molossus* in the same recording (Fig. A2.6) are also highly effective.

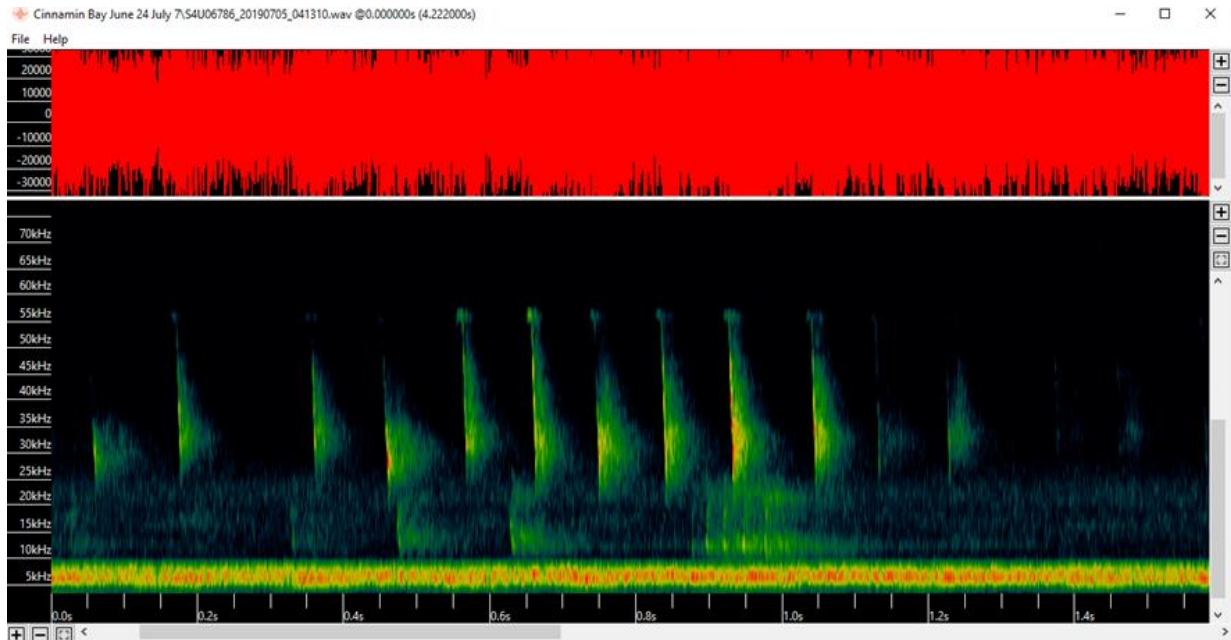


Figure A2.5. Spectrogram of *Noctilio leporinus* echolocation call.

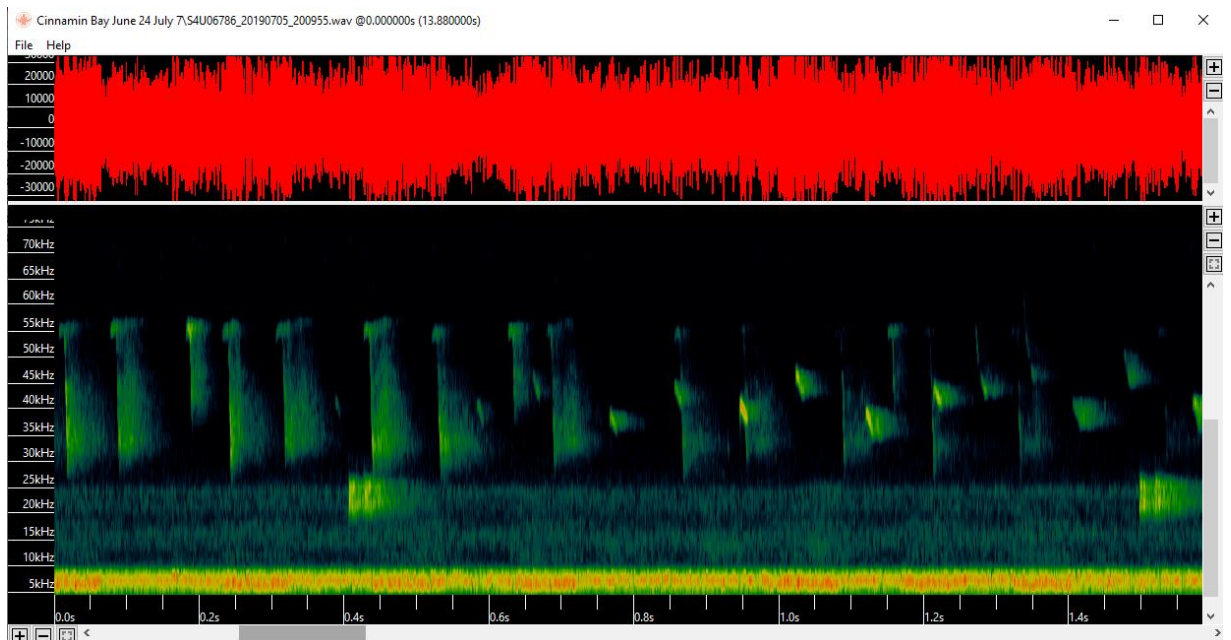


Figure A2.6. Spectrogram containing vocalizations of *Noctilio leporinus* and *Molossus molossus*.

Brachyphylla cavernarum vocalizations are at the lower end of the frequency scale and are often audible to humans. Their vocalizations are highly variable within roosts (Fig. A2.7), although show more consistent patterns while foraging (Fig. A2.8). We were unable to create a classifier to detect this species. Vocalizations are characterized by having multiple harmonics, although these are not always picked up by the microphone.

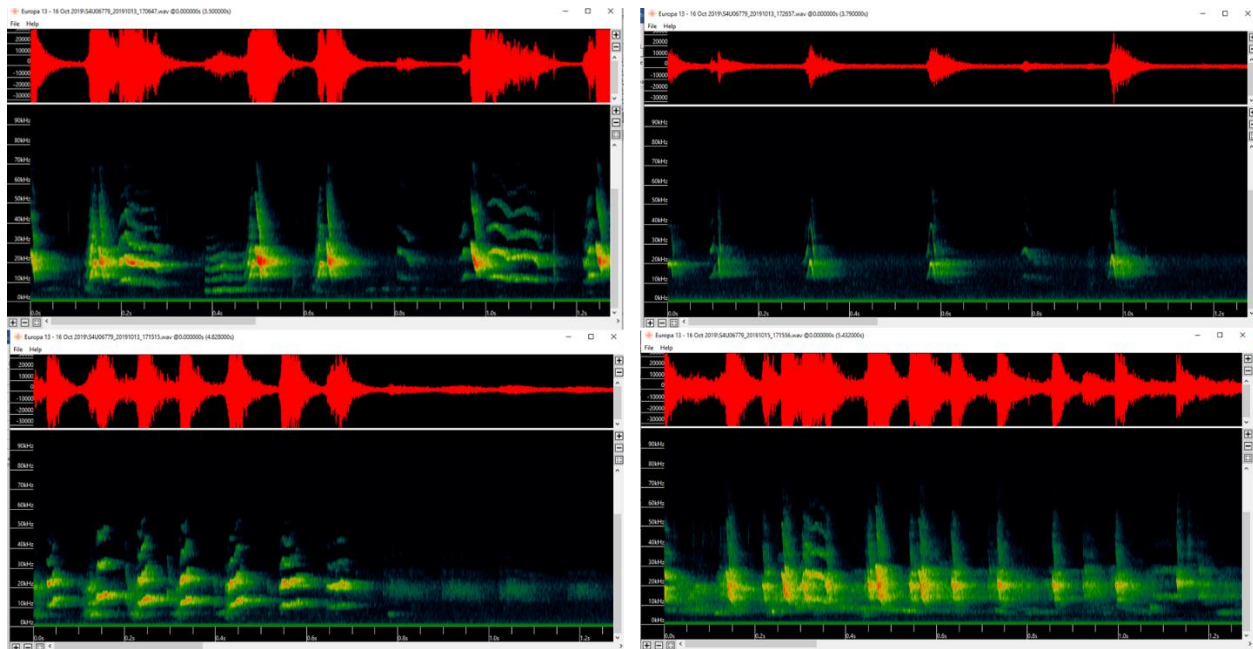


Figure A2.7. Series of spectrograms of *Brachyphylla cavernarum* vocalizing within a roost (Europa).

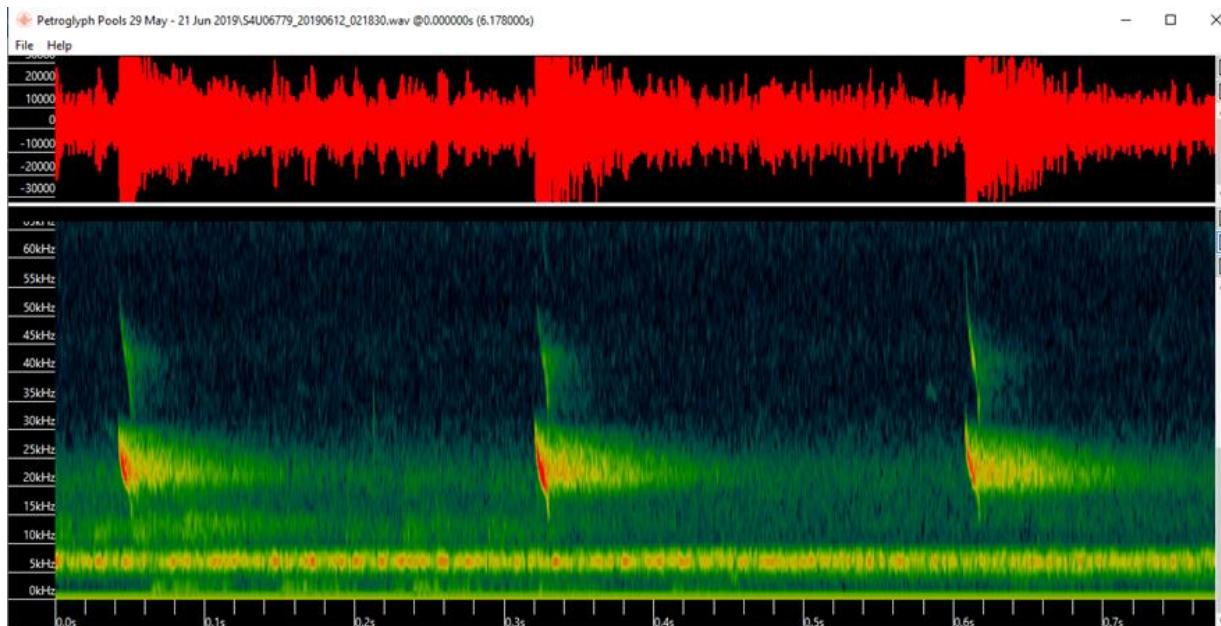


Figure A2.8. *Brachyphylla cavernarum* vocalization while away from roost site.

Artibeus jamaicensis was poorly detected, even at sites where they are known to occur (e.g., Reef Bay Great House). We attributed consistent patterns constrained within a higher frequency (~55-90kHz) to *Artibeus* (Fig. A2.9). Individual vocalization pulses show multiple harmonics similar to *Brachyphylla* (Fig. A2.10)

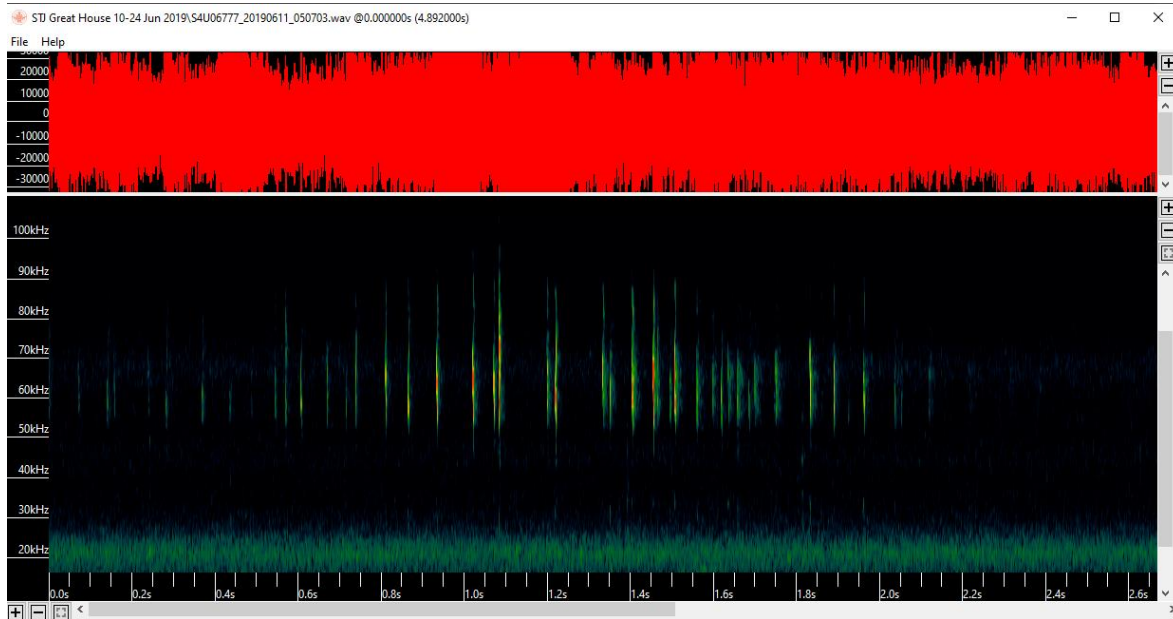


Figure A2.9. Spectrogram attributed to *Artibeus jamaicensis*.

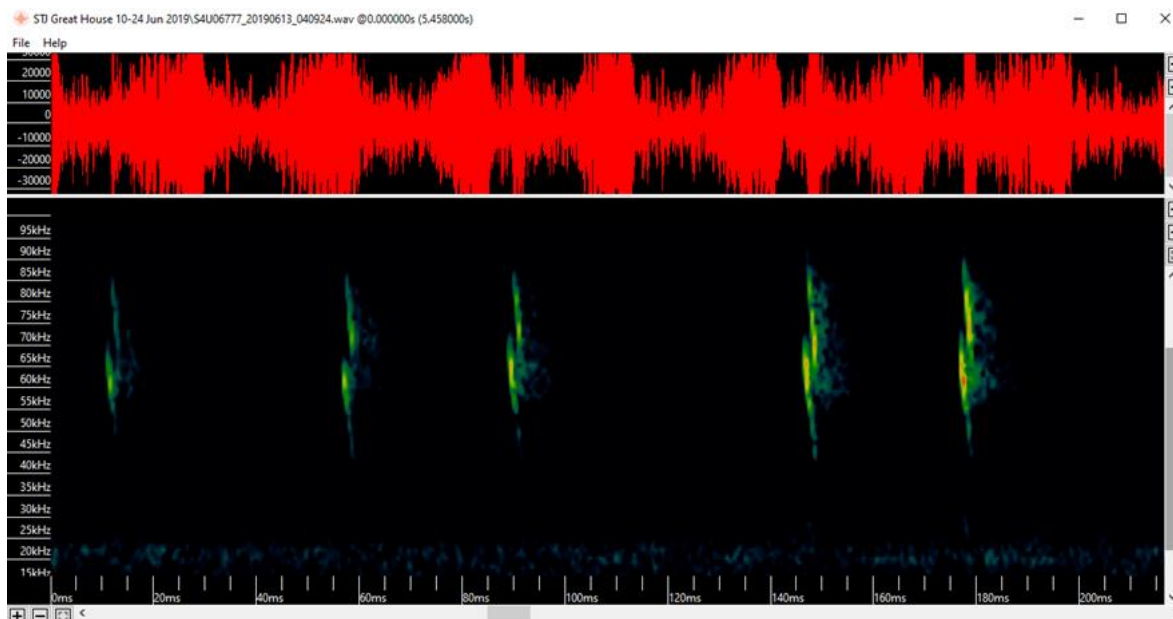


Figure A2.10. Vocalization pattern of *Artibeus jamaicensis*, showing multiple harmonics.

We detected one vocalization pattern across several sites that we were unable to identify (Fig. A2.11). Although displaying multiple harmonics of the fruit-eating bats, the directionality of the signal is inconsistent with *Brachyphylla* and *Artibeus*, and it does not fall within the published parameters for *Stenoderma rufum*. We don't know what that is.

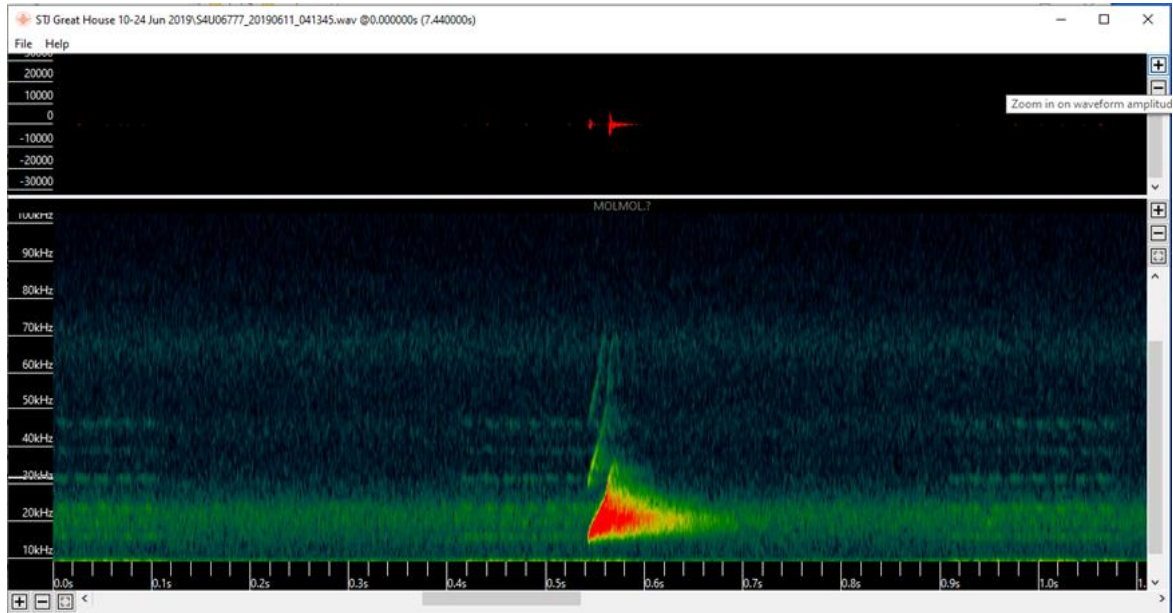


Figure A2.11. Spectrogram depicting unidentified vocalization signature.

Appendix 3. Detection Metadata



Table A3.1. Number of recordings attributed to species identification at each site. Refer to Table A1.1. for site code. Note that the total includes recordings that have been attributed to more than one species.

	ANNA	CATH	CING	CINR	FISH	FRAN	MURP	PEAC	PETR	REEF	RBGH	VIER
<i>Artibeus</i>	1	2	7	0	0	0	0	6	0	0	141	6
<i>Brachyphylla</i>	11	280	171	25	90	3	3	84	363	130	252	74
<i>Molossus</i>	8238	5180	6292	6817	15,658	2009	5455	7160	15,270	3436	14,166	2791
<i>Noctilio</i>	17	52	8	396	453	146	6	0	252	110	99	679
<i>Unknown</i>	1	46	0	0	0	0	2	6	9	5	73	7
TOTAL	8268	5560	6478	7238	16,201	2158	5466	7256	15,894	3681	14,731	3557

Appendix 4. Supplemental Conservation Information



Trees for Wildlife

Appropriate trees for bats and other wildlife. All species are native to the USVI except where noted.

Trees for wetlands

Gris-gris – *Bucida buceras*

Kapok – *Ceiba pentandra*

Sandbox – *Hura crepitans*

Royal Palm—*Roystonea borinquena*

Fruit trees for bats & birds

Hogplum – *Spondias mombin*

Black Mampoo – *Guapira fragrans*

Mespe (Sapodilla) – *Manilkara zapota*

Pigeonberry – *Bourreria succulenta*

Pig Turd – *Andira inermis*

Manjack – *Cordia* spp.

Autograph Tree – *Clusea rosea*

Royal Palm – *Roystonea borinquena*

Trees and shrubs for pollinators

Kapok – *Ceiba pentandra*

Puerto Rican Bank Century Plant – *Agave missionum*

Wattapama—*Poitea florida*

Herbaceous plants/lianas

Yellow Sage – *Lantana camara*

Night-blooming Cereus – *Hylocereus trigonus*, *Selenicereus grandiflora*

Beneficial non-native species

West Indian Almond – *Terminalia catappa*

Banana – *Musa* spp.

Mango — *Mangifera indica*

Bat Condo Plans

This set of plans was designed to house Little Brown Bats (*Myotis lucifugus*) and is provided here as an example of a bat condo that could be built for installation in service areas or areas outside of the NPS boundary. Full instructions for construction and installation can be found at: <https://bcbats.ca/attachments/WDNRBatCondo.pdf>.

