CANADIAN
WILDLIFE HEALTH
COOPERATIVE

A qualitative approach for assessing the maternity roost habitats of Myotis species and tri-colored bats for wildlife management purposes

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Prepared by the

Canadian Bat Maternity Roost Protection Working Group

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Cover illustrations: left: northern myotis; top right: little brown myotis; bottom right: eastern small-footed myotis; background: sugar maple identified as northern myotis maternity roost, Nova Scotia. Photos by Jordi Segers

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Executive summary

Many of Canada's bat species form maternity colonies in diverse habitats during pregnancy, lactation, and raising pups. Effective protection of maternity roosts and the habitats these important concentration areas are found in is key for conservation and recovery of Species at Risk (SAR) and other bat species. Wildlife managers are tasked with conservation planning for endangered species and prioritizing areas for habitat restoration and conservation. The purpose of this document is to provide guidance on how to define, characterize, and identify bat maternity roost habitats. This document provides a background on the current state of knowledge of maternity roost biology for all of Canada's myotis species and the tri-colored bat and suggests a qualitative, expert-informed approach to identify species- and range-specific maternity roost habitats.

The qualitative habitat assessment described here is designed to help wildlife and land managers rapidly evaluate and compare relatively large areas for bat roosting habitat even when regional distribution, habitat use, or population data for bat species may not be available. The primary steps involved and described include: 1) conducting a literature review to identify local, science-based information and experts; 2) using the information and local experts to identify and weigh relevant habitat components that predict maternity roost presence; 3) mapping the described suitable habitat for visualization and verification purposes; 4) utilizing the qualitative habitat assessment results to inform wildlife and land management decisions that can lead to protection of bat maternity roost habitats.

Ground truthing can be conducted in various ways with various levels of certainty to test the validity of the model's output, including trapping and tracking of reproductive bats, acoustic monitoring of bats, and expert visual assessment of the habitat or specific suspected roosting sites. However, ground-truthing may not always yield confirmation of the target species or reproductive activity, thus the cost and benefit ratio needs to be considered. Involving species and habitat experts to provide context and validation of the model's prediction of roosting habitat is recommended as a qualitative way to validate the model so it is ensured that wildlife management decisions are based on the highest quality, evidence-based information to better protect bat maternity roost habitats for Canada's myotis species and tri-colored bats.

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1 Introduction

Population recovery of hibernating bats affected by white-nose syndrome (WNS) and other threats may be constrained by a bat's ability to find suitable roosting habitats for pregnancy, lactation, and rearing pups (Lacki 2018). Where suitable habitats are limiting, effective protection of maternity roosts, and associated biophysical habitat, is a key strategy for conservation and recovery of Species at Risk (SAR) listed bat species.

With the goal to help wildlife managers better protect bat maternity roosts, **the primary purpose of this document is to provide guidance on how to define, characterize, and identify bat maternity roost habitat** specific to bat species and location. There is no one-size-fits-all approach to identifying maternity roost habitat as each bat species has their own maternity roost requirements, which differ across their range. Therefore, this document limits generalized statements that quantify range-specific maternity roost factors and instead provides a background on the current state of knowledge of many Canadian bat species' maternity roost biology and suggests an expert-informed method to identify species- and range-specific maternity roost habitat. Management aimed at promoting, preserving, and creating high-quality roosting habitat is an important conservation goal for maximizing bat diversity and abundance. Defining species- and site-specific bat maternity roost habitat will help wildlife and land managers, industry, and property owners better understand what habitat is important to maintain and protect.

Maternity roosts

Bat maternity roosts, also referred to as "nursery roosts", are the seasonal places where pregnant females congregate, give birth to their pups, and wean their pups to volancy (when pups are able to fly) from late spring, through the summer, to early fall. Female bats typically arrive at these roosts shortly after emergence from winter hibernation, when they are in an early stage of pregnancy. Unlike males and non-reproductive females, which tend to roost more solitarily (Broders et al. 2006; Fenton and Barclay 1980), reproductive females often (but not always) roost in groups, which may permit optimization of thermoregulation (Fenton and Barclay 1980), and select maternity roosts that are consistently warmer than ambient temperatures (Davis and Hitchcock 1965; Fenton 1970; Humphrey and Cope 1976), which allows them to minimize the need for torpor (a state of lower physiological activity and reduced metabolism) and shorten the gestation period (Racey 1973). Pups are born in these roosts and stay with their mothers in maternity roosting areas, a network of roosts that typically provide a range of climatic conditions required by reproductive bats and pups, until weaned and volant, with migration to fall roosts or swarming sites occurring between mid-summer and early fall. Most bat species occupying maternity roosts show high fidelity to roosting areas within and between years and are known to switch specific roosts regularly, occupying a network of roosts during the maternity season (e.g., Garroway and Broders 2008; Johnson et al. 2012; Sunga et al 2024; Veilleux and Veilleux 2004). Bats' habit of roost switching may increase resilience to low levels of roost loss because bats are more familiar with a greater number of alternative roosts available, but their limit of tolerance to roost loss

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and the impact this may have on survival and reproductive output are unknown (Silvis et al. 2015). Maternity roost requirements of bats may differ with reproductive state (pregnancy, lactation, post-lactation) (Garroway and Broders 2007; Johnson et al 2012), species, and location. Maternity roosts include natural roosts such as trees and rock crevices, and anthropogenic structures such as attics, barns, bridges, and bat houses. Thus, protecting maternity roosts requires maintaining a network of roosts that offer appropriate conditions to support breeding females throughout the reproductive period, and ensuring suitable habitat connectivity within the networks of roosts. Conservation of healthy bat populations requires the availability of suitable roosts with spatially and temporally diverse microclimates in structurally complex ecosystems that are most likely to provide adequate roost areas for most bat species (Adams and Hayes 2008; Bellamy and Altringham 2015; Boyles 2007; Broders and Forbes 2004; Legros 2023).

Timing windows

Maternity colonies form shortly after bats emerge from hibernation and typically remain occupied at least until pups are weaned. The maternity roosting season typically lasts four to five months, but may last up to seven months. However, this timing window varies significantly with species, location, climate, and local conditions (Sunga et al. 2023). Typically, maternity colonies form in April or May (Dubois and Monson 2007; Lausen et al 2022; Schowalter and Gunson 1979). Pups are born in June and early July (Caceres and Barclay 2000; Fenton and Barclay 1980; Fujita and Kunz 1984; Lausen et al. 2022; Nagorsen and Brigham 1993; Van Zyll de Jong et al. 1980), but the timing of parturition is different depending on the bat species and across species' range. For example, parturition has been observed three weeks later for northern myotis compared to little brown myotis in eastern Canada (Broders et al. 2006) and two months later for little brown myotis compared to yuma myotis in western Canada (Lausen et al. 2022). Pups become volant at about three weeks of age (Burnett and Kunz 1982; Caceres and Barclay 2000; Fujita and Kunz 1984; Schowalter and Gunson. 1979). Roost quality, environmental factors, and disturbance to roosting bats can negatively affect survival and reproductive success of bats. Timing of birth in bats is critical for pup survival and has important fitness consequences for first year survival (Frick et al. 2009). Optimally birth timing coincides with peak insect abundance, providing a higher probability of pup survival when born earlier in the summer (Frick et al. 2009; Kunz and Lumsden 2003), while delayed birth of pups can expose them to unpredictable weather conditions with reduced food availability and result in insufficient time for pups to develop before winter (Linton and Macdonald 2018). Stress in bats caused by human disturbance of maternity roosts, such as roost destruction or eviction from roosts, is shown to cause a strong decline in female bat survival (López-Roig and Serra-Cobo 2014), emphasizing the importance of maintaining and protecting bat maternity roosts and associated habitat to minimize disturbances.

Relevant species

This bat maternity roost guidance document focuses on three bat species federally listed as endangered: little brown myotis (*Myotis lucifugus*), northern myotis (*M. septentrionalis*), tri-colored bat (*Perimyotis subflavus*) (Environment and Climate Change Canada 2018; and the other *Myotis* species in Canada:

eastern small-footed myotis (*M. leibii*), fringed myotis (*M. thysanodes*), long-legged myotis (*M. volans*), long-eared myotis (*M. evotis*), western small-footed myotis (*M. ciliolabrum*), yuma myotis (*M. yumanensis*), California myotis (*M. californicus*). The scope of species was chosen by the 'Bat Maternity Roosts Working Group' (see 'Acknowledgement' section for a list of working group members and other contributors) because of the need to better protect the three bat species listed as Endangered in Canada under the Species at Risk Act that continue to be impacted by WNS (little brown myotis, northern myotis, and tri-colored bat; Environment and Climate Change Canada 2018) and because of similarities and overlap in roosting biology between them and among the other *Myotis* species in Canada. Despite this overlap, each bat species does have specific maternity roosting requirements. Species profiles are covered in the next section of this document and are summarized in table 1. Canada's three migratory bats species: (hoary bat (*Lasiurus cinereus*), eastern red bat (*L. borealis*), and silver-haired bat (*Lasionycteris noctivagans*)); big brown bat (*Eptesicus fuscus*) and other non-myotis species are not specifically considered in this guidance document but habitat requirements may overlap with some of the species that do fall within the scope of this document and applying protection to any area characterized in this document may benefit other bat species as well.

2 Roosting biology and habitat use

Myotis species and tri-colored bat maternity roost use and requirements differ between species and across a species' range. Adaptable species tend to adopt a range of different types of maternity roosts, while specialist species tend to only be found in very specific types of roosts and associated habitats. Common bat maternity roost types include cracks and crevices in trees and rocks, among lichen on tree branches, as well as artificial structures such as buildings, bat houses, and bridges.

Maternity roost area connectivity to foraging and watering sites is important for bats, who need to balance their time and energy expenditure between foraging and nursing their pups (Adams and Hayes 2008; Bellamy and Altringham 2015; Legros 2023). Bats can show high fidelity to roosting areas or even specific roosts, returning to the same area or roost for many years (Frick et al. 2009; Poissant and Broders 2009; Rancourt et al. 2005; Rodhouse and Hyde 2014; Slough and Jung 2020; Sunga et al. 2022; Veilleux and Veilleux 2004). Many bat species are known to switch roosts within a maternity season, utilizing a roosting area with a network of roosts that provide a range of climatic conditions. Roost preference and rate of roost switching typically changes between pregnancy and lactation stages. Due to roost switching, a roost may be occupied consistently during a maternity season, but composition of individual bats within a given roost may change regularly (Broders et al. 2006; Caceres and Barclay 2000; Frick et al. 2009; Foster and Kurta 1999; Kaupas 2016; Lausen 2007; Moosman et al. 2023; Naughton 2012; Olson and Barclay 2013; Slough and Jung 2020; Solick and Barclay 2006; Sunga et al. 2022). Fidelity to a roost and roost switching are influenced by roost permanency (the lifespan of the physical structure), with species roosting under bark or in decaying trees showing less fidelity and a higher rate of roost switching (Lewis 1995; Olson and Barclay 20013; Russo et al. 2017; Willis and Brigham 2004) in larger roosting areas with more roosts (Willis and Brigham 2004), and bats roosting in anthropogenic structures exhibiting less roost switching in a smaller roosting area (Webber et al. 2016). However, it is

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not well understood if rate of roost switching is associated with roost quality or roost availability in a given area.

Bat species that form maternity roosts in trees typically require landscapes that support a higher density of large-diameter trees. Best management practices in a forestry setting should promote the growth, preservation, and ongoing recruitment of large-diameter trees to better support bat species reproduction and recovery (Lacki 2018; Olson and Barclay 2013). However, maternity roost characteristics are context dependent, with bats typically selecting the largest trees possible based on what is available in a stand. What constitutes a large diameter tree varies greatly across Canada. For example, trees in northern latitudes (e.g., Yukon, Northwest Territories, Newfoundland's Great Northern Peninsula, and Labrador) are typically smaller yet are used as maternity roosts by bats (Jung et al. 2014; Kaupas 2016; Park and Broders 2012; Randall et al. 2014). Hence, specific roost characteristics may only be known or be informative at small regional scales.

Bats can form maternity colonies in various rocky-type habitats. These habitats can be associated with rock fields, talus slopes, cliff faces, caves, clay banks, and others (Lausen 2017; Moosman 2023; Naughton 2012; Pybus 1986), often facing south for high solar exposure (Lausen 2007; Lausen and Schowalter 2008; Olson and Flach 2016), but connectivity with nearby vegetation is often important as well (Johnson et al. 2011; Moosman et al. 2023). Large rocks can provide thermally stable roosting conditions suitable for various bat species. While rocky maternity roosts are a more commonly adopted strategy of western Canadian bat species, it is displayed by bat species throughout Canada (Naughton 2012).

Anthropogenic structures can provide important roosting opportunities for reproductive bats as well. Primarily, Canadian bat species using anthropogenic roosts are found inside buildings such as houses and barns (Lausen et al. 2022; Micalizzi et al. 2023; Naughton 2012), but bats are found roosting underneath bridges as well, particularly in western and northwestern Canada (C. Olson; L. Wilkinson, personal communication). Several bat species also form maternity colonies in bat houses, which are anthropogenic structures that are constructed for them especially and include bat boxes, bat condos, and rocket boxes (Lausen et al. 2022; Naughton 2012; Holroyd et al. 2023). Bats forming maternity roosts in anthropogenic structures can show high fidelity to these roosts and may display less roost switching than those in natural roosts (Balzer et al. 2023; Frick et al. 2009) (though not always), as well-designed roosts may provide a variety of microclimatic options. Conservation of these anthropogenic roosts may be important once a colony is established. However, it is not clear if a lesser degree of roost switching observed in anthropogenic maternity roosts is due to the high quality of the roost or because high quality natural roosting habitat is limited. Conservation of anthropogenic roosts can be complicated as these are often on private lands and may be inside private residences where human health conflicts can arise (McBurney 2020).

The following sections provide a literature review on the specific roosting biology and habitat use by the aforementioned bat species in a Canadian context, also summarized in table 1. It is important to

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understand that the maternity roosting biology of all species is not well studied. Many knowledge gaps exist on maternity roost locations, roost area fidelity, and roost switching. Existing knowledge may primarily be based on studies done outside of the Canadian range of the bat species, and regionally important differences in roosting behaviour and habitat selection may exist. Additionally, protection of bat maternity roosts goes beyond maintaining the roost alone. Maternity roost suitability relies heavily on the biophysical attributes of the roost itself, as well as connectivity to quality commuting, foraging, drinking, swarming, and hibernation habitats. Understanding these aspects of bat biology is essential for the development of management guidelines that reduce the impact of forestry practices, deforestation, and other threats that could degrade or destroy bat maternity roost habitat, or disturb female bats and their young during the crucial period (Jung et al. 2014).

Northern myotis (*Myotis septentrionalis*)

Northern myotis females have been recorded roosting in snags (i.e., standing, dead or dying trees, sometimes missing a top or branches), large cracks and cavities of trees, and under loose bark. Roost tree species selection is highly varied regionally and between studies, including sugar maple and yellow and white birch (New Brunswick, Broders and Forbes 2004; Prince Edward Island, Henderson and Broders 2008), balsam fir, black spruce, and white birch (Newfoundland, Park and Broders 2012), live trembling aspen (Northwest Territories, Kaupas 2016; British Columbia, Vonhof and Wilkinson 1999), western red cedar and western hemlock (British Columbia, M. Kellner, personal communication), balsam poplar, white birch (British Columbia and Alberta, Lausen et al. 2022; Olson 2011), silver maple, red maple, and green ash (Michigan, Foster and Kurta 1999), black locust (West Virginia, Drake et al. 2020; Menzel et al. 2002), pin oak, elm, sweetgum, and oak (Illinois, Carter and Feldhamer 2005), sassafras, sugar maple, white oak, red maple, red oak, yellow poplar, and mockernut hickory (Kentucky, Silvis et al. 2012; Thalken and Lacki 2018). Typically, northern myotis roosts trees are in a mid-state of decay (Broders and Forbes 2004), being characterized by having little bark, broken tops, and few limbs (Menzel et al. 2002), but live and early-decay aspen and western red cedars are essential in the western boreal forests (M. Kellner, personal communication; Olson 2011), thus regional differences caused by availability of tree species may influence ideal state of decay of trees used as maternity roosts. Northern myotis' tree species use is geographically variable across its range and this species displays preferences for certain tree species and roost characteristics on a local scale (Carter and Feldhamer 2005; Foster and Kurta 1999; Silvis et al. 2012).

Roost switching occurs frequently, about every 1 to 5 days (Broders et al. 2006; Carter and Feldhamer 2005; Foster and Kurta 1999; Kaupas 2016; Menzel et al. 2002; Sasse and Pekins 1996; Caceres and Barclay 2000). Moving between roosts with different exposures and insulative properties allows bats to select sites that minimize energetic cost based on ambient conditions (Broders et al. 2006). In West Virginia, northern myotis are known to use artificial nursery boxes, rocket boxes, and artificial bark as maternity roosts in low numbers (De La Cruz et al. 2018), but use of anthropogenic roosts by this species appears to be rare in the Canadian range, with a report of this species roosting in a barn on Prince Edward Island (Henderson and Broders 2008) and using bridges, potentially as night roosts, in Yukon, Northwest Territories, British Columbia, Alberta, and Saskatchewan (M. Kellner; C. Olson; L. Wilkinson, personal communication). Maternity roost characteristics of northern myotis change depending on reproductive status. Lactating bats more often roost higher in taller trees with higher dominant canopy, greater distance between roost and canopy, and lower density of coniferous trees and total trees compared to pre- and post-lactating bats (Garroway and Broders 2008). However, in the western boreal forests they have being observed forming maternity roosts in low vertical scars in aspen trees, sometimes only 2 meters from the ground (Mandy Kellner, personal communication).

Northern myotis roost trees are primarily in mature, shade-tolerant deciduous stands (New Brunswick, Broders and Forbes 2004; Prince Edward Island, Henderson and Broders 2008; British Columbia, Lausen et al. 2022), but can also be in deciduous stands in western and northern parts of their range (M. Kellner, personal communication). Roost areas for northern myotis have high canopy closure and are subjected to little solar exposure (Carter and Feldhamer 2005; De la Cruze et al. 2018) and higher than average slope, elevation (like ridges tops, plateaus, south facing slopes), and area of forest stand (De la Cruze et al. 2018; Silvis et al. 2012). Proximity of foraging area to water may be important for reproductive northern myotis females (Henderson and Broders 2008). In a forest-agriculture landscape, roosting areas were 0.3 to 4.13 hectares (Henderson and Broders 2008), but size of roosting areas is site-specific (Carter and Feldhamer 2005). Roost area selection by northern myotis at the edge of their range may differ from that in the interior of their distribution. At the eastern edge of their distribution, they have been reported primarily using snags with larger than average diameters in forest stands with a higher than average density of trees (Park and Broders 2012), in their northern range they have been reported using cavities and cracks in mature trembling aspen (Kaupas 2016), while studies in more southern geographic areas reported stand selection based on large diameter snags with a low density of live trees (Thalken and Lacki 2018). Primarily, maternity roost trees are in the forest interior, but some snags near forest edges are used as well (Carter and Feldhamer 2005). It is important to manage forests for a large network of suitable roosts to maintain colonies of northern myotis (Garroway and Broders 2008) and consider regional differences based on known, local bat biology (Parks and Broders 2012). Seasonal differences in habitat use among different reproductive classes should be accounted for in forest planning efforts (Thalken and Lacki 2018) and forest managers should retain snags during harvest to provide bat roosts, especially in newly regenerating forest stands (Menzel et al. 2002; Park and Broders 2012).

Little brown myotis (*Myotis lucifugus*)

Little brown myotis is known to use both natural and anthropogenic roosts throughout its distribution, showing a high degree of intra-specific variation in roost-site selection even on local scales (Kalcounis and Hecker 1996). Roost trees identified were primarily balsam poplar (Alberta, Olson and Barclay 2013), and trembling aspen (Saskatchewan, Kalcounis and Hecker 1996; British Columbia, Psyllakis and Brigham 2006), western redcedar, and Douglas-fir (British Columbia, M. Kellner personal communication), typically with a diameter at breast height (dbh) of >30 cm (Alberta, Olson and Barclay 2013). Conifer snags and large cottonwood trees likely are important maternity tree species in regions of

British Columbia where aspen are not available (Mandy Kellner, personal communication). Large diameter roost trees showed more variation in number of bats in roosts, with both small and large colonies observed within them. Selective removal of large trees negatively affects little brown myotis not only through the direct loss of roosts, but also by limiting the range of possible group size, in turn affecting the ability of bats to optimize their roosting conditions.

In tree roosts, roost switching in little brown myotis occurs every 1 to 6 days (Crampton and Barclay 1998; Olson and Barclay 2013). Little brown myotis is also reported to form maternity colonies in rock crevices. In Saskatchewan and Alberta, maternity colonies were found in sandstone crevices of southeast and south facing cliffs and coulees, occasionally observed co-roosting with other species (Holloway 1998; Saunders 1989). Bats in rock crevices were observed to use the same roosts for at least 22 consecutive days (Saunders 1989). Maternity roosts in artificial structures are reported in various types of bat houses (e.g. multi-chamber roost boxes, bat condos, and rocket boxes) (Holroyd et al. 2023) and in various parts of buildings, including occupied and abandoned houses, cottages, sheds, barns, in attic spaces, underneath shingles or siding, hollow walls, behind shutters, in chimneys (Kalcounis and Hecker 1996; Micalizzi et al. 2023; Pybus 1994; Schowalter and Gunson 1979). Little brown myotis does not create their own accessways into artificial roosts and thus rely on existing holes, like structural defects, to access buildings (Pybus 1994). Recently, little brown myotis maternity roosts have also been reported under bridges in Northwest Territories, Alberta, Saskatchewan, and British Columbia (C. Olson; L. Wilkinson; M. Kellner, personal communication). Little brown myotis show high fidelity to roosting areas (but not always to individual roosts); records have shown fidelity to roosting areas lasting decades, although regular roost switching at these areas still occurs (Frick et al. 2009; Humphrey and Cope 1976; Slough and Jung 2020; Sunga et al. 2022). However, roost fidelity alone does not account for roosting patterns among maternity colonies. Social preferences may have a large influence on little brown myotis' roosting behaviour, as this species demonstrates complex, non-random fission-fusion patterns of roosting associations with conspecific bats (Sunga et al. 2022). Use of extensive roost areas and roost switching within and between maternity seasons has been reported (Syme et al. 2001), but some building-roosting little brown myotis may show a low degree of roost switching (Balzer et al. 2023) or not switch roost at all within season (Randall et al. 2014).

As little brown myotis commonly use both natural and anthropogenic maternity roosts (Broders and Forbes 2004; Naughton 2012) and may switch between these roosts within a maternity season (Micalizzi et al. 2023), this species benefits from having access to transition zones between urban and rural areas (Coleman and Barclay 2011). Cavity and foliage roosting bats typically choose thicker and taller than average roost trees in areas with relatively open canopy in stands with snag prevalence higher than average (Kalcounis-Ruppell et al. 2005). Foraging habitat requirements differ for pregnant and lactating little brown myotis with home range decreasing during lactation (Henry et al 2002), but roosts are typically near open wetlands and forested habitats (Balzer et al. 2023). While little brown myotis' use of anthropogenic structures as maternity roosts is well-studied and understood, very little is known about the species' preferences in natural forest stand selection.

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Tri-colored bat (*Perimyotis subflavus*)

Tri-colored bats typically roost in lichen of black spruce and pines (Nova Scotia, Poissant et al. 2010), dead leaf clusters of live or recently dead oaks, pines, maples and other large dbh deciduous trees (Drake et al. 2020; Perry and Thill 2007; Arkansas, Perry and Thill 2007; Indiana, Veilleux et al. 2003), Spanish moss, tree cavities, and on rare occasions uses anthropogenic structures (Indiana, Davis and Mumford 1962). In Ontario, a maternity roost of about 6 to 10 tri-colored bats was found roosting in a building (Ontario, B. Fenton, personal communication) and a colony of about 23 adult female bats, counting about 50 bats after pups were born, in a small barn. These bats were observed switching roosts regularly, using a network of roosts consisting of several barns, sheds, a house, and several trees, including sugar maple, birch, and ironwood (Ontario, Stukenholtz 2023). Tri-colored bats in Arkansas were observed roosting in small clusters averaging 6.9 bats, singly in sub-clusters with their pups, as well singly with their pup away from others (Perry and Thill 2007). Roost switching occurs every 4 to 6 days with an average of 60 meters travelled between roosts (Veilleux et al. 2003). Tri-colored bats show high fidelity to maternity roosts or roost areas (Poissant and Broders 2009), often returning to the same area and using the same trees between years (Veilleux and Veilleux 2004).

Tri-colored bats show inter- and intra-annual fidelity to roost habitat (Veilleux and Veilleux 2004). Mature forests that contain hardwood are important for tri-colored bats, as are unharvested pine or pine– hardwood stands of more than 50 years old (Perry and Thill 2007), and upland or riparian habitats. Roost areas ranging from 0.23 to 2.3 hectares are reported by Veilleux et al. (2003) and Veilleux and Veilleux (2004).

Eastern small-footed myotis (*Myotis leibii*)

Eastern small-footed myotis summer roosts include rock fields, talus slopes, buildings, bridges, bird nests, shutters of buildings, tree bark, caves, and mines, but little is known about this species' reproductive behaviour and it is unclear whether all such habitats are used as maternity roosts (Hitchcock 1955; Moosman et al. 2023; Naughton 2012). The few maternity colonies found in Canada have been in buildings such as barns (Hitchcock 1955), consisting of 12 to 20 females (Naughton 2012). They are well-studied in the USA, roosting in talus slopes and rock fields where regular roost switching by reproductive females is observed, rarely using a roost for more than one consecutive day and traveling relatively short distances of less than 100 meters between roosts (Johnson et al. 2011; Moosman et al. 2023). Moosman et al. (2023) noted that eastern small-footed myotis roosting habits shared broad similarities with those of western rock-roosting bat species, including fringed myotis, long-eared myotis, and western small-footed myotis.

Eastern small-footed myotis ground-level rock roosts are often found in predominantly rocky habitats on steep south facing slopes with little canopy cover but with nearby vegetation (Johnson et al. 2011; Moosman et al. 2023). Talus slopes with large rocks may be of particular importance to reproductive females, as these rocks provide thermally stable roosting conditions and protection from predators (Moosman et al. 2023). Nearby water sources may be important landscape features for lactating female

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roost area selection (Johnson et al. 2011). Naughton (2012) states this species prefers hilly terrains in deciduous or coniferous forests, sometimes being found in flat lands as well, but that very little is known about their habitat preferences. Furthermore, the species' distribution in Canada is limited to southern Ontario and southern Quebec as the northern range limit, with most records coming from hibernacula, thus what little is known about the species comes primarily from their US range.

Western small-footed myotis (*Myotis ciliolabrum*)

Western small-footed myotis form small maternity colonies of 2 to 35 individuals or roost alone (Holloway and Barclay 2001; Lausen 2007; Naughton 2012) in caves, crevices of rock faces, clay banks (Pybus 1986), mudstone erosion holes (Olson and Flach 2016), rock slabs, boulder cracks (Holloway 1998; Lausen 2007), coulees (C. Olson, personal communication), and in rocky outcrops in small canyons along rivers or streams (Rodhouse and Hyde 2014) and is similar during pregnancy and lactation (Lausen 2007). Little is known about their maternity roost use in Canada (Naughton 2012), but in Alberta they are reported to roost in cavities in badland rock and mudstone crevices, like erosion holes and crevices along cliffs, typically on southern aspects with high sun exposure (Lausen 2007; Lausen and Schowalter 2008; Olson and Flach 2016). Reproductive females roost alone or in small clusters typically up to five individuals (Lausen 2007; Lausen and Schowalter 2008). Roost switching is reported to be common in Alberta, occurring daily within about a 100 m section of a valley (Holloway 1998; Lausen 2007). In Oregon, this species showed high fidelity to clusters of rocky outcrops of 0 to 25 meters high, with lactating bats roosting higher than post-lactating bats (Rodhouse and Hyde 2014).

Fringed myotis (*Myotis thysanodes*)

Fringed myotis' range in Canada is limited to south-central British Columbia and thus most of what is known about its biology comes from studies conducted on US populations. The only known maternity roosts in Canada are in buildings (Lausen et al. 2022; Naughton 2012). Outside of Canada, maternity roosts of this species have also been described in buildings and caves, with anywhere from 12 to 300 individuals in the roost (Lausen et al. 2022). Other roost types of fringed myotis are in rock substrates such as rocky outcrops, talus slopes, and boulder fields, but also trees such as ponderosa pine and Douglas-fir snags and white fir stumps, although it is unclear whether these are used as maternity roosts (Lacki and Baker 2007; Lausen et al. 2022; Weller and Zabel 2001). Although tree roosts are reported to be of less importance than rock roosts, in some areas of its southern distribution, they may only use tree snags (Lacki and Baker 2007; Weller and Zabel 2001). Roost use varies throughout this species' distribution. Tree snags may be able to host larger colonies than rock roosts do. Roost switching occurs regularly, every 1 to 2 days on average, with a distance between successive roosts up to 3.3 km. Rock crevice roosts are typically in splits or other narrow spaces 1 to 4 cm wide (Lacki and Baker 2007).

Fringed myotis roosting habitat consists of non-forested boulder fields on large flat plateaus, although the known tree roosts were in stands with high live tree density with large diameter trees near rocky ridge habitat (Lacki and Baker 2007).

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Long-eared myotis (*Myotis evotis*)

Long-eared myotis maternity colonies are primarily reported in boulders (Holloway 1998; Lausen 2007), upward facing crevices (2 cm in width) of rocks and cliffs (Holloway 1998), and to a lesser extent under bark and in snags of ponderosa pines (Washington, Rancourt et al. 2005), white spruce and lodgepole pines (Alberta, Solick and Barclay 2006), conifer stumps (Alberta, Vonhof and Barclay 1997; Oregon, Waldien et al. 2003), and in buildings, although little is known about their building roosting behaviour (Naughton 2012; Schowalter 1978; Lausen et al. 2022). Anthropogenic maternity roosts typically consist of few individuals, from 5 to 30 bats, and have been found in bat houses and buildings. This species has been observed co-roosting with little brown myotis in buildings and rock crevices (Lausen et al. 2022). On the prairies, reproductive females are typically solitary, but they roost occasionally in small groups with up to 30 adults (Holloway 1998; Nagorsen and Brigham 1993; Kunz and Lumsden 2003; Rancourt et al. 2005; Solick and Barclay 2006). Building roosting long-eared myotis may form larger colonies of 15 to 20 individuals (Schowalter 1978). Olson and Flach (2016) report that this species' maternity roost habits differ between reproductive status and across the landscape, with pregnant bats typically roosting under thin slabs of rocks to take advantage of solar heating, while lactating females roost in deep vertical splits with more stable temperatures. When using natural roosts, this species switches roost approximately every 2 days, with entire colonies switching roosts together (Chruszcz and Barclay 2002; Holloway 1998; Solick and Barclay 2006). On average, roosts are 148.0 m apart (Rancourt et al. 2005) and typically less than 400 m apart. Long-eared myotis have been observed roosting in bridges but maternity colonies in such structures have not been confirmed (C. Olson, personal communication). Lacki (2018) suggests that, while tree stumps are used occasionally, they were considered of limited value to this species. Long-eared myotis display little variation in roost tree use across their range, compared to other Myotis bats (Lacki 2018).

Long-eared myotis show high fidelity to roost areas characterized by open, rocky habitats near forest edges and away from water, with a landscape level selection of aspen stands (Rancourt et al. 2005).

Long-legged myotis (*Myotis volans*)

Long-legged myotis maternity roosts are mostly under loose bark (Vonhoff and Wilkinson 1999) or in cavities of snags taller than the forest canopy, exposing the roost to solar radiation throughout the day (Cryan et al. 2001; Lausen et al. 2022; Naughton 2012; Ormsbee and McComb 1998), with roost height ranging from 8 to 29.8 meters (Vonhof and Barclay 1996). Live, decaying Douglas fir and snags with an average height of 11 to 40 meters and dbh of 43 to 100 cm were the most commonly reported (Cryan et al 2001; Ormsbee and McComb 1998). Taller and larger trees with large hollows typically host larger maternity colonies, with observations showing maternity colonies with more than 300 individuals (Ormbsbee and McComb 1998). Long-legged myotis' maternity roosts are primarily reported in coniferous trees, including ponderosa pine, grand fir, white fir, Douglas fir, western white pine, western redcedar, western larch, and western hemlock (Ormsbee and McComb 1998; Lacki et al. 2013; Arnett and Hayes 2009), but Psyllakis and Brigham (2006) and Vonhof and Wilkinson (1999) reported maternity roosts in deciduous trembling aspen and cottonwood. Long-legged myotis also form maternity colonies

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in crevices of cliff faces (Naughton 2012; Ormsbee and McComb 1998). Long-legged myotis exhibit a high degree of roost switching (Naughton 2012). This species is reported in British Columbia and Alberta to form maternity colonies in buildings, bat houses, and under bridges (Lausen et al. 2022; Schowalter 1979), and has been observed to co-roost with little brown myotis (Lausen et al. 2022; Saunders 1989). Long-legged myotis can establish long term maternity colonies in buildings that consist of dozens (Saunders 1989) to several hundred individuals (Lausen et al. 2022; Naughton 2012), but those roosting in rock crevices are typically made of fewer individuals, with Cryan et al. (2001) reporting 10 to 31 individuals in South Dakota. Tree roost switching is reported to occur on average every 11 days and distance between subsequent roosts varies from 28 to 206 meters (Vonhof and Barclay 1996), while rock crevice roosts may be occupied for 20 days (Saunders 1989). Vonhof and Barclay (1996) found that roost height, roost switching distance, and roost occupancy duration by long-legged myotis, long-eared myotis, and silver-haired bat showed many similarities. Long-legged myotis is also known to form more permanent maternity colonies in buildings (Naughton 2012; Vonhof and Barclay 1996), sometimes forming colonies of several hundred bats (Naughton 2012).

Long-legged myotis maternity roosts in Oregon generally were found in upland habitats, outside of riparian habitat but still associated with nearby streams. Snags used as maternity colonies were more likely to be occupied when the surrounding forest stand consisted of trees of equal or lesser height. Forest stands in various successional stages, containing tall and large diameter Douglas fir snags, is important habitat for reproductive long-legged myotis (Ormsbee and McComb 1998).

Yuma myotis (*Myotis yumanensis*)

Yuma myotis form maternity colonies in a variety of site types, including buildings, bat houses, tree and cliff crevices and cavities, under bridges, abandoned bird nests, caves, and mines (Lausen et al. 2022; Naughton 2012). This species showed great variation in roost tree diameter use (Lacki 2018). Large maternity colonies, with more than 5,000 individuals reported, can form in artificial structures such as buildings and bat houses (Lausen et al. 2022; Naughton 2012), but roost switching is common and may occur daily. Roost switching decreases during lactation, before pups become volant. Yuma myotis and little brown myotis in British Columbia are known to roost in mixed-species maternity colonies during pregnancy and lactation, using artificial structures, with increased roost switching during late- and post-lactation compared to during pregnancy and early-lactation (Rensel et al. 2022; Rensel et al. 2023).

Yuma myotis habitat use is highly associated with proximity to water features, especially lakes and ponds (Duff and Morrell 2010). Because this species' maternity roost biology is studied primarily in buildings, little information is available on its natural habitat use and requirements surrounding the roost, similar to little brown myotis.

California myotis (*Myotis californicus*)

California myotis roost in crevices on rocky hillsides (Krutzsch 1954; Naughton 2012), under loose bark and cavities of dead trees of ponderosa pine, Douglas-fir, white pine, and grand fir in intermediate decay

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stage in relatively open forest stands (Barclay and Brigham 2001; Brigham et al. 1997; Naughton 2012), and in bat houses and buildings (Kellner and Rodriquez de la Vega 2023). Roost switching is common throughout pregnancy and lactation (Barclay and Brigham 2001; Brigham et al. 1997; Naughton 2012) and the mean distance between roosts was 401 meters (Brigham et al 1997). California myotis shows little roost site fidelity. California myotis maternity roosts are known to form in patches of predominantly large-dbh ponderosa pines with open canopies relative to average forest patches, requiring a substantial number of snags present in a forest stand with low canopy closure (Brigham et al 1997).

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Table 1: Summary of bat species and associated maternity roost and landscape characteristics. The information provided here comes from many small-scale studies and local expertise and may not represent roost and landscape characteristics across a species' entire range. References for data in this table are captured in the species chapters above.

Species	Roost characteristics				Stand/landscape characteristics	
	Tree characteristics	Rock characteristics	Anthropogenic characteristics	Other	Habitat type	Foraging characteristics
Northern myotis (*Myotis septentrionalis)*	Type: snags, cracks, cavities, loose bark Species: balsam fir, balsam poplar, black locust, black spruce, elm, green ash, mockernut hickory, pin oak, red maple, sassafras, silver maple, sugar maple sweetgum, trembling aspen, white birch, white oak, yellow poplar, western hemlock, western redcedar				Mature, shade-tolerant, high canopy closure, deciduous forests, mixed wood stands with mature deciduous trees, western coniferous forests	Deciduous forest, riparian zones, wetlands
Little brown myotis (*Myotis lucifugus*)	Species: balsam poplar, cottonwood, Douglas-fir, trembling aspen, western red cedar	Rock crevices, southeast/south facing cliffs	Buildings (occupied, abandoned, attics, chimney, hollow walls, shingles, siding), bridges, bat houses		Forest stands with higher than regional average snag density	Deciduous and mixed forests and edges, riparian zones, wetlands, urban and suburban areas

Tri-colored bat (*Perimyotis subflavus*)	Species: black spruce, oak, pine, sugar maple, birch, ironwood (lichen, dead leaf clusters, Spanish moss, cavities)		Buildings, barns, sheds, houses		Mature hardwood forest stands, unharvested pine or pine-hardwood stands, upland habitat, riparian habitat	Deciduous forest and edges, riparian zones, wetlands, open woodland
Eastern small-footed myotis (*Myotis leibii*)	Type: tree bark	Rock fields, talus slopes	Buildings, bridges, shutters	Caves, mines, bird nests	South facing talus slopes with large rocks with nearby vegetation and water features, hilly terrain, deciduous or coniferous forest, sparse canopy cover	Rocky habitats, forest edges and clearings, riparian zones, wetlands
Western small-footed myotis (*Myotis ciliolabrum*)		Crevices of rock faces, mudstone erosion holes, rock slabs, boulder cracks		Caves, clay banks	Badlands, coulees, rocky outcrops, small canyons along rivers and streams	Rocky habitats, desert and arid environments, riparian zones
Fringed myotis (*Myotis thysanodes*)	Species: ponderosa pine, Douglas fir snags, white pine stumps	Rock crevices	Buildings	Caves	Rocky outcrops, talus slopes, boulder fields, large flat plateaus, forest stands with high live tree density with large diameter trees near ridge habitat	Rocky habitats, desert and arid environments, riparian zones
Long-eared myotis (*Myotis evotis*)	Type: Bark, snags	Boulders, cliffs, thin slabs of rock, deep vertical splits, upward facing rock crevices	Buildings, bridges		Grasslands, coulees, badlands, rocky habitats near forest edges, near aspen stands	Forested habitats, riparian zones, wetlands, open woodland areas

	Species: ponderosa pine, white spruce, lodgepole pine, conifer stumps					
Long-legged myotis (*Myotis volans*)	Type: bark, cavities, snags Species: Douglas-fir, ponderosa pine, grand fir, white fir, western white pine, western redcedar, western larch, trembling aspen, cottonwood	Crevices of cliffs	Buildings, bat houses, bridges		Upland habitats	Forested habitats, riparian zones, wetlands, open woodland areas
Yuma myotis (*Myotis yumanensis*)	Type: tree crevices	Rock crevices	Buildings, bat houses, bridges	Bird nests	Proximity to lakes and ponds	Forest edges and clearings, riparian zones, wetlands, open water bodies, urban and suburban areas
California myotis (*Myotis californicus*)	Type: bark, cavities Species: ponderosa pine, Douglas-fir, white pine, grand fir	Rock crevices	Buildings, bat houses, bridges		Rocky hill sides, open forest stands, large dbh ponderosa pine stands, relative open canopy	Forest edges and clearings, riparian zones, wetlands, open water bodies, urban and suburban areas

Specific roost characteristics (e.g., dbh, tree height, cavity height, roost area size) are too variable across species' range and are therefore not reported in this table. Consult local literature and experts to determine appropriate metrics for these characteristics.

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3 Habitat suitability assessment

Wildlife managers are tasked with conservation planning for endangered species and prioritizing areas for habitat restoration and conservation. Scientifically rigorous methods are available to confirm the presence of bats or their roosts, and these should be the first choice to obtain the highest quality data for evidence-based decision making. There are various methods described in the literature, many relying on trapping and tracking bats (Fonderflick 2015; Karsk 2021; O'Malley et al 2023; Rainho and Palmeirim 2013) or acoustic detection data (Bellamy et al 2013; Bellamy and Altringham 2015; O'Malley et al 2023) to collect presence and absence data. However, the reality is that there are often inadequate budgets, logistical difficulties, a lack of available data—especially for rare and endangered species (Fuller et al. 2018; O'Malley et al. 2023; Wisz et al. 2008)—or insufficient time to utilize these methodologies. As a result, wildlife managers are frequently forced to make conservation decisions for environmental assessments and other land use situations under conditions of urgency, with limited personnel, and without sufficient data or resources. Often not enough is known about local bat populations and their associations with habitat to create statistical models that can inform wildlife managers on large scale habitat use in a timely manner. Fortunately, there are alternative methodologies to conduct a habitat suitability assessment on large geographical scales (e.g., at provincial and territorial levels) without the need to handle species at risk, collect recent or local data, or rely on complex statistical analyses (Allen et al. 1987; Crawford et al 2020; Leblond et al 2014; MacMillan and Marshall 2006; Snaith et al 2002).

Here, we describe a method to perform a habitat suitability assessment based on expert knowledge (Allen et al. 1987; Crawford et al 2020; Leblond et al 2014; MacMillan and Marshall 2006; Snaith et al 2002). **This type of habitat assessment is designed to rapidly evaluate and compare relatively large areas of habitat for which distribution, habitat use, or population data may not be available,** to allow wildlife managers to make appropriate decisions on what areas to conserve using the best available evidence-based information. We also provide recommendations on optional ground truthing methods.

Habitat suitability assessments typically make use of a geographic information system (GIS) exercise to map potential suitable habitat (e.g., based on forest cover types), and can be used to define appropriate conservation guidelines for protecting habitat features of interest (e.g., maternity roosts) (Crawford et al. 2020; Fonderflick 2015; O'Malley et al 2023; Wisz et al. 2008). We encourage wildlife managers to collaborate and consult with GIS experts early in their habitat suitability assessment process to understand what landscape level data and data types are available for a suitability model.

Data sources

Wildlife managers need to identify habitat scale and components that best predict the presence of target species and estimate the amount and distribution of potential suitable habitat across a species' range needed to support species conservation (Bellamy and Altringham 2015; Fonderflick et al. 2015; Leblond et al 2014; Mering and Chambers 2014; O'Malley et al. 2023; Slough and Jung 2020). Table 1 provides a summary of the specific maternity roost habitat requirements of Canadian Myotis bat species and the tri-colored bat as described in the available literature. Wildlife managers can use this

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information as a starting point to identify which habitat components should be considered as being important to reproductive bats, but should also consult local literature and engage experts (e.g., from local research institutions or identified in literature) to share their knowledge which ensures regional species' differences in habitat requirements and use are completely understood (Fuller et al 2018; Mlinaric 2023; Poissant et al. 2010; Silvis et al 2012; Thalken and Lacki 2018). If local knowledge is not available from experts or published literature, knowledge of the species from elsewhere within its range, if that area has comparable geography and habitat composition, can be used. Ultimately, the habitat suitability model that is developed will be limited by the quantity and quality of information available to the wildlife manager and models can be improved with local, detailed data on land cover (Mlinaric 2023).

Conducting a qualitative habitat suitability assessment based on expert knowledge

Herein we summarize habitat suitability assessments based on expert knowledge and provide a stepwise process that can be followed to conduct such a habitat suitability assessment. In Appendix I we share an example of using this methodology in a case study to identify northern myotis habitat on Prince Edward Island.

Snaith et al. (2002) conducted a preliminary habitat suitability analysis for moose in Nova Scotia. Their study followed methods described by Allen et al. (1987) that employ literature research and expert knowledge to determine which priority habitat components influence moose habitat selection, using readily available data to produce a distribution map of habitat suitability. A similar approach was taken by MacMillan and Marshall (2006) using the Delphi process. The Delphi process can be used to develop a GIS-based habitat suitability index to support habitat management decisions in data poor situations, considering trade-offs between conservation and commercial needs. In the Delphi process, ecological variables are weighted by experts based on their relative biological importance and results of the process are fed back to these same experts to build consensus on the ultimate model (MacMillan and Marshal 2006). After the analysis, experts review the maps that are produced to qualitatively assess the accuracy of the models, indicating where the model is under or over predicting habitat suitability which allows for adjustments to be made to improve the biological relevance of the model (Crawford et al. 2020).

We propose using similar approaches to those described by Snaith et al. (2002), Allen et al. (1987), and MacMillan and Marshal (2006) to assess habitat suitability for maternity roosting by three endangered bat species and other Canadian Myotis species. The methodology follows the steps described below, and we employ the same methodology for the case study to identify Northern myotis maternity roost habitat in Prince Edward Island forested places reported in Appendix I.

1. **Conduct a literature review** to identify local experts and review published scientific papers on the bat species' maternity roost habitat requirements. Peer reviewed papers or the grey

literature may provide information on important habitat components and metrics (e.g. distance of important habitat components to a roost site). If no local research has been done, literature on the target species conducted elsewhere in similar habitats may serve as a substitute.

2. **Identify and engage experts** with regional knowledge of the target bat species. Regional experts, including those with Indigenous Peoples and their traditional knowledge, can provide local knowledge of bat biology, using their accumulated knowledge from their published and unpublished data as well as first-hand experience. If no local species expert is available, identify those experts with experience working on the target species elsewhere in ecosystems that are comparable to the area of interest or consider collecting presence data, including acoustic activity metrics, to develop a habitat suitability model (see below).
3. **Identify habitat components** and associated metrics that predict maternity roost presence for the species of interest in a particular study area using the available published data and expert knowledge. Ideally, a panel of experts is brought together to discuss and find consensus on which habitat components should be included in the model. Habitat components may include those with a positive association or negative association. Associated metrics, such as minimum or maximum distance of important habitat components to roosting habitat, or specific metrics of roost characteristics (e.g., diameter at breast height of roost trees, height of roost) should be decided upon as well. Involving GIS experts during or prior to this step can help to ensure that identified habitat components are compatible with available data mapping layers for the region in question, informing complexity of the model. Table 2 provides a starting point on habitat components that could be considered.
4. **Assign relative weights** to the identified habitat components using available published data and expert knowledge. A panel of experts should use the published data for discussion of the relative weights of identified habitat components and arrive at a consensus on them if deemed appropriate. As there may be various degrees of uncertainty around the known importance of habitat components, relative weights can function as a surrogate metric of confidence, especially when there is expert consensus about them. If all identified habitat components are considered equal positive predictors for habitat suitability, no relative weights need to be assigned. Otherwise, habitat components that positively predict roost suitability should be assigned a positive value (e.g., on a scale from 0 to 1) and habitat components that negatively predict roost suitability should be assigned a negative value (e.g., on a scale from 0 to -1). For example, positive scores may be assigned to forest stands with an average dbh above a certain value, while negative scores could be assigned to habitat within a specified distance from anthropogenic or natural disturbances like busy roads, areas with light or noise pollution, or contaminated sites.
5. **Produce visualization of suitable habitat** by generating a habitat suitability index based on the identified and weighted habitat components. Specifically, partner with GIS experts to input the data from the weighted habitat components to produce heat maps (a visualization of the assigned habitat suitability index scores) to demonstrate where suitable or unsuitable bat

maternity roost habitat is predicted to occur. Subsequently, the output maps should be carefully reviewed by wildlife managers, expert biologists, Indigenous Peoples, and habitat managers to determine their validity and ensure the model is not over- or under-predicting suitable habitat. This process helps to verify accuracy of mapping layers and helps to tweak the input parameters to model the best representation of the current state and suitability of bat maternity roost habitat in the selected area.

6. **Inform wildlife and land managers** (and potentially land owners and industry) of suitable bat maternity roost habitat using output maps with habitat suitability index designated. The output map and habitat suitability index values associated with habitats enables people to make expert-informed and evidence-based decisions on bat roosting habitat quality in the chosen area and have certainty in their recommendations for protection and conservation actions.

While the focus of habitat protection here is on habitat specifically used by reproductive female bats as maternity roosting habitat, connectivity with habitats used by bats to fulfill other ecological needs should also be considered for inclusion in the model. Specifically, roosting habitat is associated with proximity and connectivity to suitable foraging and drinking habitats, with absence of either of the two latter habitats rendering the first unsuitable (Adams and Hayes 2008; Bellamy and Altringham 2015; Boyles 2007; Broders and Forbes 2004; Legros 2023). Habitat components that may not be directly associated with roosting habitat, but are associated with foraging and drinking habitats, can include freshwater courses, marshes, ponds, edge habitat, and other types of wetlands or water bodies. Table 1 suggests additional and species-specific habitat characteristics that may be considered, but local scientific literature and bat experts should be consulted to inform regional applicability of such criteria to the model. While it may be tempting to include as many landscape variables into a habitat suitability model as an expert panel can think of, confounding factors need to be recognized and eliminated. Variables with poor predictive power should be excluded, and only the primary, high value variables for predicting roosting habitat use should be selected. Bellamy et al. (2013) found that the best models have few variables, making them easier to interpret and use in conservation planning. The principle of parsimony, the scientific principle that the simplest way or explanation is the best one, is a valuable guideline, but the optimal number of variables in a model should be chosen with the complexity of the species' habitat needs as a deciding factor (Coelho et al 2018; Stoica and Söderström 1982).

Notes on quantitative habitat suitability assessments

Quantitative means, using presence data collected in the field, may be the gold standard of conducting habitat suitability assessments. While we do not go into detail on how to conduct such habitat suitability assessments, below are a few notes with relevant references for those interested in pursuing this method.

Habitat suitability modeling can help identify the most influential environmental variables that explain species occurrence and abundance and predict species distribution in relation to biotic and abiotic variables (Fonderflick et al. 2015). While the use of generalized linear models can provide good results for data-rich species, model types that incorporate presence-only data are better used for data-poor species like some endangered bats (Fonderflick et al. 2015; Wisz et al. 2008).

Presence data can be acquired in different ways. Location data can be collected by directly recording species' locations using acoustic detection, trapping, or radio tracking, including using archival data centre records or research data that already exists. Lausen et al. (2025) provides extensive guidance for conducting bat surveys to locate roosts, covering topics such as bat ecology, acoustic surveys, bat captures, roost inspections, colony counts, and data collection. Bellamy and Altringham (2015) tested habitat suitability modelling to predict roost habitat suitability for multiple bat species with historical capture records and acoustic data from bat roosts, generating roosting habitat suitability models with a useful level of accuracy. When using historical data, species records should be carefully selected to counteract potential sampling bias, using only high-confidence species identifications and locations (Bellamy and Altringham 2015). Note that acoustic detection of bats alone does not typically confirm use of habitat as maternity roosts and this method is not always suitable for measuring the true value of a habitat component because it doesn't provide information on sex, age, or specific habitat use, and is often limited by landscape and bat species-specific characteristics.

Trapping and radio tracking of reproductive bats to their roost can confirm maternity roost locations which can be put in the context of the surrounding habitat through habitat suitability modelling, but the use of such invasive techniques needs to be weighed against the value of the data collected (Patriquin 2023). Karsk (2021) used radio telemetry to collect location data of northern myotis roosts and identify the environmental variables most important at a forest stand scale.

Bellamy and Altringham (2015) provide an online toolkit for bat roost habitat suitability modelling, accessible at: http://www.arcgis.com/home/item.html?id=e406a43e6ba84512aaeaff3fb7c59ef2.

Absence data can strengthen habitat suitability models, but such data are not always available or reliable, as lack of detection does not always mean true absence, especially with rare, elusive, or otherwise hard to detect species. Instead of absence data, background data can be used to compare observed used habitat to available habitat. If absence data is required but cannot be obtained, background data can be generated in place of absence data, allowing for a presence-only modelling approach to map distribution of potentially suitable bat maternity roost habitat (Fuller et al. 2018). Background data can be generated as random points on a map, where the assumption is made that the species is not randomly distributed across the landscape. Background data should be generated specific to maternity roost habitat use, as bat species may be present in habitats unsuitable for maternity roosts outside of the maternity roosting season. See Fuller et al. 2018 for additional information on presence-only modelling with background data.

Ground-truthing

Ground-truthing to test the validity of the model is an optional but recommended step that can be taken after the habitat suitability model is completed. Ground-truthing is particularly recommended when there is a high uncertainty around habitat components that are predictive of maternity roost habitat, which is especially true in those cases of data-poor species or data-poor ranges of species. Ground-truthing techniques are similar to those used to generate presence data and are subject to the same limitations. Radio tracking or other visual confirmation of reproductive female bats is required to specifically confirm the presence of maternity roost (O'Malley et al. 2023). Alternatively, acoustic monitoring can be done to confirm bat species presence in the habitat, but this method provides no confirmation of bat reproductive status. O'Malley et al. (2023) conducted spatially balanced acoustic monitoring for bat species presence and verified these data with radio tracking at highest activity sites to show that the number of bat passes within an hour of sunset is the best predictor of occupied bat roost in the area. In this study, at least one acoustic detector had to record four or more barbastelle bat passes within the first hour after sunset to identify a woodland as likely to contain a colony of barbastelle bats. However, the authors caution due to species-specific variation in detection probability, these parameters may need to be modified (O'Malley et al. 2023).

Ground-truthing may be difficult, especially when the target species is rare or hard to detect and capture despite being abundant. In such circumstances, ground-truthing may not yield confirmation of the target species and may not support that the habitat suitability model successfully identified suitable habitat. This stresses the importance of involving species and habitat experts when selecting the habitat components for the model and having them provide validation of the model's outcomes, including providing context to explain any inconsistencies in the model's outputs. In addition to, or in place of radio tracking and acoustic monitoring, experts can conduct visual assessments of habitats that ranked highest in the habitat suitability model to identify potential roosting sites and use their expertise to qualitatively validate the model output. While this does not typically confirm bat presence or reproductive activity of bats, experts can provide valuable insights on the perceived quality and suitability of the habitat selected by the model.

When resources are limited or chances of conducting successful ground-truthing are considered low, wildlife managers can opt to forego ground-truthing and base their decisions on the habitat suitability index alone with the recognition of the uncertainty that is created in such circumstances.

Additional considerations

Cost-benefit:

Wildlife managers need to weigh the cost and benefits of the methods they use to achieve their mandate in delivery of their program's goals and objectives. A habitat suitability assessment based on expert knowledge is a rapid-assessment that, in many cases, does not require additional field-data confirmation. As such, this method requires relatively few resources and relatively little time to gather the necessary evidence-based knowledge and requires little time. As described above, conducting ground-truthing activities such as acoustic monitoring or radio-tracking can considerably increase the time requirements and resource costs, and may or may not result in increased confidence in the habitat suitability assessment results. Based on the biology of bat species, bat experts can help to advise

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whether ground-truthing and the use of the associated additional resources are likely to provide results that will lead to increased confidence in the wildlife management decision making process.

Temporal habitat change:
Temporal habitat change needs to be considered when using previously collected data for habitat suitability modelling (Fuller et al. 2018). Bats may have preferentially used a certain habitat in the past due to biotic and abiotic components that were present at that time, but the habitat may have changed drastically since the historical data collection occurred (e.g., natural disturbances such as hurricanes). Similarly, temporal habitat change may have occurred since jurisdictional mapping data was last updated. Ensure habitat modeling is done with the most recent knowledge on species occurrence, as well as up to date landscape data layers and account for over- or under-estimation of habitat suitability in those areas that are most prone to change. Ecological processes of forests, like past land use, forest development, fires, and pests may play a greater role in bats' selection of maternity roost areas than is currently recognized (Silvis et al. 2012). Caution should be exercised when making local management decisions based on data collected elsewhere (Poissant et al. 2010) and such extrapolation should only occur when necessary.

Multi-taxa approach:
Multi-species habitat suitability assessments can be conducted as well, but giving equal weight to all species involved prioritizes generalist species and fails to accurately represent specialist species. Models with representation proportional to the threat level of each species perform well but model outputs are skewed towards the most endangered species in the model (Rainho and Palmeirim 2013). Management targeting one species may provide benefit to co-occurring species under the principle of the umbrella species concept: a species whose conservation benefits co-occurring species and/or an occupied ecosystem (Drake et al. 2020). Drake et al. (2020) synthesised and compared roosting niche of forest-dwelling bats to provide reference for multi-species habitat management. Little brown myotis, northern myotis, big brown bat, and silver-haired bat were grouped in the roosting guild of dead tree generalists, with northern myotis being the best candidate umbrella species for this guild. Drake et al. (2020) suggest that forest management techniques that promote roosting habitat for northern myotis will also likely benefit little brown myotis and others in its guild at a broad scale. Tri-colored bat is the umbrella species of the guild of foliage roosting specialists, which also includes hoary bat and eastern red bat (Drake et al. 2020). Consider performing habitat suitability assessment modelling for best candidate umbrella species, conduct separate habitat suitability assessments for each species of interest, or account for species bias if common generalists and endangered species are included in a single assessment. Additionally, Waldien et al. (2003) reported the value of snags to western long-eared myotis as well as to other, non-bat vertebrates such as lizards, providing evidence that a multi-taxa approach to species conservation, including bat- and non-bat taxa, can be done efficiently.

Hierarchical process:
Habitat suitability modelling is a hierarchical process, meaning that the model output indicating most

suitable habitat represents the most suitable in that given area (Leblond al. 2014). 'Most suitable' may be the same as the least unsuitable and in the absence of preferred habitats, suboptimal habitats may be selected by animals (Perry and Thrill 2007). A thorough understanding of bat species' habitat needs as well as on-the-ground habitat structure and quality are required to assess whether a high relative suitability index truly represents high habitat suitability for the species. Involvement of both bat species and landscape ecology experts is pertinent to inform this process.

Artificial roosts:
Literature review by Mering and Chambers (2014) indicates that wildlife managers can use artificial roosts that mimic natural roosts to supplement natural habitat or mitigate habitat that is altered or lost for some species in temperate regions, but conservation of natural roosts should be the highest priority for bat species that do not typically use artificial roosts.

Cumulative habitat loss:
A study conducted on big brown bats using live and dead trees in a forest stand with trees of multiple age classes and stages of decay demonstrated that cumulative loss of roost trees over several years caused these bats to abandon their roosting area, occupying new roosting areas instead (Bondo et al. 2019). This result demonstrates that relatively small alterations to suitable roosting habitats over several years can eventually render such habitats unsuitable to bat species. Bondo et al. (2019) recommend maintaining live trees in a variety of age and decay classes, conducting censuses of roost trees used by bats over the long term to understand longevity of roost trees and monitor for changes in habitat quality, and assuming a loss of roost trees as low as 18% over three years to be a significant reduction in habitat quality.

Pre- and post-WNS representation:
Having an understanding of pre-WNS bat maternity roost habitat requirements is important, as post-WNS bat distribution and habitat use data may not accurately reflect the needs of healthy bat populations. Especially when identifying maternity roost habitats for endangered or elusive species, this is an important consideration when conducting post-modeling ground-truthing (Drake et al. 2020). Many habitats that previously had robust populations of bats may now have low bat populations despite being highly suitable and productive habitat for certain bat species impacted by WNS. Not identifying target bat species in high-scoring habitat does not necessarily mean that the habitat is not suitable and the model incorrect.

Table 2: Habitat components (and associated variables) to consider for use in a habitat suitability assessment. Note that this list is not all-inclusive but can serve as a starting point to determine which landscape components are important factors in predicting availability of bat maternity roost habitat. Discuss with local GIS experts to ensure that chosen habitat components are compatible with available data mapping layers.

Forest components	Rock components	Anthropogenic components	Atmospheric components	Other landscape components
• Forest age (old, mature, young) • Forest composition (deciduous, coniferous, mixed) • Tree species • Presence of emergent or veteran trees in a stand • Patch or stand size, height • Diameter at breast height (average, maximum) • Forest cover % (grasslands, tundra, open forest, closed forest) • Snag density • Canopy closure %	• Terrain ruggedness / slope / aspect • Soil / substrate (sedimentary rock, limestone, granite, etc.)	• Proximity to other potential roosting sites • Bridge type • Bat house style (rocket box, condo, size, number of chambers) • Disturbance (sound, light, urbanization, etc.) • Distance to human settlements • Sun exposure • Roads and traffic	• Temperature (seasonal average, maximum, minimum) • Precipitation (seasonal average, maximum, minimum) • Wind speed (seasonal average, maximum, minimum)	• Ecoregion • Latitude • Water features (freshwater lake, pond, river, stream, marsh, bog, etc.) • Edge habitat / linear features (forest edge, ridgeline, hedgerow, etc.) • Elevation • Habitat / patch connectivity (treed corridors, wildlife corridors, road density, agricultural lands, etc.) • Native vegetation (grassland, tame pasture, cultivated fields, etc.) • Aspect, slope

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Appendix I - Case study: Identification of Northern myotis occupancy and maternity roost habitat in PEI Forested Places

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Identifying Northern Myotis Occupancy and Maternity Roost Habitat in PEI Forested Places

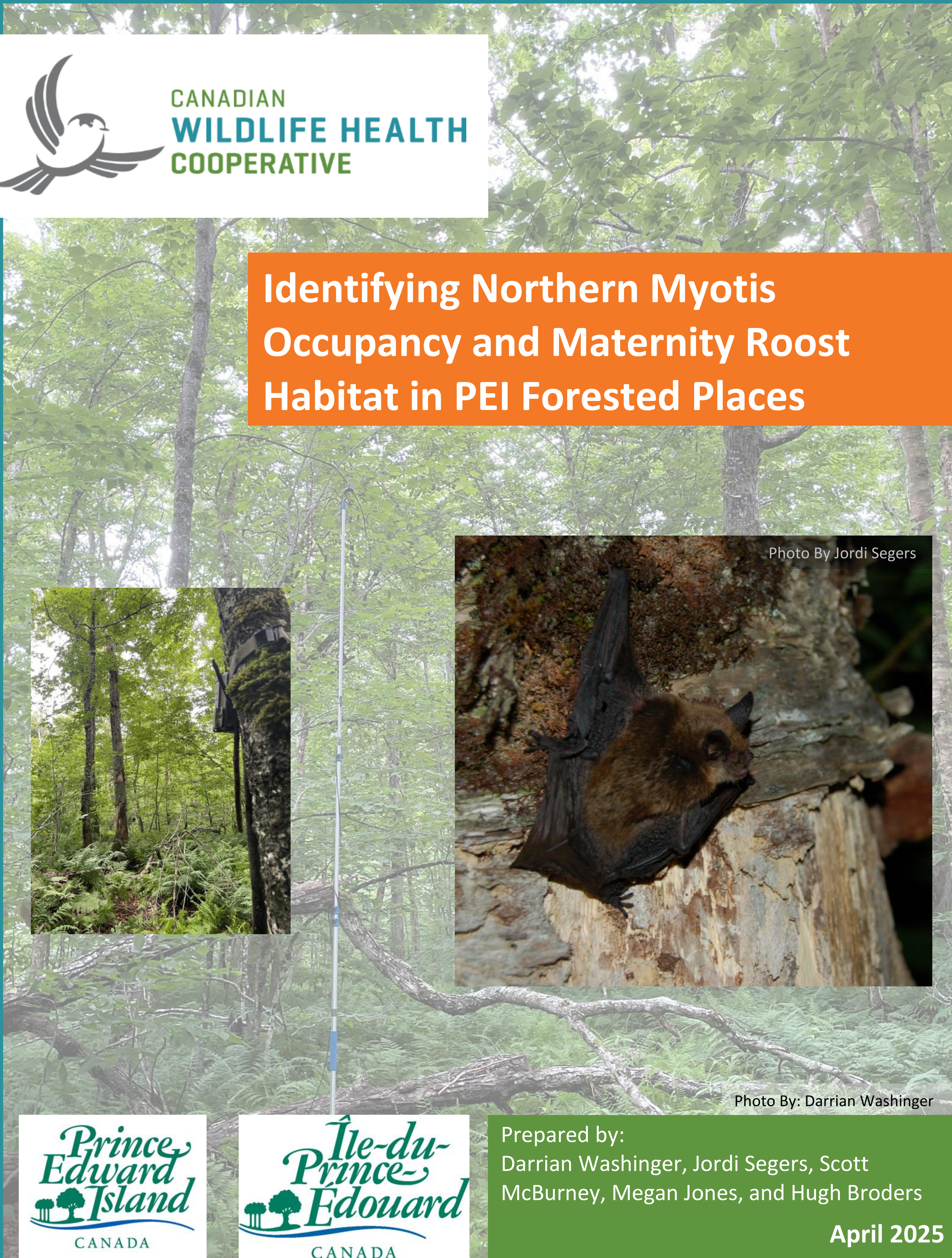

Photo By Jordi Segers

Photo By: Darrian Washinger

Prince Edward Island CANADA

Île-du-Prince-Édouard CANADA

Prepared by:
Darrian Washinger, Jordi Segers, Scott McBurney, Megan Jones, and Hugh Broders

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Species key and acoustic definitions

- **Bat call/pulse**: a single echolocation pulse emitted by a bat
- **Bat pass/sequence**: an echolocation sequence containing at least three identifiable bat calls
- **Bat activity**: a metric used to represent the number of bat passes recorded at a given site over a given time (e.g., bat passes per night). There may or may not be a relationship between bat activity and abundance.
- **Clutter**: any type of obstacle that could affect bat echolocation behaviour (e.g., trees, vegetation, structures, etc.)
- **DBH:** diameter at breast height
- **Forest stand:** a delineated community of trees that has a similar species composition, height structure, age, and size class
- **Forest patch:** a continuous composition of forest stands
- **EPFU**: Big brown bat (*Eptesicus fuscus*)
- **LANO**: Silver-haired bat (*Lasionycteris noctivagans*)
- **EPFULANO**: A common species grouping when echolocation calls for EPFU and/or LANO cannot be distinguished from one another acoustically.
- **LACI**: Hoary bat (*Lasiurus cinereus*)
- **MYLU**: Little Brown Myotis (*Myotis lucifugus*)
- **MYSE**: Northern Myotis (*Myotis septentrionalis*)
- **40kMyo**: A common species grouping for MYLU and/or MYSE when their echolocation calls cannot be distinguished from one another acoustically.
- ***Myotis* spp.**: MYLU, MYSE, and/or 40kMyo
- **LABO**: Eastern Red Bat (*Lasiurus borealis*)
- **High-frequency bat (HighF):** a bat pass with a characteristic frequency above 35kHz
- **Low-frequency bat (LowF):** a bat pass with a characteristic frequency below 35kHz
- **Noise**: any recording that did not include at least 3 bat calls

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Introduction

Prince Edward Island (PEI; the Island) is part of the Wabanaki-Acadian Forest region, a unique transition zone between the southern temperate forests and the northern boreal forests (Taylor et al. 2017). Natural Wabanaki-Acadian Forests are composed of a mixture of tolerant hardwood tree species, boreal spruce-fir forests, and mixed intermediate forest types (Loo and Ives 2003, Curley et al. 2019). Before European settlement, PEI was historically composed of nearly 98% natural forests. However, by the 20th century, PEI lost nearly 70% of its forests after decades of settlement, development, and forest conversion (Loo and Ives 2003).

Given the various natural and human disturbances, forest composition in PEI today differs from historic forests (Loo and Ives 2003). The landscape today is a patchwork of agricultural (37.6%) and forested (43.2%) landscapes (Government of PEI 2023a) with five main forest types, including upland hardwood forest, black spruce forest, wet rich woodland, white spruce forest and disturbed forest (Sobey and Glen 2004). The former three forest types are relatively similar to the pre-European settlement Wabanaki-Acadian forests; the latter two have been created due to human influence and characterize nearly half of the current forested landscape (Sobey and Glen 2004). These changes in forest composition have the potential to affect the biodiversity of both flora and fauna communities. Most mammal species requiring large blocks of undisturbed forested landscape have been extirpated (Curley et al. 2019). Therefore, the Province of PEI and Environment and Climate Change Canada (ECCC) have identified forested landscapes in PEI as one of the twelve Priority Places for Species at Risk under the Pan-Canadian Approach (ECCC 2018a, Government of Prince Edward Island 2023b).

Today, PEI forests are home to thirteen species at risk, as designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). All four bat species known to occur PEI are classified as endangered by COSEWIC and or/ ECCC: Little Brown Myotis (*Myotis lucifugus*), Northern Myotis (*Myotis septentrionalis*, ECCC 2018b), Hoary Bat (*Lasiurus cinereus*), Eastern Red Bat (*Lasiurus borealis,* ECCC 2023). The latter two species are migratory bats and are relatively uncommon in PEI. Hoary Bats were first identified on PEI in 1999 (McAlpine et al. 2002) and have been consistently detected through acoustic surveys in recent years, suggesting that while the species is likely rare, it is still present on the Island as a rare migrant (Henderson et al. 2009). Similarly, although Eastern Red Bats have not been directly observed on PEI, acoustic monitoring by various groups has detected them across different years and sites, indicating their presence, though likely in smaller numbers compared to resident species (CWHC, unpublished data; PEI watershed alliance, unpublished data).

Little Brown Myotis and Northern Myotis are resident species that were once common and abundant on PEI (Henderson et al. 2009). However, both populations have experienced significant population declines due to the emergence of white-nose syndrome (WNS) on PEI during the 2012–2013 winter. While there has been some evidence of recovering Little Brown Myotis in some northeastern United States populations, Northern Myotis populations have not seen the same signs of potential recovery (Cheng et al. 2024). Across their range, Northern

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Myotis have experienced rapid and severe population declines and have consequently been widely extirpated (Cheng et al. 2021). On PEI, capture studies conducted after the onset of WNS have failed to capture a single Northen Myotis individual (Balzar et al. 2021; Tessa McBurney, unpublished data from 2021–2022; Sepidar Golestaneh, unpublished data from 2023). This is despite increased, targeted capture efforts focused on previously documented occupied Northern Myotis habitats (Balzar et al. 2021). Consequently, regional experts are concerned about the possible extirpation of Northern Myotis in the Maritimes.

Wildlife managers and those responsible for protecting endangered species and their habitats often must make rapid decisions concerning habitat restoration and conservation for species at risk. This is often necessary despite insufficient information on local populations and their habitat use. Therefore, exploring various survey methods, depending on time and resources, can be important to help make informed decisions. One such method that can be used when considering relatively large areas is conducting a qualitative habitat suitability assessment to help identify and protect endangered species' habitats (Canadian Bat Maternity Roost Protection Working Group 2024). Various types of habitat assessments have been used to prioritize conservation areas (Allen et al. 1987, Snaith et al. 2002, MacMillan and Marshall 2006, Leblond et al. 2014, Crawford et al. 2020), often in conjunction with other survey methods for validation. For studying bat species, acoustic monitoring can be a relatively accessible survey method to complement a habitat suitability assessment.

Acoustic surveys have gained popularity in recent years due to them being a non-invasive method for studying cryptic, nocturnal species, which can be used to study bat activity in various habitats (Frick et al. 2013). Given the technological advances in acoustic detectors and microphones, acoustic monitoring has become a widely used method to study bat populations. The North American Bat Monitoring Program (NABat) was established as a multi-national effort to monitor bats using standardized methodologies, with an emphasis on acoustic monitoring (Loeb et al. 2015). This approach has since been adopted in the Canadian Recovery Strategy for at-risk hibernating bat species (Environment and Climate Change Canada 2018). However, acoustic monitoring also has its drawbacks that should be considered, including but not limited to the inability to establish population sizes or identify individuals; the inability to determine sex or age, interspecific variation in echolocation calls; and the difficulty distinguishing species with overlapping echolocation characteristics. Regardless, acoustic monitoring can be a helpful first step in verifying species' presence and overall activity.

Considering the low numbers of Northern Myotis and the importance of protecting their habitat, we conducted a case study to determine if we could use a habitat suitability assessment with expert elicitation to identify potential Northern Myotis roosting habitats on Prince Edward Island. We used acoustic monitoring as the first step to determine if Northern Myotis occupied the forest stands identified in the habitat suitability assessment.

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Methodology

Study Area

PEI has an area of approximately 5,620 km^2, with nearly 2,100 km^2 of natural forested landscapes sparsely distributed with agricultural fields across Prince Edward Island (Government of PEI 2023a). PEI forest stands are a mixture of boreal and temperate tree species along with disturbed and regenerating forests. Forest stand composition is made up of hardwood (38%), softwood (25%), hardwood/softwood (22%), and softwood/hardwood (15%) tree species (Government of PEI 2023a).

Habitat Suitability Assessment

To perform the habitat suitability assessment, a panel of experts was convened to identify the specific habitat components required for Northern Myotis maternity roost habitat on PEI. Given prior research conducted on PEI and the expected roosting ecology of Northern Myotis in the northeastern extent of their range (Menzel et al. 2002, Broders and Forbes 2004, Garroway and Broders 2008, Henderson et al. 2008, Henderson et al. 2009), we selected habitat components from the PEI Forestry Inventory that we predicted would best support their maternity roost requirements. We were parsimonious and chose four criteria that we believed would best predict Northern Myotis maternity roost presence on the Island: patch sizes > 15 hectares (Henderson et al. 2008), deciduous or hemlock stands (Broders and Forbes 2004, Garroway and Broders 2008, Henderson et al. 2008), number of > 30 cm DBH (Menzel et al. 2002), with a distance < 1,000 m to any freshwater feature present in the qualifying contiguous forested patch (Henderson and Broders 2008).

These criteria were then used to create a habitat suitability index, which was mapped in ArcGIS Pro (ESRI 2024) by the Government of PEI, Forests, Fish & Wildlife Division using the Forest Resource Inventory (2020). Forest stands that met the aforementioned criteria were predicted to have suitable maternity roost habitats for Northern Myotis. Suitability for maternity roosts was further assessed by assigning these forest stands relative weights based on habitat components we considered to be the most important predictors. We gave increasing weight to larger deciduous forest stands with a higher density of large-diameter trees. Consequently, forest stands were separated into five size classes and five density classes (Appendix A), which were then combined to rank each forest stand with an overall habitat score from 1–10. The highest habitat score (10) had the largest deciduous forest patch size with the highest number of >30 cm DBH trees relative to the forest patch size, therefore giving an estimate of the most suitable maternity roost habitats for Northern Myotis on PEI (https://peigov.maps.arcgis.com/apps/instant/basic/index.html?appid=ae1a28f2203a40b8ad87e75ac1941ee8). As the majority (85%) of PEI forests today are privately owned, the results of the habitat suitability maps were further refined to prioritize those suitable roosting sites situated on public lands and/or private lands with landowner permissions.

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While technological advancements have greatly enhanced the ability to measure forest variables for forest management (e.g., LiDAR), ground-truthing remains essential to ensure that the habitat suitability assessment accurately reflects the actual conditions of what is considered suitable habitat. This is especially important given that PEI was impacted by high wind speeds associated with Post-Tropical Storm Fiona on 24 September 2022, which led to significant damage to the Island's forest structure, primarily due to blowdowns (Government of PEI 2024). The Government of PEI used satellite imagery from the months following Post-Tropical Storm Fiona to identify forested areas affected and found that 9.4% of forests were affected by the high wind speeds, meaning >70% of the trees were blown down in those areas (Government of PEI 2023b, Government of PEI 2024). All forest cover types were affected by the storm, but hardwood-dominated stands were slightly more impacted than softwood-dominated stands because Fiona hit when PEI's hardwood tree species were in full leaf, resulting in proportionately higher impacts compared to needle-leaved conifers (Government of PEI 2024).

Site Selection

We surveyed 7 forest patches that were accessible and contained forest stands that were highly ranked based on the habitat suitability assessment (Figure 1, Figure 2, Table 1, Table 2). At each forest patch, we ground-truthed to confirm the presence of flyways, potential roost trees, and the overall forest characteristics that we considered suitable roosting habitats for Northern Myotis.

Within each forest patch, we selected two sites to deploy acoustic detectors and trail cameras. These sites were chosen in forest stands with high habitat scores and in areas predicted to have suitable maternity roost habitats for Northern Myotis. Specifically, we focused on areas with a higher proportion of potential roost trees, such as large DBH trees or snags (standing dead trees) that had cracks, crevices, or exfoliating bark that were free from obstruction by nearby vegetation. These trees needed to be large enough to accommodate a maternity colony while still providing protection from predators. Since Northern Myotis are known to frequently switch roosts (Menzel et al. 2002, Thorne et al. 2021), we selected sites with a higher density of potential roost trees to facilitate roost switching. Other factors prioritized when choosing potential roosting areas includeed microsites with a high proportion of deciduous trees or hemlock trees, relatively tall crack/crevice/bark from the ground, and areas with increased solar exposure. At each site (n=14), we deployed one acoustic detector and one trail camera nearby. Sites were a minimum of 75m apart (min–max: 87.5 – 189.0m; mean: 126.8m).

Acoustic Monitoring

Acoustic detectors were deployed from 14 June to 19 Aug, 2024 (Table 1) in highly-ranked forest stands based on our habitat suitability assessment. While we cannot determine the sex of a bat recorded during acoustic monitoring, we attempted to target adult females by choosing sites with suitable habitat characteristics for maternity colonies during a time period when

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female Northern Myotis are mostly likely to aggregate. At all but two sites, acoustic detectors were deployed before mid-July, when the parturition date for Northern Myotis is expected in the region (~20 July, Broders et al. 2006). We surveyed sites for a minimum of four nights with ideal weather conditions: no sustained rainfall, >10°C, low wind speeds (~<15 km/h), and no fog. Detectors were set to record 30 minutes prior to sunset until 30 minutes after sunrise, using detector settings recommended in McBurney and Segers 2021 (3.3.1 SM4Bat Detector Set-up for Stationary Point Surveys).

At each site, one SM4BAT-FS with a hemi-directional SMM-U2 microphone (Wildlife Acoustics, Concord, MA, USA; www.wildlifeacoustics.com) was deployed at a 0° vertical angle (parallel to the ground) at approximately 5m from the ground using telescopic poles. The poles were affixed to vegetation and the microphone was situated in areas with a relatively more open midstory and the least amount of vegetative clutter in an attempt to capture echolocation calls that were less affected by clutter variables. The microphone was aimed in the direction with the highest number of potential roost trees.

Trail Cameras

Trail cameras were used in conjunction with acoustic detectors in an effort to determine if it was feasible to confirm roost trees by recording bats flying into and out of identified potential roost trees. We deployed one Bushnell CORE S-4K no glow trail camera (model #119949C) at each site near (≤20m) the acoustic detector. The trail camera was set to night mode so that it only recorded videos during the nighttime. We used settings (Appendix B) to maximize the chances of capturing fast-moving animals such as bats in low/no light. The trail camera was affixed to a tree between 1.5 – 3.5 m above the ground. At most sites (12 out of 14), the trail camera was focused on an entry/exit point on a potential roost tree; at the remaining two sites, the trail camera was aimed towards the space between several different roost trees to maximize the chances of capturing free-flying bats on video (Table 3).

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Table 1. Survey information for locations where SM4BAT acoustic detectors with SMM-U2 microphones and Bushnell CORE S-4K no glow trail cameras were deployed to survey bats.

Site Name	NABat GRTS Cell ID	County	Latitude	Longitude	Public Land FID	Public Land PID	PEI F&W Bat Metrics Field ID	Region	Start Date	End Date	Survey Nights
FLPP1-1	320457	Queens	46.2096	-63.3336	770	218925	951037	5	14-Jun	20-Jun	6
FLPP1-2	320457	Queens	46.2094	-63.3349	770	218925	951037	5	14-Jun	20-Jun	6
FLPP2-1	327185	Kings	46.4262	-62.3407	1805	114694	1810609	9	28-Jun	5-Jul	7
FLPP2-2	327185	Kings	46.4258	-62.3393	1805	114694	1810609	9	28-Jun	5-Jul	7
FLPP3-1	248524	Queens	46.0850	-62.8503	private	private	1341045	6	2-Jul	10-Jul	8
FLPP3-2	248524	Queens	46.0838	-62.8503	private	private	1341047	6	2-Jul	10-Jul	8
FLPP4-1*	327185	Kings	46.4375	-62.2333	531	539478	1860348	9	5-Jul	11-Jul	6
FLPP4-2	327185	Kings	46.4379	-62.2322	233	525212	1860341	9	5-Jul	17-Jul	12
FLPP5-1	327185	Kings	46.4166	-62.2895	535	105726	1860580	9	12-Jul	26-Jul	14
FLPP5-2*	327185	Kings	46.4161	-62.2904	535	105726	1860438	9	12-Jul	13-Jul	1
FLPP6-1	327185	Kings	46.3974	-62.2704	1918	550244	1870725	9	19-Jul	26-Jul	7
FLPP6-2	327185	Kings	46.3984	-62.2683	1918	550244	1870714	9	19-Jul	26-Jul	7
FLPP7-1	134860	Queens	46.2067	-63.0438	private	private	1150827	6	9-Aug	19-Aug	10
FLPP7-2	134860	Queens	46.2078	-63.0426	private	private	1150807	6	9-Aug	19-Aug	10

* Sites that experienced an equipment malfunction

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Table 2. Habitat information for sites where SM4BAT acoustic detectors and SMM-U2 microphones and Bushnell CORE S-4K no glow trail cameras were deployed to monitor for Northern Myotis. Forest variables were assigned using the Forest Resource Inventory from 2020, with the top 5 tree coverage types (COVER) and their respective rounded percent coverage (PER); see Corporate Landuse Inventory 2010 for more details. Habitat scores were ranked from lowest (1) to the highest (10), with the highest habitat score having the largest deciduous forest patch size with the highest number of >30 cm DBH trees relative to the forest patch size, therefore giving an estimate of the most suitable maternity roost habitats for Northern Myotis on PEI.

Site Name	COVER 1	PER 1 (%)	COVER 2	PER 2 (%)	COVER 3	PER 3 (%)	COVER 4	PER 4 (%)	COVER 5	PER 5 (%)	Height (m)	Crown Dens. (%)	Stand Area (ha)	Patch Area (ha)	LiDAR Height (m)	Count of >30cm DBH Trees	Count of Trees	Average max. DBH	Size Score	Density Score	Habitat Score
FLPP1-1	RM	50	YB	30	SM	20		0		0	19	90	9.9	79.8	20.2	18.1	180.0	32.6	5	5	10
FLPP1-2	RM	50	YB	30	SM	20		0		0	19	90	9.9	79.8	20.2	18.1	180.0	32.6	5	5	10
FLPP2-1	RM	40	SM	30	YB	20	BE	10		0	19	90	17.6	132.3	19.3	21.2	372.0	33.4	5	5	**10***
FLPP2-2	RM	40	SM	30	YB	20	BE	10		0	19	90	17.6	132.3	19.3	21.2	372.0	33.4	5	5	**10***
FLPP3-1	RM	50	SM	20	WB	10	YB	10	HE	10	20	0	13.7	250.5	19.5	20.8	286.0	33.2	5	5	**10***
FLPP3-2	RM	50	HE	20	YB	20	BF	10		0	18	0	3.1	250.5	20.3	-	-	-	-	-	-
FLPP4-1	RM	40	SM	30	BE	10	YB	10	WB	10	19	85	18.5	106.2	18.2	12.4	229.0	31.8	5	5	10
FLPP4-2	RM	40	WB	20	SM	20	BF	10	BE	10	17	85	7.6	106.2	18.2	12.2	93.0	31.9	5	5	10
FLPP5-1	SM	40	RM	30	YB	20	BF	10		0	19	85	13.2	286.0	19.2	18.2	241.0	32.3	5	5	10
FLPP5-2	SM	40	RM	30	YB	20	WB	10		0	20	90	16.8	286.0	20.7	23.7	398.0	33.6	5	5	**10***
FLPP6-1	RM	40	YB	20	SM	20	WB	20		0	18	95	13.4	46.6	17.7	8.3	112.0	32.0	5	5	10
FLPP6-2	SM	50	RM	20	YB	20	WB	10		0	20	90	6.0	46.6	20.8	22.2	133.0	33.3	5	5	10
FLPP7-1	SM	30	RM	30	WB	20	BF	10	YB	10	18	85	5.3	18.5	19.3	17.3	92.0	32.9	4	5	9
FLPP7-2	SM	60	RM	20	YB	10	BE	10		0	17	85	4.7	18.5	18.5	13.1	61.0	32.8	4	4	8

* Forest stands that ranked in the top 15%

\- N/A. Note: Hemlock stands were not initially scored in the habitat suitability assessment and thus were not given a score. Instead, they were added to habitat suitability maps to inform our site selection.

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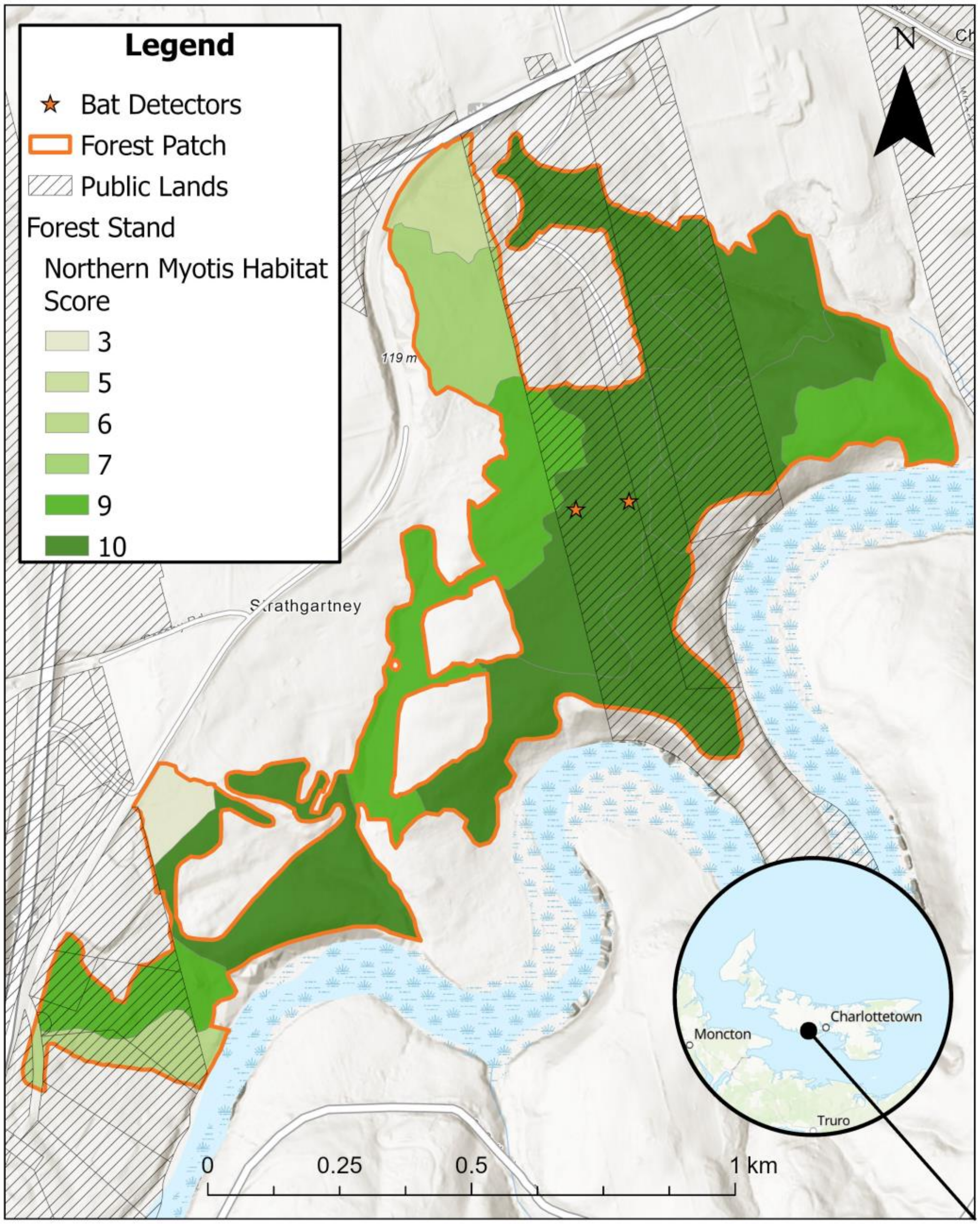

Esri, NASA, NGA, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, Esri, USGS

Figure 1. Example of a forest patch (orange outline; area: 79.8 ha) where forested stands were chosen based on the habitat suitability models. Forested stands were ranked with a habitat score (low: 1 to high: 10), indicating which stands were predicted to have higher suitability for Northern Myotis roosting habitat.

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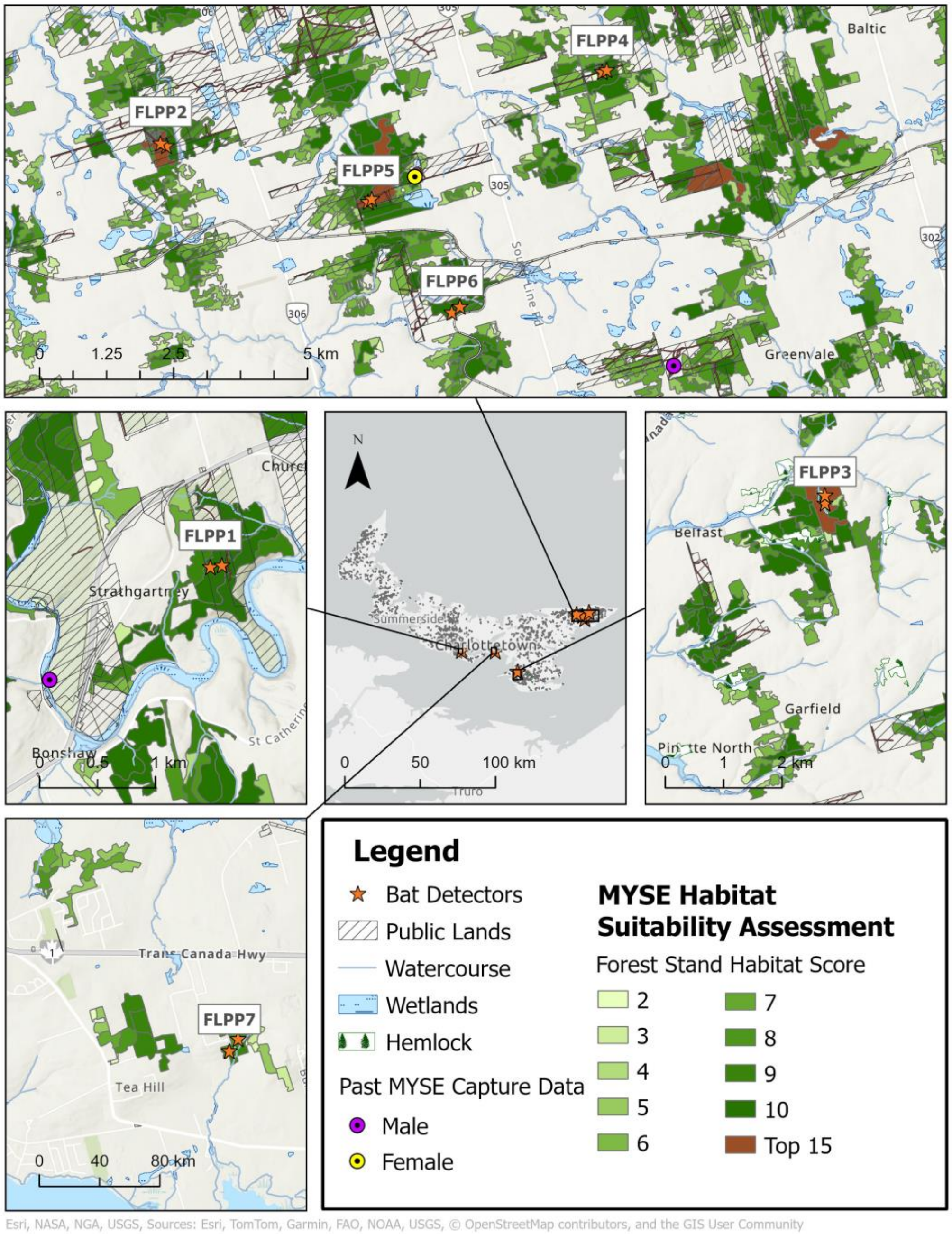

Figure 2. Forest patches where SM4BAT acoustic detectors and SMM-U2 microphones along with trail cameras were deployed in forest stands identified through the habitat suitability assessment. At each site, there was one bat detector deployed in an area with a high density of natural roosts and one trail camera focused on the entry/exit point of a potential roost tree near the detector. Also shown are results from prior Northern Myotis (MYSE) capture data (Henderson 2007).

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Manual Identifications

All recordings were first processed through Kaleidoscope Pro 5.6.8, acoustic software used to assign an Auto-ID (Appendix C). This initial process filters out potential noise files and performs statistical analysis to calculate the metrics that were subsequently used for manual identification.

There is considerable interspecies overlap between Northern Myotis and Little Brown Myotis echolocation calls, especially in structurally complex environments where all bat species will alter their echolocation calls (Broders et al. 2004). Therefore, disambiguating these two species can be very difficult, and is often impossible. Automated classifiers have also largely failed to accurately identify species with similar echolocation characteristics, such as Myotis species (Nocera et al. 2019, Roby and Jordan 2024). Therefore, we manually vetted each recording with a minimum of 3 high-quality bat calls and used the following criteria to distinguish Northern Myotis (MYSE) to species, when possible:

- Bat sequences with <12 bat calls per second (Roby and Jordan 2024)
    - Slope of 200 OPS (McBurney and Segers 2021)
    - Broadband of >75 kHz (Vesper, Ratcliffe and Dawson 2003)
    - Pulse duration <4ms (Szewczak et al. 2022), <2ms (Lausen et al. 2022)
    - Minimum frequency of ≥ 35 kHz (Hoff et al. 2024)
    - Time between calls of > 100ms (Slough et al. 2022)
- Fmax > 118kz if ≥ 12 calls per second (McBurney and Segers 2021)

Each potential MYSE sequence was then given a confidence level based on the overall quality of the recording and how well the pulses fit the above criteria. Manual identifications with a “high” degree of confidence fit within all the criteria for the majority of the sequence; “medium” fit all or most of the criteria for a slight majority of the sequence; “low” fit at least three of the criteria for less than half of the sequence, but the call quality was generally low; “very low” fit at least two of the criteria for a minimum of 3 individual pulses, but the overall call quality was low and/or was complicated with approach and terminal call phases.

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Results

Northern Myotis Roosting Habitat Suitability Assessment

Of the 245,919 hectares of forested habitat on PEI, 38,776 hectares (16%) fit the qualitative habitat suitability criteria for high quality Northern Myotis roosting habitat, and 5,084 of these hectares were on public lands. The cumulative area of these forested stands was highest in Queens County (48.4%), followed by Kings (30.8%) and Prince (20.7%) Counties, respectively. The average height of the canopy based on LiDAR data was 17.4 ± 1.8 m for all forest stands. The average number of trees per stand was 40.1 ± 41.3, with an average maximum DBH for all forest stands of 32.5 ± 1.29 cm.

There were 9,683 unique forest stands identified, with less than 30% ranked as the top three highest habitat scores: 886 ranked as a 10 (9.15%), 913 ranked as a 9 (9.43%), and 1,015 ranked as an 8 (10.48%). The top three coverage types of stands identified through the habitat suitability assessment were composed of primarily red maple (*Acer rubrum*, 65%), sugar maple (*Acer saccharum*, 18%), or poplar (*Populus sp.*, 11%); the secondary coverage types included red maple (23%), white birch (*Betula papyrifera*, 22%), and sugar maple (17%). The average crown height based on LiDAR imagery was 17 ± 1.8 m. Over 90% of stands with a classified development stage were young (n=2,730; 28.2%) or mature (n= 6,436; 66.5%), and <1% of stands were classified as old-growth (n=67; 0.7%).

Surveyed Sites

During our ground-truthing process, we visited 37 unique forest stands (Appendix C, Appendix D). Of these forest stands, 17 were determined to be of insufficient quality to survey. These stands were heavily affected by windfall caused by Post-Tropical Storm Fiona and/or did not meet the high-quality habitat components that we expected based on the habitat suitability assessment. The remaining 20 forest stands were all in forest patches in which we ultimately deployed detectors and trail cameras.

We surveyed 14 independent sites from 7 distinct forest patches across PEI (Figure 2, Appendix E1-7). All but three sites (n=11) had a habitat suitability score of 10; of which, 4 were ranked in the top 15% of forest stands predicted to be the best Northern Myotis maternity roost habitat (Table 2). One site was located in a hemlock stand, which was not ranked during the habitat suitability assessment. The remaining two sites were located in a forest patch that was added at the end of the survey period after getting private landowner land access; the forest stands within this forest patch had habitat scores of 9 and 8, respectively. All surveyed sites were in mature forest stands, with red maple or sugar maple as the dominant species coverage. There was also a high proportion of yellow birch and white birch coverage at each site. Two sites were selected in stands with eastern hemlock (*Tsuga canadensis*) as one of the top 5 dominant tree species.

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For surveyed sites, the average crown coverage was 75.7 ± 32.2% and crown height based on LiDAR was 19.4 ± 1.0m. The average area of the forest stands was 11.2 ± 5.3 ha and the average area of the forest patches these stands were situated within was 122.3 ± 94.6 ha. The average number of trees per hectare was 17.4 ± 4.6, and the largest trees within these stands had an average max DBH of 32.7 ± 0.6 cm.

Trail Cameras

There were 272 videos recorded across all sites and recording nights (Appendix F). We omitted any videos that were recorded during set up or tear down (n=52). All but two of the remaining 220 videos (Table 3) were nearly all triggered by something in the environment, such as moving leaves, wind, rain, insects, etc. There were no videos recorded from 9 sites. Of the 5 sites that recorded videos, the majority (94%, n = 206) of videos were recorded at a single site with substantial vegetation in the camera's field of view, thus artificially triggering it considerably more frequently than other sites (Appendix F). There were very few videos outside of this site, with 4 sites recording 2 videos and 1 site recording 8 videos. All but 2 of these videos were likely triggered by something in the environment other than bats.

There were only 3 videos where an animal could be identified (Figure 3): 2 rodents and 1 Northern flying squirrel (*Glaucomys sabrinus*, Figure 3C). While it is impossible to ascertain colours in infrared videos, there appeared to be a dark strip of fur running along the back of the rodent, which suggests a deer mouse (*Peromyscus maniculatus*, Figure 3A). The other small mammal had a long, pointed snout, which suggests a *Sorex* sp. (Figure 3B); given the length of tail (~70-80% of the length of the head and body) and known populations in PEI, it is possibly a Masked Shrew (*Sorex cinereus*, Curley et al. 2019). Both the rodent and shrew appear to be the trigger for the trail camera; conversely, the video of the flying squirrel was likely triggered by something in the environment rather than the actual animal. Additionally, there were 8 videos, all of which were recorded from the site with most videos (FLPP 1-2), showing a fast-moving object that could not be precisely identified, and thus could possibly have been a free-flying bat. In all of these cases, the camera was likely triggered by something else in the environment other than the object of interest. Given the low resolution of these objects and how quickly they moved through the field of view, we cannot confidently identify what kind of object it is, let alone distinguish if it was a bat. Therefore, we are not confident these trail cameras had a trigger speed fast enough to capture free-flying bats where they could accurately be identified as such.

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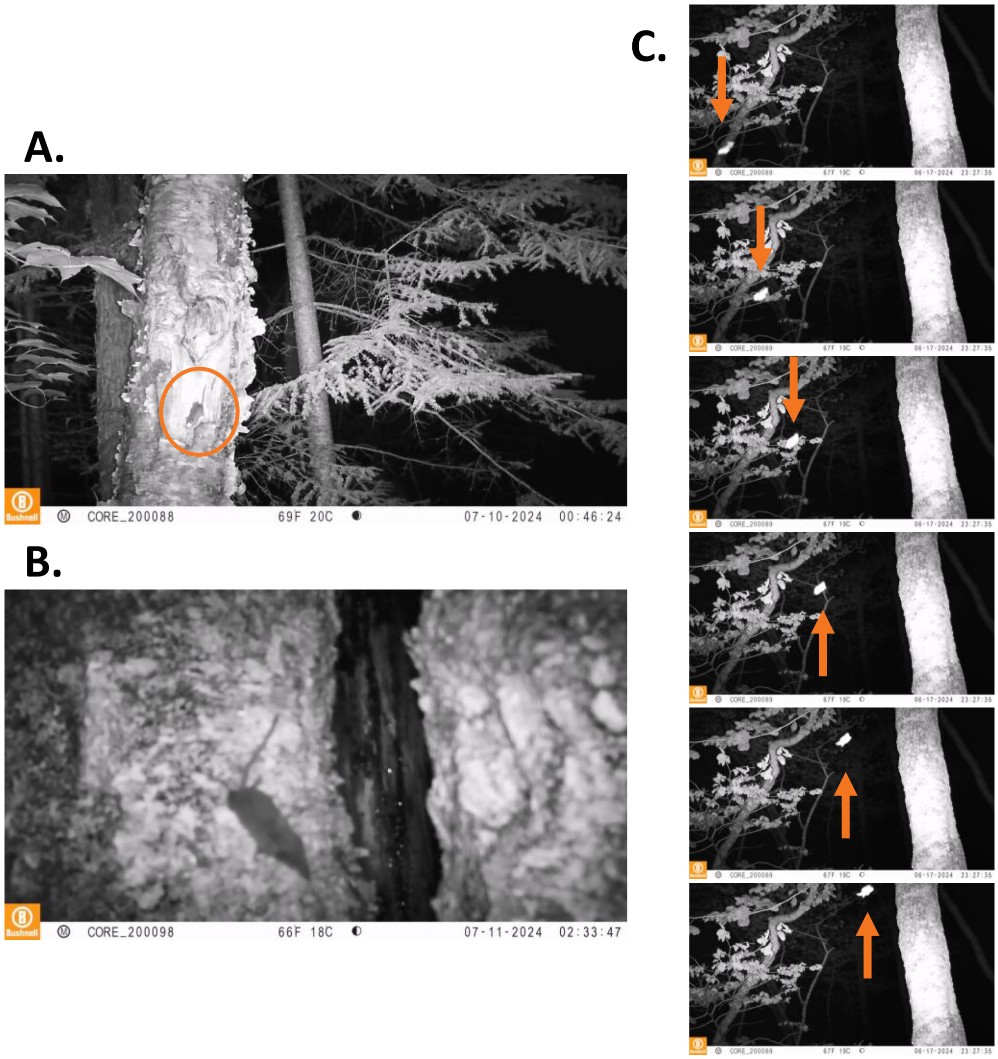

Figure 3. Still frames from videos recorded by the Bushnell CORE S-4K no glow trail cameras that were deployed at three sites. **A**) Rodent (potentially a Deer Mouse, *Peromyscus maniculatus*) recorded at site FLPP 3-1 on 10 July. **B**) Shrew (potentially a Masked Shrew, *Sorex cinereus*) recorded at FLPP 4-2 on 11 July. **C)** Several stills from a video of a Northern flying squirrel (*Glaucomys sabrinus*) captured at site FLPP 1-2 on 17 June.

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Table 3. Information for the Bushnell CORE S-4K no glow trail cameras. Trail camera angle is measured with 0° as parallel to the ground and positive values are above horizon. The total videos recorded did not include those accidentally recorded during set up/ tear down. Nearly all the triggers were likely activated by something in the environment, but if an animal triggered the camera, the number of videos that resulted is indicated in parenthesis. The potential bat videos are those videos where a moving object could not be identified and therefore a bat could not be ruled out. Given the low resolution of these objects and how quickly they moved through the field of view, we cannot confidently identify what kind of object it is, let alone distinguish if it was a bat. Any animals that were able to be identified are given in the last column.

Site	Trail Camera Model #	Trail Cam Height m (ft)	Trail Cam Direction	Trail Cam Angle (°)	Trail Cam Focus	Videos Recorded	Bats Recorded	Potential Bat Video	Animal Recorded
FLPP 1-1	200098	3.05 (10')	E 80°	0	Open space between potential roost trees	0	0	0	
FLPP 1-2	200089	3.35 (11')	NW 320°	20-30	Cavity and crack in snag	206	0	8	flying squirrel
FLPP 2-1	200098	3.35 (11')	S 180°	5	Crack in a live beech tree	0	0	0	
FLPP 2-2	200089	1.52 (5')	SE 150°	40	Large crack in a live red maple tree	0	0	0	
FLPP 3-1	200088	1.83 (6')	N 20°	10	Cavity in a white birch	8 (1)	0	0	rodent
FLPP 3-2	200090	2.13 (7')	NE 40°	10	Open space between hemlock trees	0	0	0	
FLPP 4-1	200089	3.05 (10')	E 90°	0	Crack in snag	0	0	0	
FLPP 4-2	200098	2.44 (8')	W 270°	5-10	Hole in live maple tree	2 (1)	0	0	shrew
FLPP 5-1	200088	1.68 (5.5')	S 200°	30	Whole snag (holes, cracks, exfoliating bark)	0	0	0	
FLPP 5-2	200090	2.74 (9')	W 280°	10	Cavity in a snag (leaning)	2	0	0	
FLPP 6-1	200089	3.05 (10')	SW 250°	0	Snag with a lot of cracks/cavities	0	0	0	
FLPP 6-2	200098	1.52 (5')	N 10°	0	Crack in a snag	0	0	0	
FLPP 7-1	200098	2.13 (7')	SE 130°	40	Cavity and exfoliating bark of a snag	0	0	0	
FLPP 7-2	200089	3.05 (10')	SW 230°	0	Woodpecker hole in a snag	2	0	0	

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Equipment Malfunctions

There were two sites (FLPP4-1 and FLPP5-2) with equipment malfunctions. At these sites, there was a “DIRTY” SD card error message. The SM4BAT detectors will mark an SD card as “DIRTY” if there are sufficient errors being reported; consequently, the detector will stop attempting to use that SD card to prevent possible data loss or corruption. When this occurs that card can no longer be used until the “DIRTY” state is resolved. Unfortunately, neither detector recorded a “.sm4dump” file, which would have given the Wildlife Acoustics technical support team more diagnostic insight as to what errors were being reported by the detector. Nevertheless, the underlying issue could not be determined or resolved after a lengthy troubleshooting process with the Wildlife Acoustics technical support team. While the most common cause of “DIRTY” SD cards is when the detector’s power source falls below the minimum recommended operating voltage, neither detector fell below the cutoff of 3.8 V (FLPP 4-1 voltage at the time of error: 5.6V; FLPP 5-2: 6.5 V). Therefore, the top hypothesis and thus recommendation is to change the internal battery every 3 years and make sure two SD cards are deployed with each detector. By installing two SD cards, the detector would continue to record on the second SD card, therefore the dump file would have been written for diagnostics.

At site FLPP4-1, the detector (Serial #: S4U15014) recorded from 5 July until 11 July at 3:49 AM and recorded 2,673 recordings; however, there was considerable rain during this period, so the survey does not fully represent unbiased bat activity at this site. Similarly, at FLPP5-2, the detector (Serial #: S4U15028) recorded from 12 July until 13 July at 1:05 AM before the detector stopped recording and therefore should be considered incomplete.

Species Detected

There were 15,662 recordings across all sites and the 109 nights surveyed (Appendix G). The vast majority of the recordings (91%, n=14,211) were classified as noise (any recording that was not a bat). There were 1,451 (9%) identified as bat passes and all but 12 recordings were identified as high-frequency bat species.

Nearly all recorded bat passes were identified as high-frequency species (n=1,439). Approximately 94% of high-frequency bat passes were identified to the species group 40kMyo (n=1,326). The two myotis species, MYLU and MYSE, have overlapping echolocation characteristics, making it difficult, often impossible, to distinguish between the two species. There were no recordings that fit the echolocation characteristics needed to confidently identify MYLU: consistent minimum frequency, characteristic frequency between 35 and 45 kHz, and slope between 50 and 80 OPS. Of the remaining 113 bat passes, we were able to identify 27 potential MYSE recordings based on the aforementioned criteria, with varying levels of confidence: 1 with high confidence (Figure 4), 3 with medium/high confidence, 3 with medium confidence, 10 with low confidence, and 10 with very low confidence. The rest of the high-frequency bat passes (n = 86) were not of sufficient acoustic quality to identify to species-level or species-group with confidence and thus were identified as HighF. There were not any recordings that fit the echolocation characteristics of LABO.

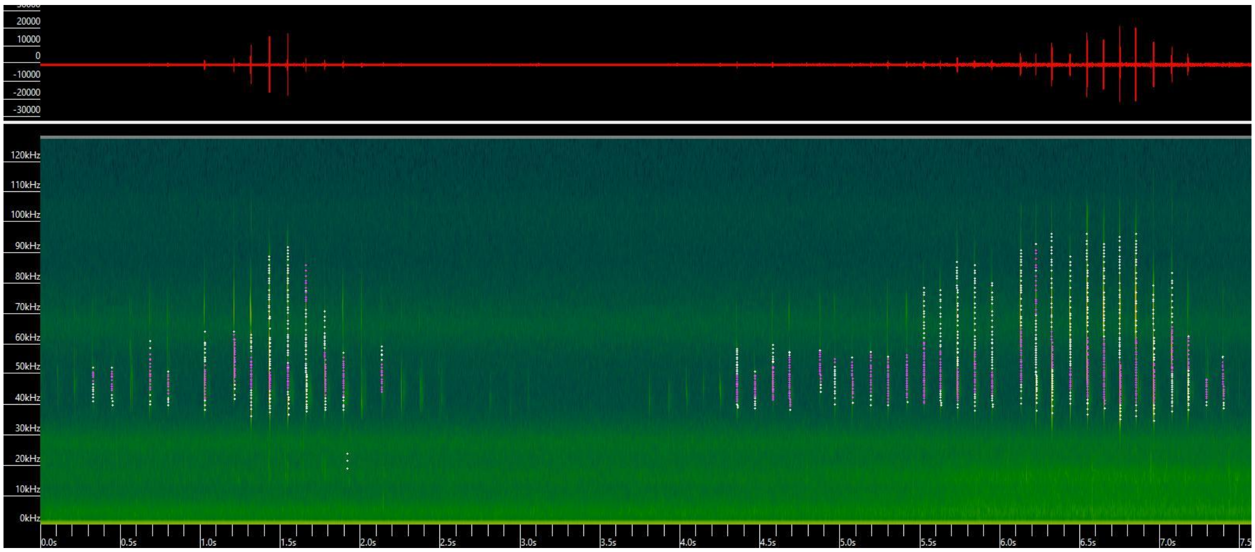

Figure 4. Spectrogram of a potential Northern Myotis (*Myotis septentrionalis*) with a high degree of confidence. The following criteria were met: time between bat calls are ≥ 100 ms, <12 calls per second, characteristic slope > 200 OPS, broadband ≥75kHz (partial, in full spectrum), pulse duration < 4ms, and minimum frequency > 35 kHz.

The were also 12 recordings identified as low-frequency bat species, all of which were quiet and/or of low quality, making species-level identifications difficult, with the exception of LACI, which has characteristic undulation of the minimum frequency. Four bat passes were identified as LACI, 2 as EPFULANO and the remaining 6 passes were not of sufficient acoustic quality to identify to species-level or species-group with confidence and were therefore identified as LowF. Of the 6 LowF bat passes, 3 also had subtle undulation, which may suggest LACI, but the recording quality was too low to be confident in a species-level identification. The overlapping echolocation characteristics of EPFU and LANO make it difficult to distinguish between the two species, which often results in the EPFULANO species-group identifications. Notably, one of the recordings classified as EPFULANO had call characteristics more indicative of LANO: a consistent minimum frequency, characteristic frequency around 26 kHz, and a characteristic slope lower than 15 OPS. This recording met the criteria of LANO with a medium-level confidence; however, there were only ~2 higher-quality bat calls within the recording and no other recordings to increase confidence. Thus, we conservatively identified it as EPFULANO.

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Table 4. Manual identifications for recordings collected during a stationary acoustic survey. At each site, an SM4BAT acoustic detector and SMM-U2 microphones were deployed for a minimum of four nights. Each recording was then manually identified to species-group, or species, when possible. For recordings manually identified as potentially Northern Myotis (MYSE), with various degrees of confidence: high, medium/high, medium, low, or very low. Recordings with low quality bat pulses could only be identified to species-group, but if there was some evidence of a particular species, that species is given in parenthesis.

	High-frequency Bats												
			Potential MYSE					Low-frequency Bats					
Site	**HighF**	**40kMyo**	**high**	**medium/high**	**medium**	**low**	**very low**	**EPFULANO**	**EPFULANO (LANO)**	**LACI**	**LowF**	**LowF (LACI)**	**Total**
FLPP 1-1	44	506				4	2		1				**557**
FLPP 1-2	5	515		1		1	1						**523**
FLPP 2-1		8											**8**
FLPP 2-2		1											**1**
FLPP 3-1		12				1					1		**14**
FLPP 3-2		8										1	**9**
FLPP 4-1		9											**9***
FLPP 4-2		10											**10**
FLPP 5-1	2	4					1						**7**
FLPP 5-2													**0***
FLPP 6-1	2	3											**5**
FLPP 6-2	1	41				1							**43**
FLPP 7-1	17	164	1	2	3	2	6			2	2	2	**201**
FLPP 7-2	15	45				1		1		2			**64**
Total	**86**	**1,326**	**1**	**3**	**3**	**10**	**10**	**1**	**1**	**4**	**3**	**3**	**1,451**

* Sites with equipment malfunctions

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Bat Activity per Night

There was a wide variability in the average number of bat passes per survey night, with an overall average of 13.20 ± 41.27 (mean ± standard deviation) across all sites (Figure 5). The forest patch with the highest bat activity (FLPP1) had an average of 92.6 ± 86.72 bat passes per survey night at FLPP1-1 and 87.17 ± 109.67 at FLPP1-2. The second most active forest patch (FLPP7) had an average of 20.1 ± 15.8 bat passes per survey night at FLPP7-1 and 6.4 ± 4.4 at FLPP7-2. All other sites had an average of 1.38 ± 4.38 bat passes per survey night.

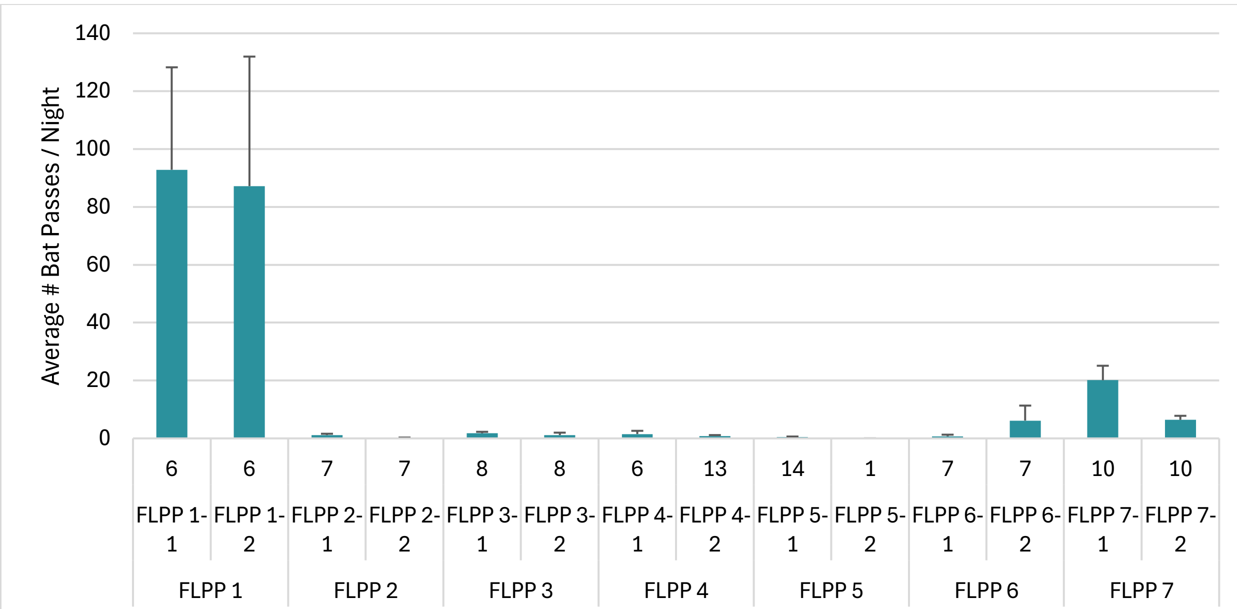

Figure 5. Average number of bat passes per survey night during the survey period between June and August. Positive standard error bars are shown. The x-axis from top to bottom indicates: number of survey nights conducted, site ID, and patch ID.

On average, average bat activity was widely variable throughout the night, but had the highest average bat activity between 2:00 (3.08 ± 13.90) and 3:00 (3.13 ± 15.48) across all sites (Figure 6). June surveys were skewed by the overall high activity at FLPP1 (Figure 7A), which had the highest peak average bat activity in the middle of the survey night, between 2:00–3:00. July surveys (FLPP2–FLPP6) were variable at each forest patch, with no obvious trends (Figure 7B), with the exception of FLPP 6-2, which had a peak activity near the beginning of the survey: 22:00 (two hours after sunset). The August survey (FLPP7-1) had a slightly higher average bat activity towards the end of the survey period (4:00).

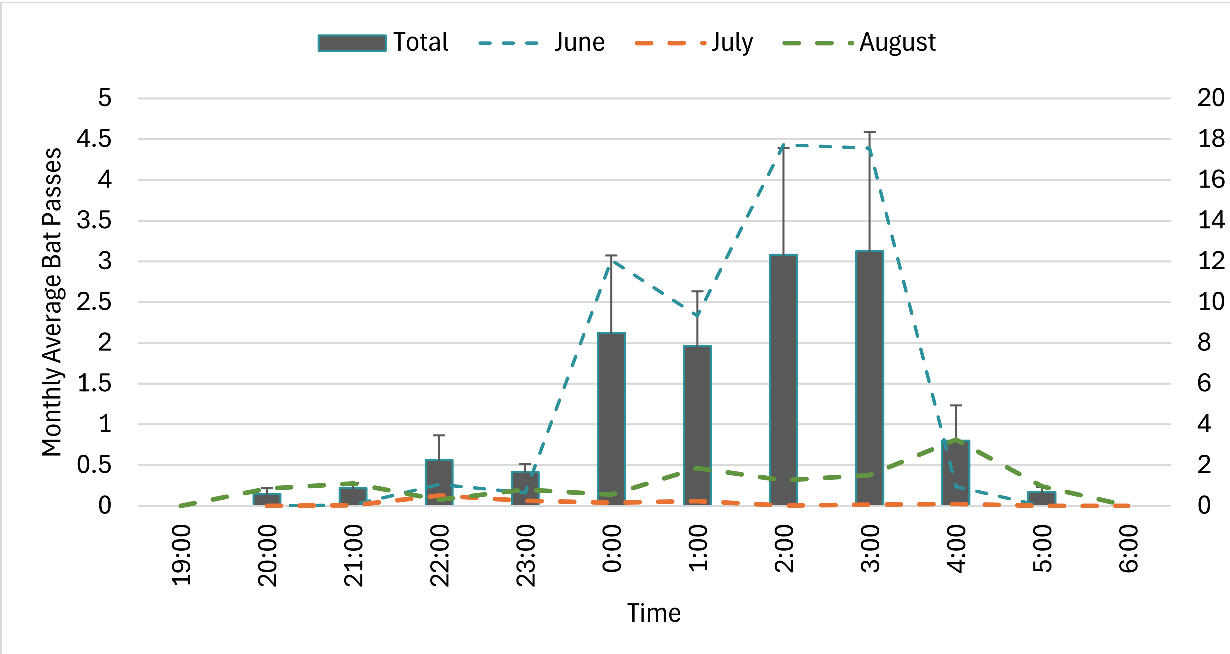

Figure 6. The average number of bat passes recorded per hour during acoustic surveys across the survey period from June to August. The bars show the total average bat activity per hour plus positive standard error bars and correspond with the primary y-axis (left). Dashed lines show the average bat passes per hour for each month surveyed and correspond with the secondary y-axis (right).

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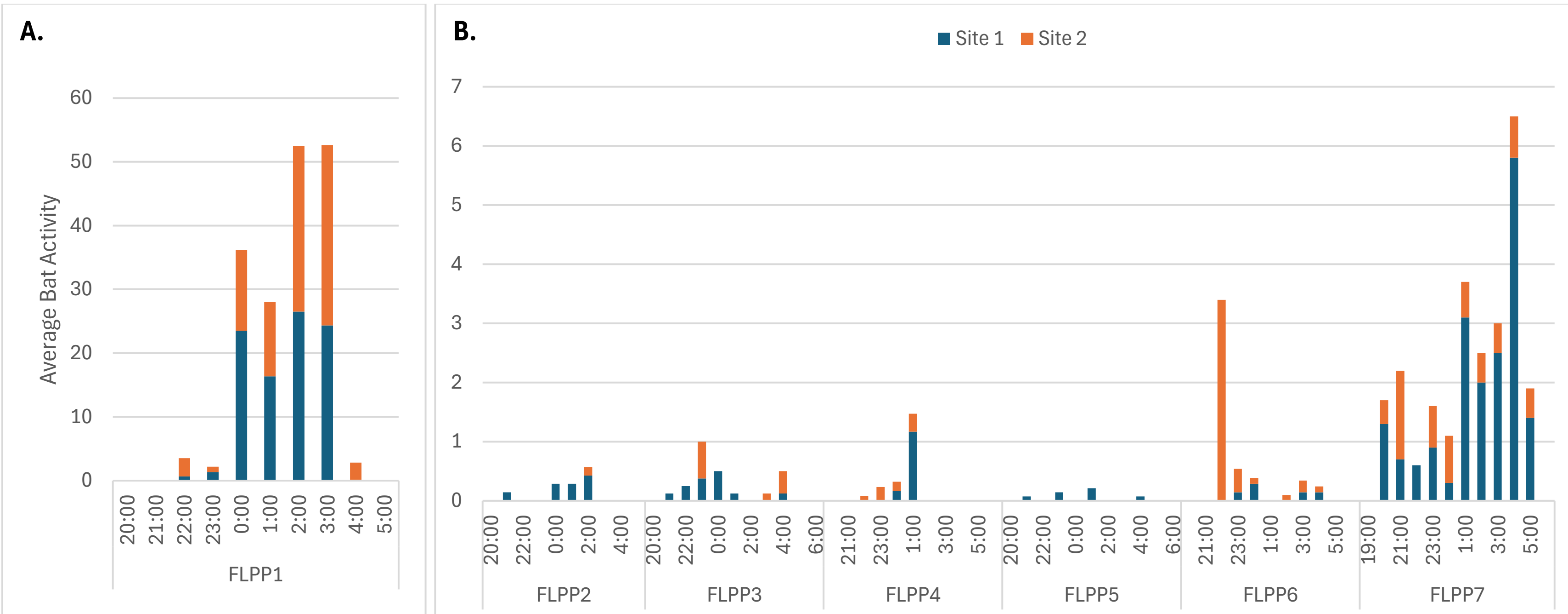

Figure 7. Average number of bat passes recorded at each hour across the survey period from June to August in each forest patch. Stacked bars are coloured based on the individual sites within the forest patch: site 1 (blue) and site 2 (orange). Due to the significantly higher bat activity among forest patches, we split bat activity into: A. Sites in forest patch FLPP1 with the highest bat activity; B. Remaining sites within forest patches FLPP2–FLPP7.

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Northern Myotis

Habitat

Of the 27 potential MYSE detections (Figure 8), the only sequence identified as MYSE with a high degree of confidence was from a relatively small (18.5 ha) forest patch with a high proportion of sugar maple, red maple, white birch, balsam fir, and yellow birch trees, respectively (FLPP 7-1). At the same site, there were also 13 other sequences identified as potential MYSE pass with varying degrees of confidence (Table 4). This forest patch was smaller and more isolated than the other forest patches we surveyed. The site was in a forest stand with a habitat score of 9, area of 5.3 ha, crown coverage of 85%, crown height of 19.3 m, and average DBH of trees of ~ 33 cm. The average number of large DBH trees per hectare was ~17. There was a dry, ephemeral creek ~50m away from both sites, which was covered by a significant number of wind-fallen trees from Post-Tropical Storm Fiona. There was another site (FLPP 7-2) within the forest patch that also had a MYSE detection with a low degree of confidence. This site had very similar habitat metrics, apart from a few large eastern hemlocks in the nearby vicinity.

There was 1 other sequence identified as a potential MYSE with a medium/high degree of confidence in a 79.8 ha forest patch (FLPP1) with a high proportion of red maple, yellow birch, and sugar maple, respectively, in the stand (FLPP1-2). At the same site, there were two more sequences identified as potential MYSE: 1 made with a low and 1 with a very low degree of confidence. Within the same forest patch and forest stand, the other detector (FLPP1-1) recorded 3 sequences identified as potential MYSE, made with low (n=1) and very low (n=2) degrees of confidence. This forest stand had a habitat score of 10, area of 9.9 ha, crown coverage of 90%, crown height of 20.2 m, and average DBH of trees of ~ 33 cm. The average number of large DBH trees per hectare was ~18. West River and an open water wetland (106 ha) are approximately 197m away. Notably, Henderson et al. (2007) captured a male MYSE approximately 1.7 km away from this site in 2005.

There was 1 sequence identified as a potential MYSE with a low degree of confidence recorded in a forest stand (13.7 ha) that had a habitat score ranked in the top 15% (FLPP3-1). It was the only potential MYSE detection in the forest patch, which was the second largest we surveyed (250.5 ha). The stand had a high proportion of sugar maple, white birch, and yellow birch, and hemlock, respectively. The crown height was 19.5 m with unknown coverage, an average DBH of trees ~ 33 cm. The average number of large DBH trees per hectare was ~20. Pinette River, the nearest water source, was 100m away from the site.

There was 1 sequence identified as a potential MYSE with a low degree of confidence recorded in a relatively small forest stand (6.0 ha) that had a habitat score of 10 (FLPP6-2). It was the only potential MYSE detection in the large (250.5 ha) forest patch. The stand had a high proportion of sugar maple, red maple, yellow birch, and white birch, respectively. The crown height was 20.8 m with 90% coverage, and there was an average DBH of trees ~ 33 cm.

The average number of large DBH trees per hectare was ~22. Souris River was the closest water source at approximately 183m away from the site.

There was 1 sequence identified as a potential MYSE with a very low degree of confidence recorded in a forest stand (13.2 ha) that had a habitat score of 10 (FLPP5-1). It was the only potential MYSE detection in the largest (286.0 ha) forest patch we surveyed. The forest stand had a high proportion of sugar maple, red, maple, yellow birch, and balsam fir, respectively. The crown height was 19.2 m with 85% coverage, an average DBH of trees ~ 32 cm. The average number of large DBH trees per hectare was ~18. Cross River was approximately 329m away from the site. There was also a female MYSE captured approximately 900m NE (Henderson 2007).

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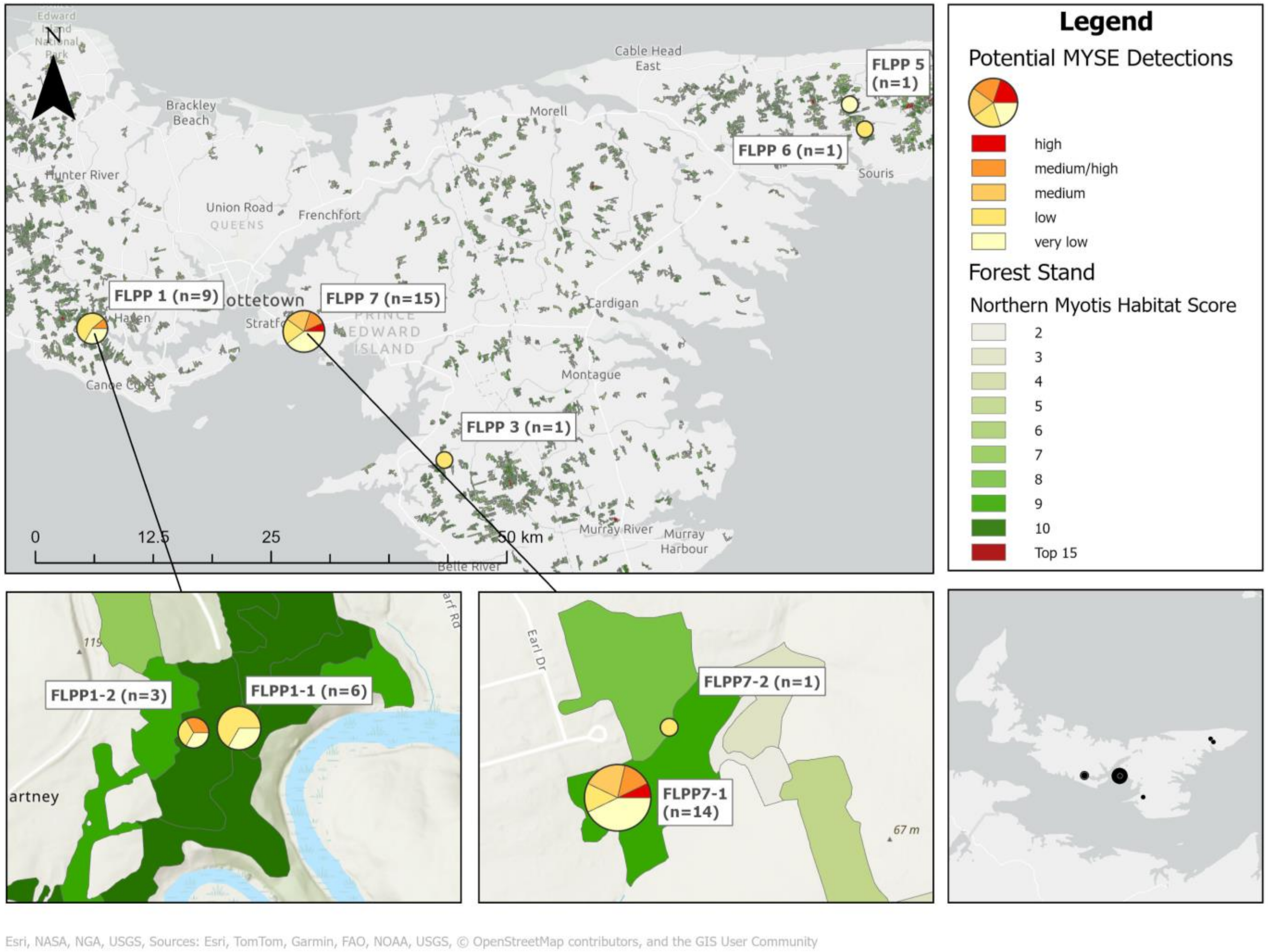

Figure 8. Twenty-seven potential Northern Myotis (*Myotis septentrionalis*, MYSE) detections from acoustic surveys, categorized by confidence level: high, medium/high, medium, low, very low. Forest patches with more than one site where potential MYSE were detected have corresponding higher-resolution maps.

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Temporal

There were potential MYSE detections recorded at dates throughout the survey period from 15 June until 14 August (Figure 9). The majority of potential MYSE detections were collected at the last sites surveyed, with the highest number of detections on 10 August (n=12). On 10 August, sunset was 20:31 and sunrise was at 6:06, but the majority of detections were at 4:00, including the recording with the highest degree of confidence.

There were not any potential MYSE detections recorded within an hour of sunset, which would have been expected if our detectors were near a roost. Instead, the timing of potential MYSE detections occurred throughout the night, with at least one detection recorded every hour between 22:00 and 4:00 across all sites. There were 3 detections recorded before midnight, one at 23:34 on 4 July when sunset was 21:05 (2h 38m after sunset); one at 22:04 on 25 July when sunset was at 20:48 (1h 56m after sunset); and one at 22:54:37 on 14 August when sunset was at 20:25 (2h 29m). The rest of the detections were after midnight and averaged 2h 26m ± 1h 13m before sunrise (min-max: 1h 08m–4h 49m).

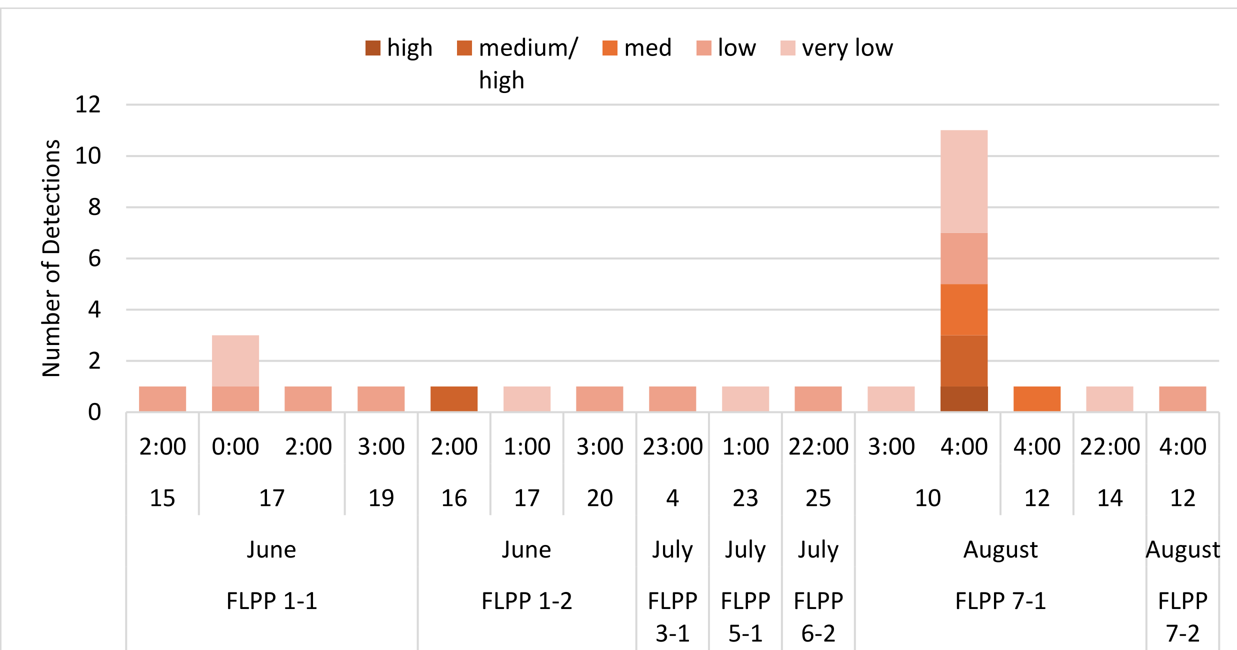

Figure 9. Temporal distribution of 27 potential Northern Myotis (*Myotis septentrionalis*) detections from acoustic surveys, categorized by confidence level: high, medium/high, medium, low, very low. From top to bottom, the x-axis represents the hour, day, month, and site where the detection was recorded.

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Discussion

We were able to detect potential Northern Myotis echolocation sequences at several sites that were identified as potential Northern Myotis roosting sites by the habitat suitability assessment. The number of acoustic detections that we were able to identify confidently to species was very low, likely due to surveying structurally complex environments that inherently affect how bats echolocate, often precluding their use of the specific echolocation characteristics required for accurate species identifications. Nevertheless, the few echolocation sequences that were indicative of Northern Myotis are promising, indicating that conducting habitat suitability assessments is a viable method for wildlife and land managers to rapidly evaluate Northern Myotis roosting habitat on a province-wide scale. In addition, the ground-truthing exercise confirmed that there are suitable maternity roost habitats on PEI with habitat components important for maternity colonies.

Unexpectedly, the majority of the potential Northern Myotis activity was at a relatively small, fragmented forested patch with lower habitat scores than other sites we surveyed. However, the higher level of activity could be due to the timing of the surveys. This was the only site where detectors were deployed after the expected partition date for Northern Myotis of mid-July. Further, Henderson et al. (2009) captured juvenile Northern Myotis in late July and August, which may suggest that the roosting behaviour during our last survey had already changed from maternity colony purposes. It is equally possible this activity was recording males and/or juvenile bats. Because it is impossible to know the age or sex of the individual using acoustics alone, it is not possible to ascertain if this stand was used during the time when maternity colonies were aggregated. Follow-up acoustic surveys earlier in the year or capture surveys can better help us understand how this particular stand is being used by Northern Myotis.

We also recorded a potential Northern Myotis sequence with a medium/high level of confidence at the first site we surveyed in mid-June (FLPP1), which—based on the timing of the survey—would be more representative of the habitat being used for maternity roost purposes. While it is not possible to know if we recorded female Northern Myotis, the seasonal timing of overall higher bat activity is more suggestive than the prior stand. Further, this site is located near a large body of water, in a relatively large forest patch, with highly ranked forest stands, is <2km from a prior capture record (Henderson et al. 2007) and a known hibernaculum in Bonshaw. This site met all of our expectations for an ideal Northern Myotis roosting habitat and is a good candidate site to conduct further capture surveys.

Another area that would be a good focus for further survey efforts is northeastern PEI, where we recorded two potential Northern Myotis detections, one with a low degree of confidence (FLPP6-2) and one with very low confidence (FLPP5-1). These sites were geographically close (~2.5km apart) and while they were not in the same forest patch, they had many highly ranked forest stands between them, allowing for some connectivity. In this region, there were two forest stands that ranked in the top 15 of the habitat suitability assessment,

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freshwater ponds, and riverine habitats. FLPP5 is also located in the top 5 largest forest patches in the habitat suitability assessment and is also the same forest patch with a prior capture record of a female Northern Myotis (Henderson et al. 2007).

The last site with a potential Northern Myotis detection with a low degree of confidence was recorded in a forest stand that was ranked with one of the top 15 highest habitat scores (FLPP3-1). This particular site was on private land, with both hemlock stands and highly ranked forest stands. Southeastern PEI (south of Grandview) had nearly all identified stands with relatively more eastern hemlock trees (n=51; 89%). There were 15 small hemlock forest stands within ~1km of the site where we recorded a potential Northern Myotis detection. Eastern Hemlock was one of the tree species most used by roosting Northern Myotis in Dollar Lake Provincial Park, Nova Scotia (Garroway and Broders 2008) and central Appalachia (Kalen et al. 2022). Because we detected a potential Northern Myotis sequence in an area with a relatively high occurrence of Eastern Hemlock stands, it is worth exploring if Northern Myotis are using this tree species to roost on PEI. We recommend continuing to use Eastern Hemlock as a key indicator of potential Northern Myotis roosting habitat during habitat suitability assessments in the region.

There was relatively low bat activity throughout the rest of the sites, nearly all of which was identified as *Myotis sp.* As our habitat suitability assessment was focused on environments where Northern Myotis are expected to occupy, we focused on structurally complex environments that are more suitable for clutter-dependent species, like Northern Myotis. Little Brown Myotis are generalists and use a wide variety of habitats, including forested landscapes, but are often found along trails, forest edges, and open aquatic environments. We did not choose any sites that would be more suitable for Little Brown Myotis, such as those situated in open environments or along forest edges or along flyways, with the exception of two sites. Both FLPP4-2 and FLPP 5-1 were along forested trails, but neither site had any species-level identifications or higher bat activity levels. Instead, we primarily focused on forest interiors to increase the chances of predominantly recording Northern Myotis. It is notable that we did not record any sequences that were indicative of stereotypical Little Brown Myotis, despite seeing time between calls indicative of low-clutter echolocation calls (Roby and Jordan 2024). It is likely that the overall low bat activity could be due to the significantly reduced regional Northern Myotis population (Balzar et al. 2021). However, because we chose our sites specifically as high-quality habitats where Northern Myotis would typically be found, the lack of echolocation calls indicating Little Brown Myotis is notable. Therefore, more work is required to know whether Little Brown Myotis are also present in these forested stands and to determine the relative abundance of the two endangered species in them.

We did not record an increase in bat activity near sunset, which likely means we did not deploy acoustic detectors near a roost tree. This is further substantiated by the lack of bats detected by our trail cameras. There was one site (FLPP6-2) with higher bat activity at 22:00, but this was still two hours after sunset. Given the lack of bat activity nearer to sunset, we

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cannot make assumptions as to whether the sites we surveyed were used as maternity roost habitat. However, based on our acoustic data, we believe that Myotis bats, in some cases Northern Myotis specifically, are likely in many of the habitats identified by the habitat suitability assessment.

In addition to Myotis species, we recorded one low-frequency bat that had echolocation characteristics most consistent with a Silver-haired Bat. This would be one of very few potential identifications of LANO on PEI. Given the habitat was a mature forest interior, Silver-haired Bats are more likely given their ecology and preference for such habitats (Environment and Climate Change Canada 2023). Conversely, EPFU is more generalist, but with a strong affinity for roosting in human dwellings (Kurta and Baker 1990); therefore, it is more likely that this species would be first discovered in human-associated structure on PEI if its range continues to expand northward (McAlpine et al. 2024).

We would not recommend using trail cameras as a method to confirm if bats were potentially roosting in a tree for several reasons. First, the chance of identifying the exact tree that a maternity colony is using out of an entire forest is highly unlikely. Especially since Northern Myotis often use entrances and exits that are situated high in taller trees (Garroway and Broders 2008). Second, there is often more than one entrance and/or exit point in a roost tree, further lessening the likelihood that pointing a camera directly at one crack/crevice/hole in a tree would result in confirmation of the species using that particular tree. Also, at sites where we positioned our cameras with a less specific focal object (e.g., the empty space between several potential roost trees), we did not record any animals and the camera was more likely to be triggered by swaying vegetation. At this time, we believe that bats are too fast-flying animals to trigger and subsequently be recorded by trail cameras. Perhaps if there are technological advances in both the trigger speeds and infrared technology, it would be more possible to record free-flying bats in their natural, vegetated habitats. But until that time, we would not recommend spending time and resources on the same methodology and/or technical equipment used in this study. An alternative avenue to explore is to use trail cameras at known roosts where the exit/entrance has been identified. However, natural roosts are often difficult to discover without capturing and tracking bats back to their roosts.

In conclusion, our habitat suitability assessment combined with acoustic monitoring resulted in the identification of several sites that Myotis species are using during the summer months when females would typically be aggregating in maternity colonies. We were able to ground-truth the results of the habitat suitability assessment and record possible Northern Myotis sequences in highly-ranked forested stands. While acoustics alone cannot confirm the presence of maternity colonies in these habitats, it can inform locations to be prioritized for future capture studies. Our acoustic data strongly suggest the possibility that Northern Myotis are still present on PEI, albeit in very low numbers. Therefore, protecting the contiguous forested landscapes identified in our habitat suitability assessment should be prioritized. Additionally, because we recorded possible Northern Myotis detections on both private and public lands, focusing habitat suitability assessments on all land types is important as well as collaborating with local landowners to garner their support and stewardship to manage and protect these important habitats. Lastly, we also recognize that acoustic survey methods can underrepresent Northern Myotis (Thorne et al. 2021), so further research, including capture studies at the sites where Northern Myotis were potentially acoustically identified in this project, is recommended.

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Appendices

Appendix A. Forest stands were given a habitat score based on the size of the forest patch and the density of >30 DBH trees within the forest patch based on the Enhanced Forest Inventory (EFI). The size score and the density score were combined to calculate the habitat score.

Size Class (ha)	Size Score	Density (EFI)	Density Score
2.09	1	7	1
2.95	2	20	2
3.97	3	39	3
5.47	4	67	4
52.28	5	473	5

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Appendix B. Trail camera settings for the Bushnell CORE S-4K no glow trail cameras.

Camera Setting	Value
Pres-sets	Advanced
Mode	Video
Illumination Mode	Fast Motion
Video Size	3840 x 2160
Video Length	15 S
Delay	0.5 S (delay between videos)
Sensor Level	High
Camera Mode	Night (only captures images at nighttime.)
Field Scan	Off

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Appendix C. Settings used with Kaleidoscope Pro 5.6.8 for the initial analysis and automatic identification.

Signal Parameter	Description
15 – 120 kHz	Minimum – maximum frequency range
1 – 500 ms	Minimum – maximum length of detected pulses
500 ms	Maximum inter-syllable gap
3	Minimum number of pulses
EPFU, LABO, LACI, LANO, MYLU, MYSE, PESU	Auto ID species classifer

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Appendix D. Habitat information for forest stands where we spent time ground-truthing. Forest variables were pulled from the Forest Resource Inventory from 2020 and the top 3 coverage types are shown. Size scores and density scores were added to rank the forest stand from lowest (1) to highest (10) suitability for Northern Myotis roosting habitat. Details on whether or not the forest stand was chosen to survey are displayed in the last column. For those forest stands that were surveyed, an SM4BAT acoustic detector with an SMM-U2 microphone and a Bushnell CORE S-4K no glow trail camera were deployed to monitor for Northern Myotis. If the particular forest stand was not chosen for the survey, the details as to why are indicated in the last column.

Date Visited	Description	FID_BatMetrics_Project	COVER1	PER1	COVER2	PER2	COVER3	PER3	COVER4	PER4	COVER5	PER5	Height (m)	Crown (%)	Stand Area (ha)	Patch Area (ha)	COUNTY	LiDAR Crown Height (m)	Count of Trees	Average Max. DBH	Size Score	Density Score	Habitat Score	Details
14-Jun	FLPP1	4596	RM	5	YB	3	SM	2		0		0	19	90	9.9	79.8	Q	20.2	180	32.6	5	5	10	surveyed
14-Jun	FLPP1	4597	YB	4	RM	4	WS	1	SM	1		0	19	95	5.1	79.8	Q	20.8	123	34.3	4	5	9	surveyed
26-Jun	Brookvale	3297	RM	4	SM	2	WB	2	YB	1	BF	1	15	90	3.7	137.0	Q	16.7	21	33.2	3	3	6	N/A - waa
26-Jun	Brookvale	3456	YB	3	RM	3	SM	3	BF	1		0	19	85	12.3	137.0	Q	19	217	33.4	5	5	10	N/A - waa
26-Jun	Brookvale	3490	RM	4	WB	2	YB	2	BF	1	WS	1	16	65	1.8	137.0	Q	15.7	10	33.8	1	2	3	N/A - waa
26-Jun	Brookvale	3632	SM	3	YB	2	BF	2	RM	2	WB	1	19	75	6.7	137.0	Q	17.7	87	34.3	5	5	10	N/A - waa
26-Jun	Granville	2421	RM	4	SM	3	BE	1	YB	1	WB	1	19	85	6.4	46.1	Q	18.4	113	32.8	5	5	10	N/A - isq[1]
26-Jun	Granville	2423	SM	4	RM	3	BE	1	YB	1	WB	1	20	85	8.7	46.1	Q	18.3	109	32.1	5	5	10	N/A - isq[1]
26-Jun	Granville	2551	SM	4	RM	2	YB	2	WB	1	BE	1	19	85	3.5	46.1	Q	18.2	35	32.6	3	3	6	N/A - isq[1]

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28-Jun	FLPP2	6302	RM	4	SM	3	YB	2	BE	1		0	19	90	17.6	132.3	K	19.3	372	33.4	5	5	**10***	surveyed
28-Jun	FLPP2	6294	RM	5	WB	2	SM	2	YB	1		0	19	85	6.2	132.3	K	18	91	32.3	5	5	10	N/A - patch
28-Jun	FLPP2	6388	RM	4	PO	2	WB	2	BF	1	SM	1	12	95	3.8	132.3	K	16.9	18	31.2	3	2	5	N/A - patch
2-Jul	FLPP3	8648	RM	5	SM	2	WB	1	YB	1	HE	1	20	0	13.7	250.5	Q	19.5	286	33.2	5	5	**10***	surveyed
2-Jul	FLPP3	8573	RM	6	WB	2	YB	1	BF	1		0	18	0	2.6	250.5	Q	17	8	31.5	2	2	4	N/A - patch
9-Jul	FLPP4	7779	RM	4	WB	2	SM	2	BF	1	BE	1	17	85	7.6	106.2	K	18.2	93	31.9	5	5	10	surveyed
9-Jul	FLPP4	7783	RM	4	SM	3	BE	1	YB	1	WB	1	19	85	18.5	106.2	K	18.2	229	31.8	5	5	10	surveyed
9-Jul	FLPP4	7774	RM	4	SM	3	WB	1	BF	1	YB	1	18	80	8.6	106.2	K	16.2	13	31.6	5	2	7	N/A - patch
9-Jul	FLPP4	7793	RM	5	WB	2	SM	1	PC	1	PO	1	12	95	1.5	106.2	K	15.1	1	30.7	1	1	2	N/A - patch
10-Jul	Klondyke Road, SE	9193	RM	3	WB	3	PO	2	WS	2		0	16	0	1.5	318.6	Q	17.9	20	33.4	1	2	3	N/A - waa/isq[2]
10-Jul	Klondyke Road, SE	9198	RM	4	PO	2	BE	2	BF	1	SM	1	14	0	3.1	318.6	Q	18.4	30	33.2	3	3	6	N/A - waa/isq[2]
10-Jul	Klondyke Road, SE	9242	RM	6	BF	2	WB	1	YB	1		0	15	0	2.8	318.6	Q	18.4	33	33.1	2	3	5	N/A - waa/isq[2]
10-Jul	Klondyke Road, SE	9247	RM	4	PC	2	WB	2	BF	1	SM	1	12	0	52.3	318.6	Q	17	217	33.1	5	5	10	N/A - waa/isq[2]

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12-Jul	FLPP5	7830	SM	4	RM	3	YB	2	WB	1		0	20	90	16.8	286.0	K	20.7	398	33.6	5	5	**10***	surveyed
12-Jul	FLPP5	7875	SM	4	RM	3	YB	2	BF	1		0	19	85	13.2	286.0	K	19.2	241	32.3	5	5	10	surveyed
12-Jul	FLPP5	7839	SM	5	RM	3	YB	1	WB	1		0	20	65	15.6	286.0	K	18.3	167	32.1	5	5	10	N/A - patch
12-Jul	FLPP5	7840	RM	4	WB	2	BF	2	SM	1	PO	1	11	95	3.6	286.0	K	16.2	3	30.9	3	1	4	N/A - patch
12-Jul	FLPP5	7841	RM	4	SM	3	WB	2	YB	1		0	18	95	14.7	286.0	K	18.1	214	32.9	5	5	10	N/A - patch
17-Jul	Goose River 1	6065	WB	3	RM	3	PO	2	BF	1	WS	1	13	80	6.8	33.2	K	15.8	43	31.8	5	4	9	N/A - waa
17-Jul	Goose River 1	6066	PO	4	RM	3	WB	2	BF	1		0	19	85	11.9	33.2	K	18.6	170	32.3	5	5	10	N/A - waa
17-Jul	Goose River 1	6164	PO	5	WB	2	RM	2	BF	1		0	17	65	0.9	33.2	K	16.6	3	31.3	1	1	2	N/A - waa
17-Jul	Goose River 1	6224	RM	3	PO	3	BF	2	WB	2		0	19	85	3.7	33.2	K	18.1	51	32.0	3	4	7	N/A - waa
17-Jul	Goose River 2	6060	RM	4	PO	3	WS	1	WB	1	BF	1	18	90	10.9	16.8	K	18.6	199	32.7	5	5	10	N/A - waa
19-Jul	Klondike Road, NE	7039	RM	4	WB	2	BF	2	BE	1	SM	1	17	85	8.6	207.1	K	18.7	185	33.3	5	5	10	N/A - waa/isq[2]
19-Jul	FLPP6	8005	SM	5	RM	2	YB	2	WB	1		0	20	90	6.0	46.6	K	20.8	133	33.3	5	5	10	surveyed
19-Jul	FLPP6	8010	RM	4	YB	2	SM	2	WB	2		0	18	95	13.4	46.6	K	17.7	112	32.0	5	5	10	surveyed

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9-Aug	FLPP7	7243	SM	6	RM	2	YB	1	BE	1		0	17	85	4.7	18.5	Q	18.5	61	32.8	4	4	8	surveyed
9-Aug	FLPP7	7247	SM	3	RM	3	WB	2	BF	1	YB	1	18	85	5.3	18.5	Q	19.3	92	32.9	4	5	9	surveyed

* Forest stands that ranked in the top 15% due to the larger forest patch area and higher counts of >30cm DBH trees.
N/A: forest stand was not chosen to survey due to one of the following reasons:

- patch: this particular forest stand was not chosen to survey, but a different location within the same forest patch was surveyed
- waa: wind-affected area
- isq[1]: insufficient quality prevented a survey at this forest stand due to a very cluttered midstory, which would decrease our ability to record quality acoustic data
- isq[2]: insufficient quality prevented a survey at this forest stand due to the lack of large diameter potential roost trees in areas that were unaffected by wind

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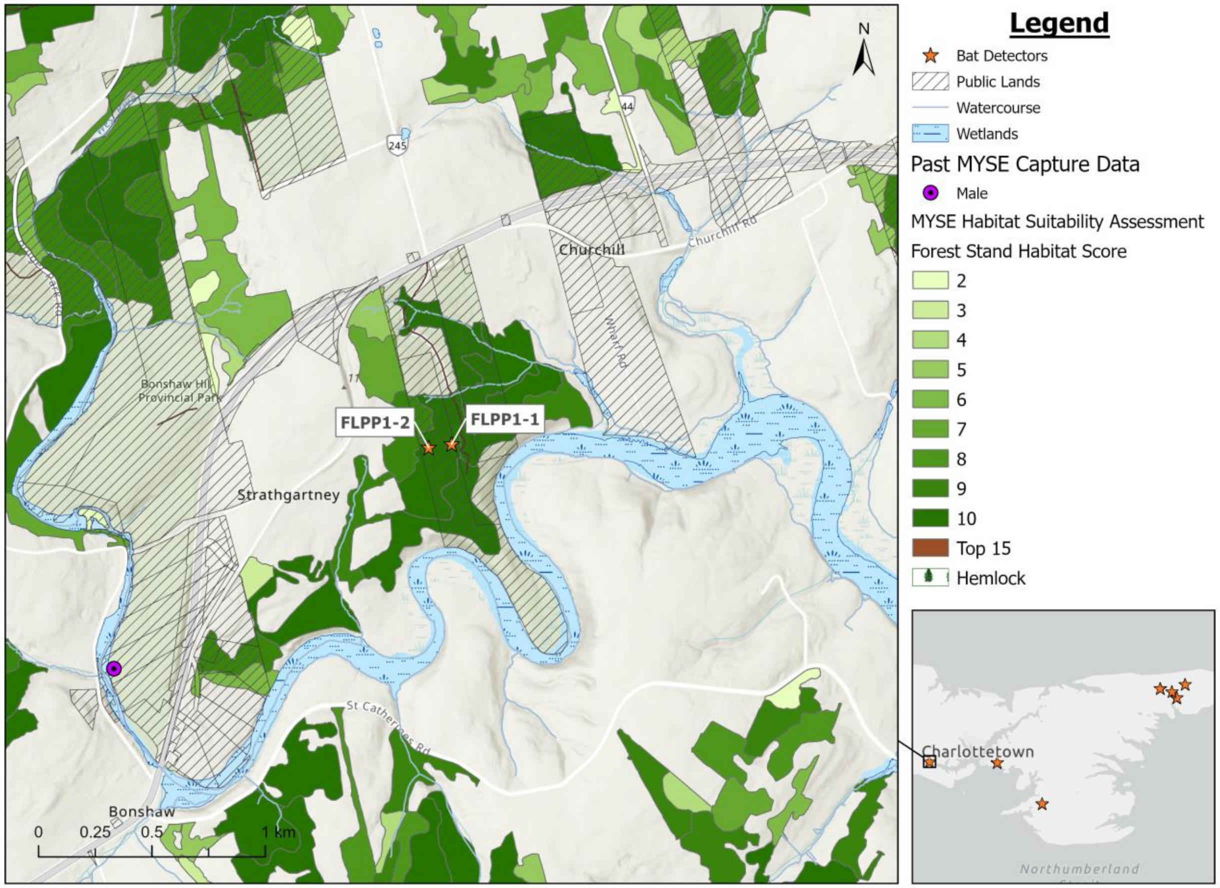
Appendix E. Forest patches where SM4BAT acoustic detectors with SMM-U2 microphones and Bushnell CORE S-4K no glow trail cameras were deployed in forest stands identified by the habitat suitability assessment. At each site, there was one bat detector deployed in an area with a high density of natural roosts and one trail camera focused on a potential roost tree near the detector. Also shown are results from prior past Northern Myotis (MYSE) capture data (Henderson 2007).

FLPP 1.



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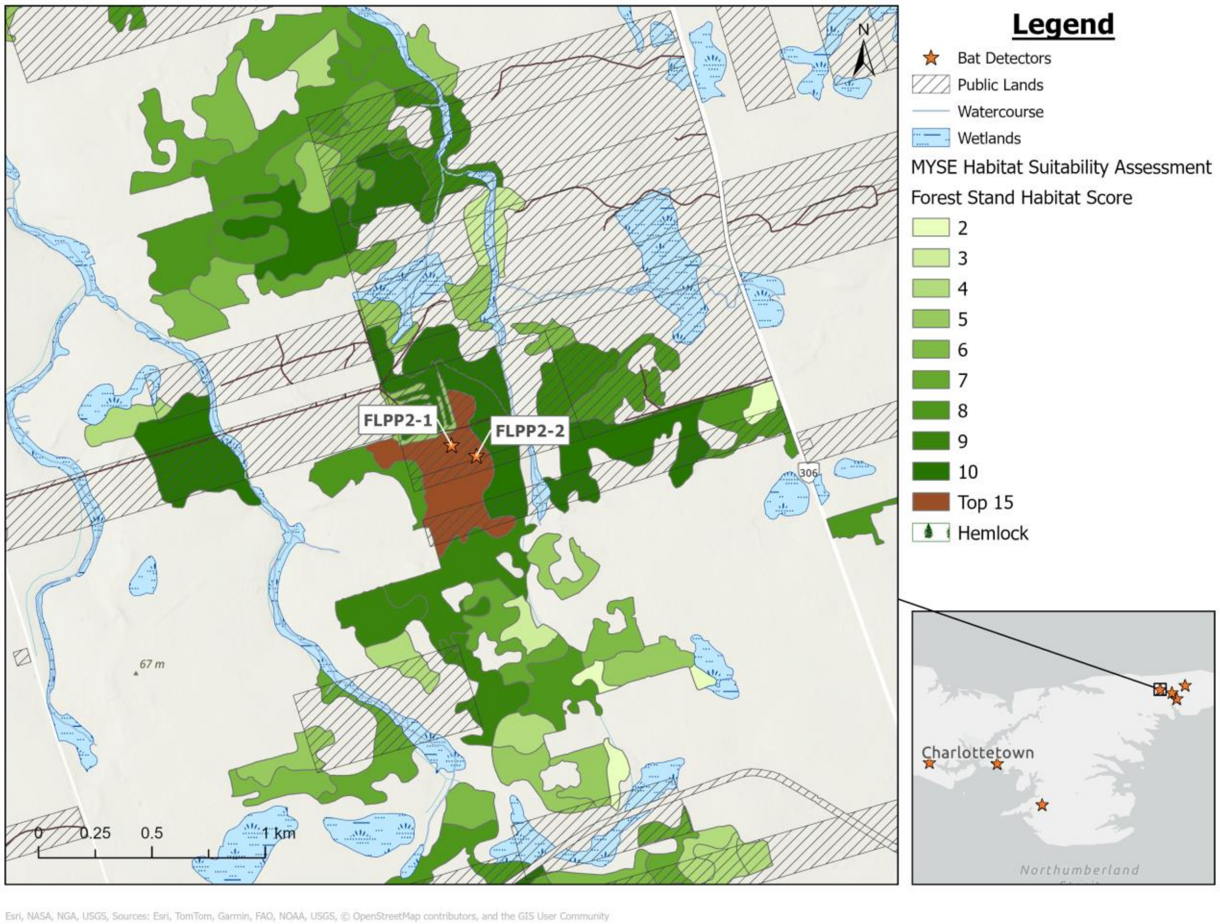
FLPP 2.



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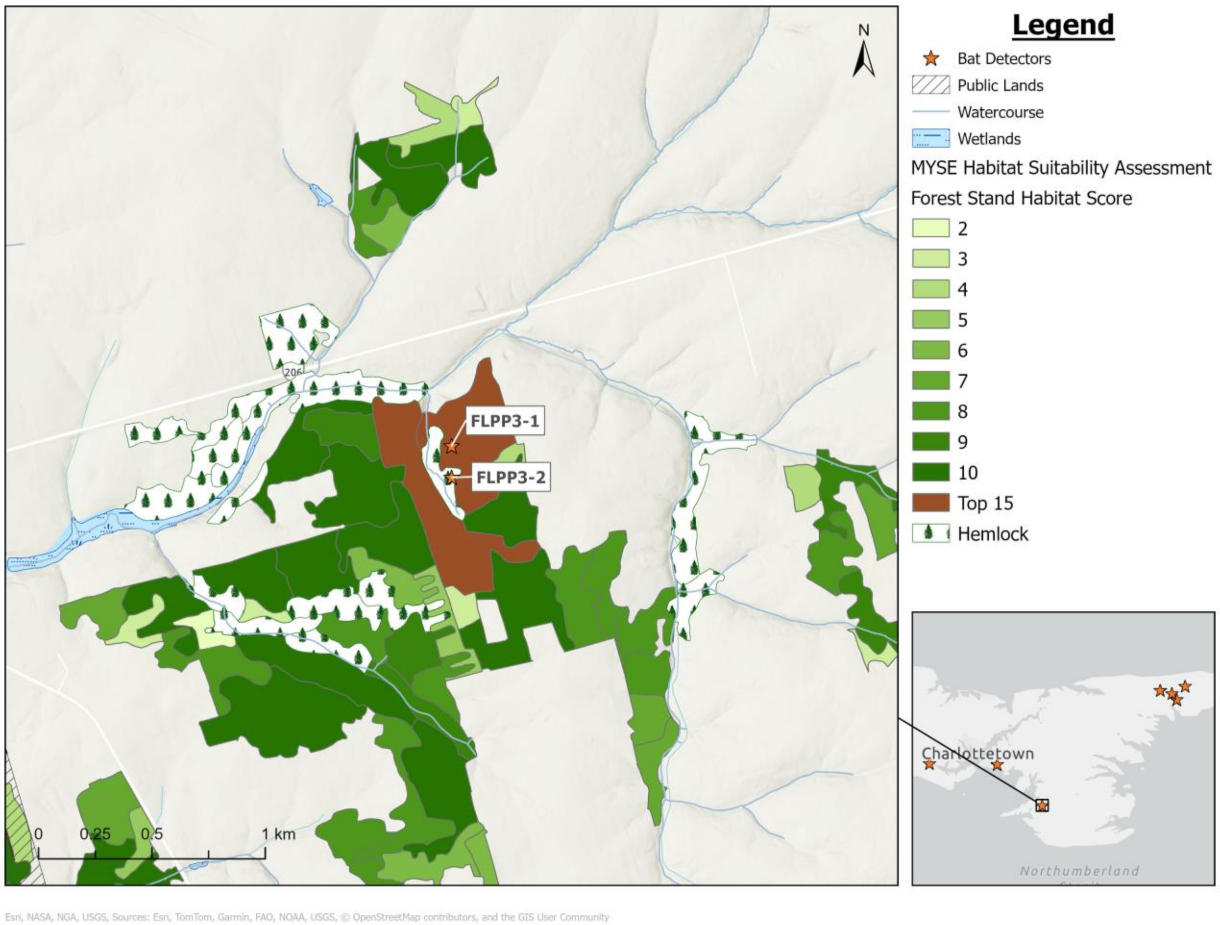
FLPP 3.



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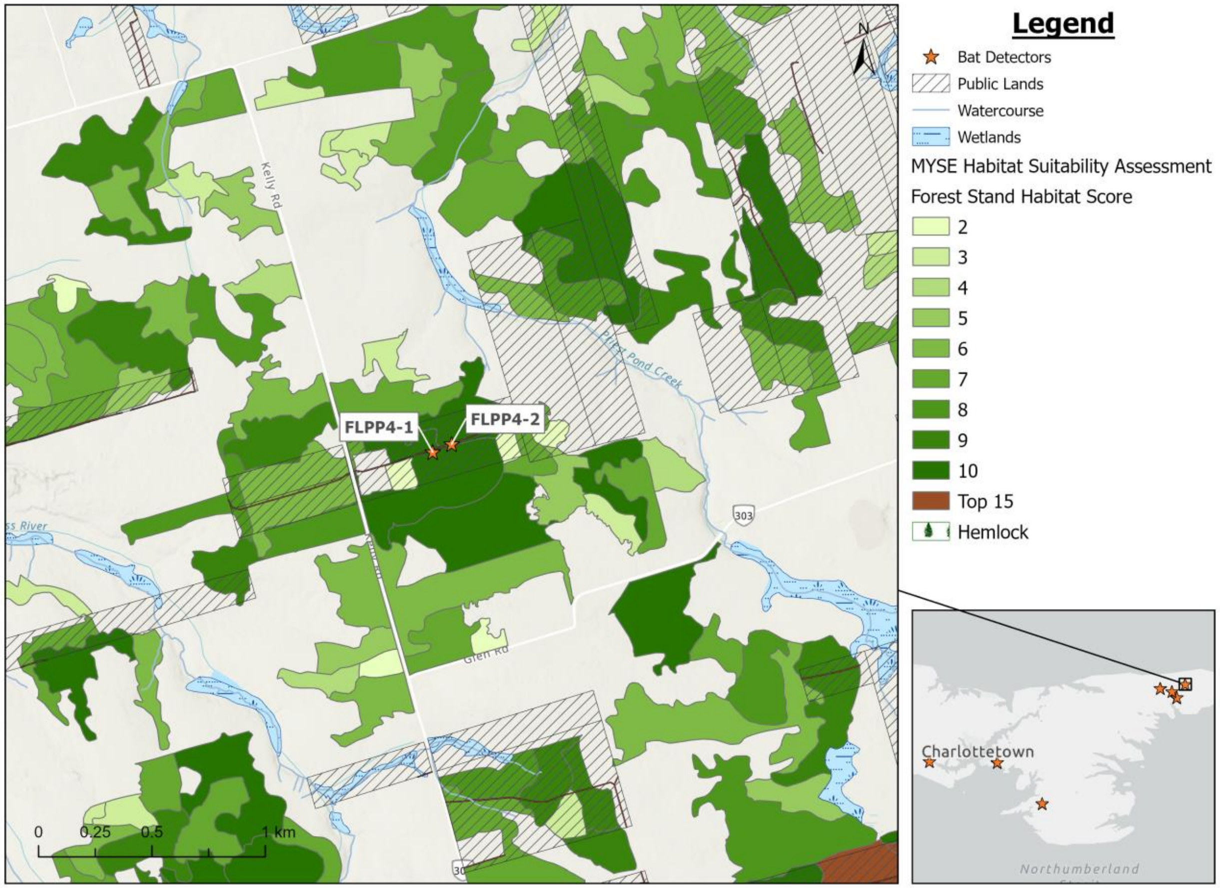
FLPP 4.



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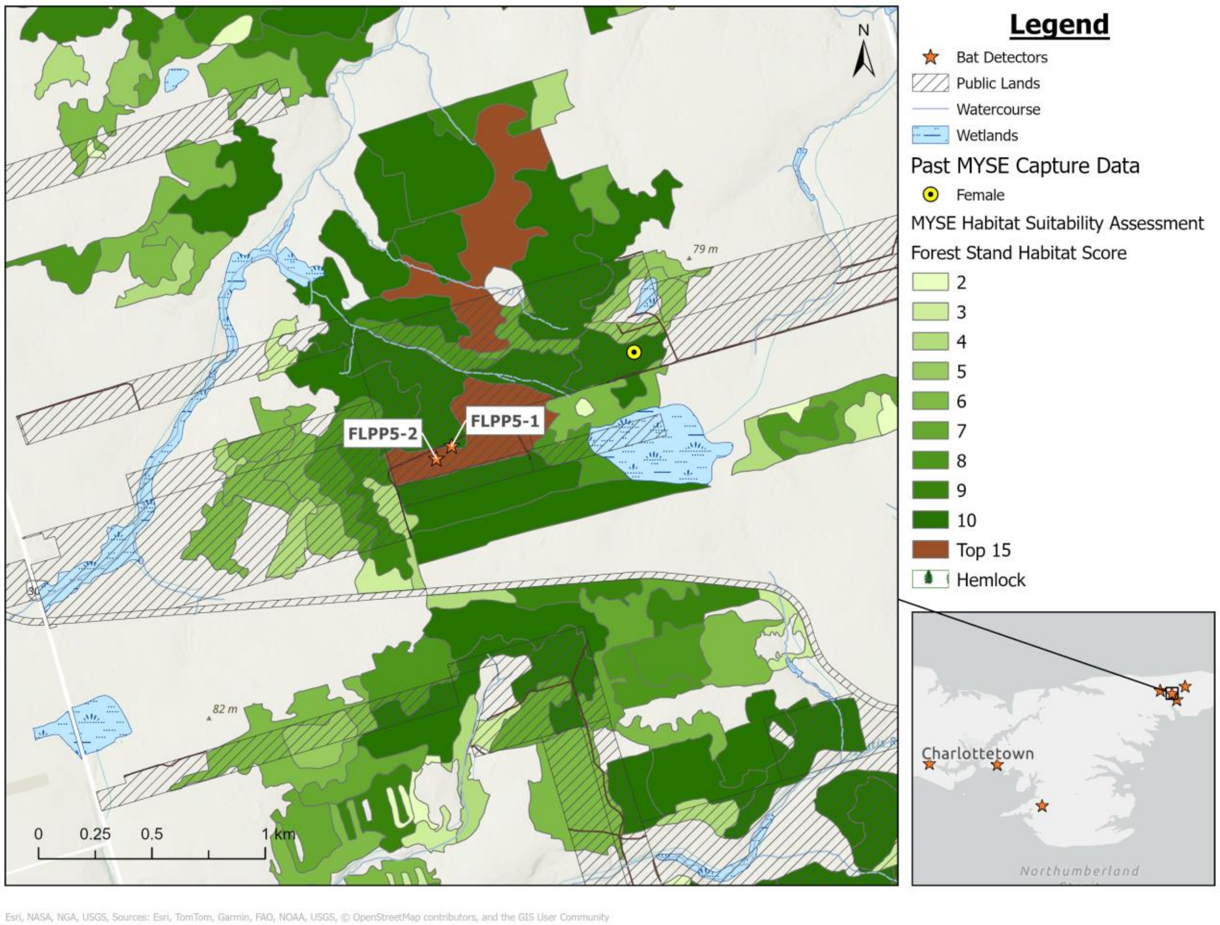
FLPP 5.



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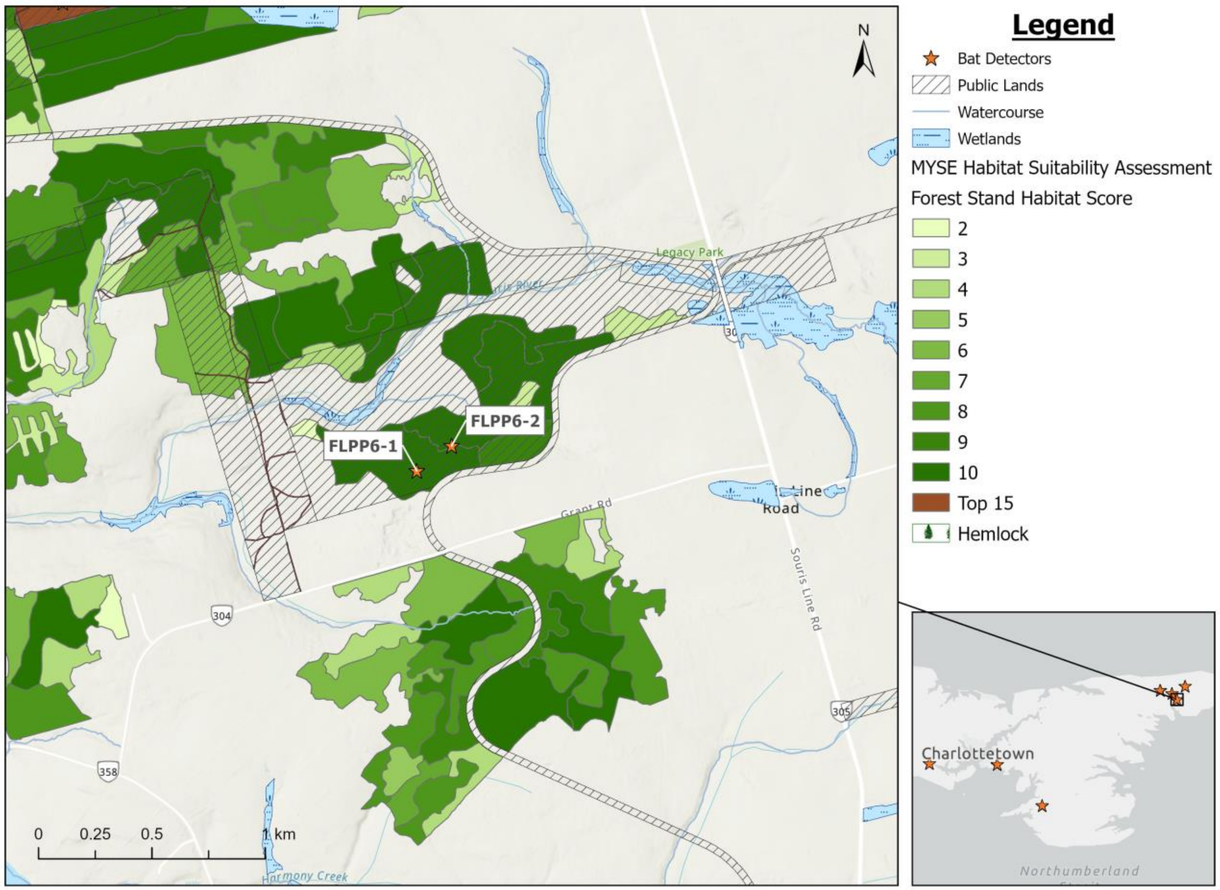
FLPP 6.



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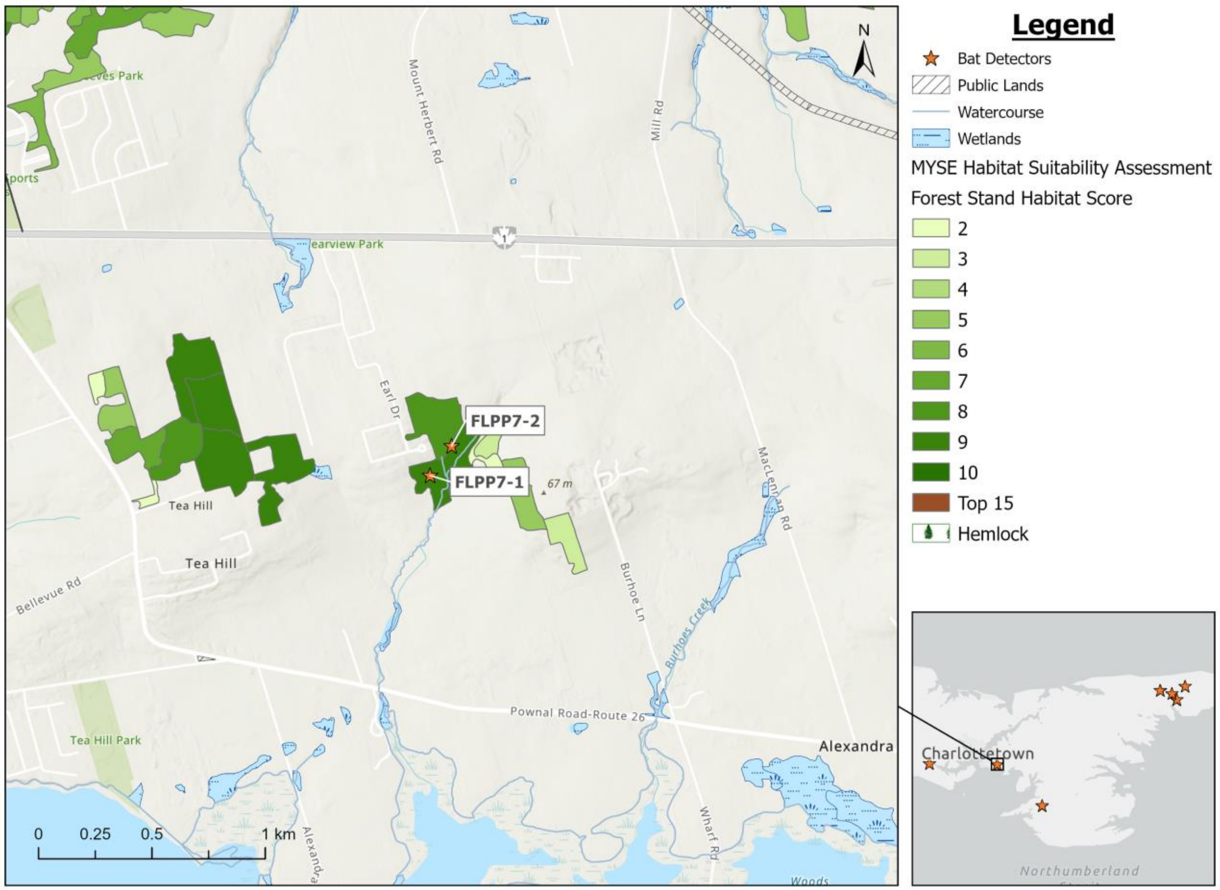
FLPP 7.



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Appendix F. Raw data from Bushnell CORE S-4K no glow trail cameras deployed at every site. The trigger was categorized as environmental (wind, leaves, etc.), person, or animals. Potential bats were indicated with "M" and accompanying notes are given in the last column.

Site	File	Date	Timestamp	Bat? (1/0/M)	Environmental	Person	Animal (non-insect)	Animal observed	Notes
FLPP 1-1	06140001.MOV	6/14/2024	16:14:16	0		1			set up
FLPP 1-1	06200002.MOV	6/20/2024	12:07:13	0		1			tear down
FLPP 1-1	06200003.MOV	6/20/2024	12:07:29	0		1			tear down
FLPP 1-1	06200004.MOV	6/20/2024	15:35:29	0		1			tear down - office
FLPP 1-2	06140001.MOV	6/14/2024	17:42:10	0		1			Trail cam setup
FLPP 1-2	06140002.MOV	6/14/2024	17:44:39	0		1			Trail cam setup
FLPP 1-2	06160003.MOV	6/16/2024	3:18:12	0	1				Tree branch
FLPP 1-2	06160004.MOV	6/16/2024	3:24:17	0	1				Tree branch moving
FLPP 1-2	06160005.MOV	6/16/2024	3:26:57	0	1				something moving; indistinguishable, but potentially larger than the insects on next videos
FLPP 1-2	06160006.MOV	6/16/2024	3:27:33	0	1				Tree branch moving
FLPP 1-2	06160007.MOV	6/16/2024	3:29:29	0	1				tree branch moving
FLPP 1-2	06160008.MOV	6/16/2024	3:29:50	0	1				Something moving (insect?)
FLPP 1-2	06160009.MOV	6/16/2024	3:32:17	0	1			insect	insects (x3)
FLPP 1-2	06160010.MOV	6/16/2024	3:32:56	0	1				tree branch moving
FLPP 1-2	06160011.MOV	6/16/2024	3:34:22	0	1			insect	several insects flying around
FLPP 1-2	06160012.MOV	6/16/2024	3:34:43	0	1			insect	tree branch moving
FLPP 1-2	06160013.MOV	6/16/2024	3:35:00	0	1				tree branch moving
FLPP 1-2	06160014.MOV	6/16/2024	3:36:19	0	1				something moving at 3:36:29; not distinguishable, but didn't

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							look like the smaller insects in previous frames
FLPP 1-2	06160015.MOV	6/16/2024	3:36:43	0	1		tree branch moving
FLPP 1-2	06160016.MOV	6/16/2024	3:37:57	0	1		tree branch moving
FLPP 1-2	06160017.MOV	6/16/2024	3:39:26	0	1	likely insect	insect flying; somewhat larger
FLPP 1-2	06160018.MOV	6/16/2024	3:40:46	0	1	likely insect	insect flying; somewhat larger
FLPP 1-2	06160019.MOV	6/16/2024	3:42:30	0	1		tree branch moving
FLPP 1-2	06160020.MOV	6/16/2024	3:44:03	0	1	insect	Something moving; likely larger insect
FLPP 1-2	06160021.MOV	6/16/2024	3:46:05	0	1		tree branch moving
FLPP 1-2	06160022.MOV	6/16/2024	3:46:29	0	1		tree branch moving
FLPP 1-2	06160023.MOV	6/16/2024	3:46:58	0	1		tree branch moving
FLPP 1-2	06160024.MOV	6/16/2024	3:47:19	0	1		tree branch moving
FLPP 1-2	06160025.MOV	6/16/2024	3:47:41	0	1		tree branch moving
FLPP 1-2	06160026.MOV	6/16/2024	3:50:00	0	1	insect	Something moving, likely a moth?
FLPP 1-2	06160027.MOV	6/16/2024	3:50:45	0	1		tree branch moving
FLPP 1-2	06160028.MOV	6/16/2024	3:52:12	0	1		tree branch moving
FLPP 1-2	06160029.MOV	6/16/2024	3:53:23	0	1		tree branch moving
FLPP 1-2	06160030.MOV	6/16/2024	3:53:40	0	1		tree branch moving
FLPP 1-2	06160031.MOV	6/16/2024	3:55:27	M	1	likely insect	Something moving, somewhat dark, but insect?
FLPP 1-2	06160032.MOV	6/16/2024	3:55:47	0	1		tree branch moving
FLPP 1-2	06160033.MOV	6/16/2024	3:56:06	0	1		tree branch moving
FLPP 1-2	06160034.MOV	6/16/2024	3:56:24	0	1		tree branch moving
FLPP 1-2	06160035.MOV	6/16/2024	3:56:44	0	1		tree branch moving
FLPP 1-2	06160036.MOV	6/16/2024	3:57:11	0	1		tree branch moving
FLPP 1-2	06160037.MOV	6/16/2024	3:58:00	0	1		vertical drop - water? Insect?
FLPP 1-2	06160038.MOV	6/16/2024	3:59:20	0	1	insect	likely insect
FLPP 1-2	06160039.MOV	6/16/2024	4:01:06	0	1		tree branch moving

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FLPP 1-2	06160040.MOV	6/16/2024	4:02:54	0	1		tree branch moving
FLPP 1-2	06160041.MOV	6/16/2024	4:07:41	0	1		Something moving; vertically down; water or insct
FLPP 1-2	06160042.MOV	6/16/2024	4:11:08	0	1		Tree branch moving
FLPP 1-2	06160043.MOV	6/16/2024	4:11:31	M	1	likely insect	something moving, perhaps larger and darker; likely insect
FLPP 1-2	06160044.MOV	6/16/2024	4:11:57	0	1		tree branch moving
FLPP 1-2	06160045.MOV	6/16/2024	4:12:16	0	1	insect	likely insect; bright and fairly small
FLPP 1-2	06160046.MOV	6/16/2024	4:13:58	0	1		Tree branch moving
FLPP 1-2	06160047.MOV	6/16/2024	4:15:36	0	1		Tree branch moving
FLPP 1-2	06160048.MOV	6/16/2024	4:16:37	0	1		Tree branch moving
FLPP 1-2	06160049.MOV	6/16/2024	4:20:33	0	1		Tree branch moving
FLPP 1-2	06160050.MOV	6/16/2024	4:21:43	0	1		slight movement; indistinguishable
FLPP 1-2	06160051.MOV	6/16/2024	4:22:24	0	1		Tree branch moving
FLPP 1-2	06160052.MOV	6/16/2024	4:25:37	0	1		Tree branch moving
FLPP 1-2	06160053.MOV	6/16/2024	4:26:59	0	1		Tree branch moving
FLPP 1-2	06160054.MOV	6/16/2024	4:28:31	0	1		Tree branch moving
FLPP 1-2	06160055.MOV	6/16/2024	4:29:00	0	1		Tree branch moving
FLPP 1-2	06160056.MOV	6/16/2024	4:29:53	0	1	insect	visible insect moving slowly by tree
FLPP 1-2	06160057.MOV	6/16/2024	4:30:18	0	1	insect	tree branch moving; daylight coming
FLPP 1-2	06160058.MOV	6/16/2024	4:39:28	0	1	insect	insect, likely moth
FLPP 1-2	06160059.MOV	6/16/2024	4:39:52	0	1		tree branch moving
FLPP 1-2	06160060.MOV	6/16/2024	4:42:08	0	1		falling leaf; potential insect (or another leaf)
FLPP 1-2	06160061.MOV	6/16/2024	4:44:09	0	1	insect	likely a moth flying the full length of the frame - good for outreach
FLPP 1-2	06160062.MOV	6/16/2024	4:46:14	0	1	insect	insect flying

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FLPP 1-2	06160063.MOV	6/16/2024	4:48:03	0	1		trees moving
FLPP 1-2	06160064.MOV	6/16/2024	4:52:38	0	1		trees moving
FLPP 1-2	06160065.MOV	6/16/2024	5:04:12	0	1		trees moving
FLPP 1-2	06160066.MOV	6/16/2024	5:11:35	0	1		trees moving
FLPP 1-2	06160067.MOV	6/16/2024	5:12:12	0	1		trees moving
FLPP 1-2	06160068.MOV	6/16/2024	21:49:31	0	1		something moving; indistinguishable and too fast
FLPP 1-2	06170069.MOV	6/17/2024	5:19:00	0	1	insect	insect flying
FLPP 1-2	06170070.MOV	6/17/2024	21:15:25	0	1		trees moving
FLPP 1-2	06170071.MOV	6/17/2024	21:17:20	0	1		trees moving
FLPP 1-2	06170072.MOV	6/17/2024	21:17:47	0	1		trees moving
FLPP 1-2	06170073.MOV	6/17/2024	21:20:54	0	1	insect	insect flying down
FLPP 1-2	06170074.MOV	6/17/2024	21:23:19	0	1	insect	insects flying (x4); also good for showing
FLPP 1-2	06170075.MOV	6/17/2024	21:53:52	0	1	insect	insects flying
FLPP 1-2	06170076.MOV	6/17/2024	21:54:21	0	1	insect	inscts flying and mosquito close up (good for outreach)
FLPP 1-2	06170077.MOV	6/17/2024	21:59:08	M	1	insects; leaf?	rain, leaves; upward path @ 21:59:14 potential to be a bat
FLPP 1-2	06170078.MOV	6/17/2024	22:01:00	0	1	insect	Something moving downward, likely insect
FLPP 1-2	06170079.MOV	6/17/2024	22:01:20	0	1	insect	lots of winds; insects flying; leaves flying
FLPP 1-2	06170080.MOV	6/17/2024	22:01:55	0	1	insect	moth flying; lots of wind (good to share)
FLPP 1-2	06170081.MOV	6/17/2024	22:04:07	0	1		trees moving
FLPP 1-2	06170082.MOV	6/17/2024	22:04:52	0	1		trees moving
FLPP 1-2	06170083.MOV	6/17/2024	22:05:14	M	1	likely insect	likely insect; dark shadow passing through center at 22:05:25, then a bright, odd-shaped animal coming from the right

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FLPP 1-2	06170084.MOV	6/17/2024	22:06:02	0	1		insects
FLPP 1-2	06170085.MOV	6/17/2024	22:06:44	0	1		insects and leaves flying around
FLPP 1-2	06170086.MOV	6/17/2024	22:07:24	M	1	likely insect	insects, something flying that could be larger @ 22:07:30?
FLPP 1-2	06170087.MOV	6/17/2024	22:08:33	0	1	insect	insects flying and something moved
FLPP 1-2	06170088.MOV	6/17/2024	22:09:38	0	1	insect	insects/leaves
FLPP 1-2	06170089.MOV	6/17/2024	22:10:08	0	1		trees moving
FLPP 1-2	06170090.MOV	6/17/2024	22:10:36	0	1	insect	insect flying/leaves falling; moth
FLPP 1-2	06170091.MOV	6/17/2024	22:10:56	0	1	insect	insect
FLPP 1-2	06170092.MOV	6/17/2024	22:12:16	0	1		trees moving
FLPP 1-2	06170093.MOV	6/17/2024	22:12:59	0	1		trees moving
FLPP 1-2	06170094.MOV	6/17/2024	22:13:45	0	1		something flying from l to right; too fast to distinguish
FLPP 1-2	06170095.MOV	6/17/2024	22:14:45	M -0	1	blurred object	something flying too quickly to distinguish, unlikely a bat, but possible; leaves falling
FLPP 1-2	06170096.MOV	6/17/2024	22:15:05	0	1	insect	clearly insect flying - good to share
FLPP 1-2	06170097.MOV	6/17/2024	22:15:42	0	1	insect	insects flying (moth)
FLPP 1-2	06170098.MOV	6/17/2024	22:16:48	0	1	insect	clearly insects flying around
FLPP 1-2	06170099.MOV	6/17/2024	22:17:34	0	1	insect	insect
FLPP 1-2	06170100.MOV	6/17/2024	22:18:40	0	1	insect	leaving falling; insects
FLPP 1-2	06170101.MOV	6/17/2024	22:19:39	0	1		insects
FLPP 1-2	06170102.MOV	6/17/2024	22:20:29	0	1	insect	beautiful moth flitting around; insect falling directly into a branch and falling??
FLPP 1-2	06170103.MOV	6/17/2024	22:21:03	M	1	insect; indistinguishable object	something moving very quickly at 22:21:03 to the right; good video of an insect
FLPP 1-2	06170104.MOV	6/17/2024	22:21:33	0	1	insect	moth (black at the end)

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FLPP 1-2	06170105.MOV	6/17/2024	22:21:54	0	1		insects flying (moth); (black at the end?)
FLPP 1-2	06170106.MOV	6/17/2024	22:22:05	0	1		trees moving (black at the end)
FLPP 1-2	06170107.MOV	6/17/2024	22:22:34	0	1		another t shaped insect? (black at the end)
FLPP 1-2	06170108.MOV	6/17/2024	22:24:54	0	1	likely insect	likely an insect
FLPP 1-2	06170109.MOV	6/17/2024	22:25:20	0	1		trees moving
FLPP 1-2	06170110.MOV	6/17/2024	22:27:02	0	1	insect	dragonfly?
FLPP 1-2	06170111.MOV	6/17/2024	22:29:16	0	1		trees moving
FLPP 1-2	06170112.MOV	6/17/2024	22:30:17	0	1	likely insect	blurred object coming towards camera; likely insect
FLPP 1-2	06170113.MOV	6/17/2024	22:33:28	0	1		trees moving
FLPP 1-2	06170114.MOV	6/17/2024	22:36:11	0	1	insect	insects
FLPP 1-2	06170115.MOV	6/17/2024	22:36:30	0	1		tree branches
FLPP 1-2	06170116.MOV	6/17/2024	22:37:33	0	1	insect	moth flying across from R to L
FLPP 1-2	06170117.MOV	6/17/2024	22:38:21	0	1		trees moving
FLPP 1-2	06170118.MOV	6/17/2024	22:39:08	0	1		trees moving (black at the end)
FLPP 1-2	06170119.MOV	6/17/2024	22:39:55	0	1		insct flying (black at the end)
FLPP 1-2	06170120.MOV	6/17/2024	22:40:09	0	1		trees moving (black at the end)
FLPP 1-2	06170121.MOV	6/17/2024	22:40:16	0	1	insect	insect moving
FLPP 1-2	06170122.MOV	6/17/2024	22:41:22	0	1	insect	moth flying (good for outreach); leaf falling (black at the end)
FLPP 1-2	06170123.MOV	6/17/2024	22:41:45	0	1		trees moving
FLPP 1-2	06170124.MOV	6/17/2024	22:42:33	0	1		moth/leaf fluttering
FLPP 1-2	06170125.MOV	6/17/2024	22:44:13	0	1	insect	moth (good for outreach)
FLPP 1-2	06170126.MOV	6/17/2024	22:57:27	0	1		trees moving
FLPP 1-2	06170127.MOV	6/17/2024	23:00:19	0	1		trees moving
FLPP 1-2	06170128.MOV	6/17/2024	23:01:05	0	1		trees moving
FLPP 1-2	06170129.MOV	6/17/2024	23:03:50	0	1	insect	moth

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FLPP 1-2	06170130.MOV	6/17/2024	23:04:30	0	1			Something indistinguishable flying
FLPP 1-2	06170131.MOV	6/17/2024	23:05:50	0	1		insect	two moths flying
FLPP 1-2	06170132.MOV	6/17/2024	23:12:14	0	1		insect	insects moving
FLPP 1-2	06170133.MOV	6/17/2024	23:13:55	0	1			leaf dropping (black at the end)
FLPP 1-2	06170134.MOV	6/17/2024	23:18:23	0	1		insect	moth flying
FLPP 1-2	06170135.MOV	6/17/2024	23:19:58	0	1			Something indistinguishable moving
FLPP 1-2	06170136.MOV	6/17/2024	23:21:56	0	1			trees moving
FLPP 1-2	06170137.MOV	6/17/2024	23:24:12	0	1			trees moving
FLPP 1-2	06170138.MOV	6/17/2024	23:25:06	0	1			trees moving
FLPP 1-2	06170139.MOV	6/17/2024	23:27:35	0	1	1	flying squirrel	something flying/jumping up - likely flying squirrel (whiskers, flat tail, legs); (*Glaucomys sabrinus*)
FLPP 1-2	06170140.MOV	6/17/2024	23:27:59	0	1			odd shadow
FLPP 1-2	06170141.MOV	6/17/2024	23:28:05	0	1			trees moving
FLPP 1-2	06170142.MOV	6/17/2024	23:28:34	0	1			trees moving
FLPP 1-2	06170143.MOV	6/17/2024	23:28:51	0	1			trees moving
FLPP 1-2	06170144.MOV	6/17/2024	23:35:02	0	1			trees moving
FLPP 1-2	06170145.MOV	6/17/2024	23:36:36	M	1		blurred object	dark shadow flying quickly by @ 22:36:37
FLPP 1-2	06170146.MOV	6/17/2024	23:37:06	0	1			insects
FLPP 1-2	06170147.MOV	6/17/2024	23:38:53	0	1			trees
FLPP 1-2	06170148.MOV	6/17/2024	23:39:02	0	1			trees
FLPP 1-2	06170149.MOV	6/17/2024	23:39:09	0	1			trees
FLPP 1-2	06170150.MOV	6/17/2024	23:40:16	0	1		insect	moth flying
FLPP 1-2	06170151.MOV	6/17/2024	23:40:34	0	1		insect	insect
FLPP 1-2	06170152.MOV	6/17/2024	23:42:23	0	1			leaves moving (black at the end)
FLPP 1-2	06170153.MOV	6/17/2024	23:42:38	0	1			leaves moving (black at the end)

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FLPP 1-2	06170154.MOV	6/17/2024	23:55:28	0	1		leaves moving (black at the end)
FLPP 1-2	06180155.MOV	6/18/2024	0:00:23	0	1	insect	luna moth?
FLPP 1-2	06180156.MOV	6/18/2024	0:01:35	0	1		insect flying
FLPP 1-2	06180157.MOV	6/18/2024	0:05:49	0	1		leaves moving
FLPP 1-2	06180158.MOV	6/18/2024	0:06:21	0	1		leaves moving
FLPP 1-2	06180159.MOV	6/18/2024	0:10:50	0	1		leaves moving
FLPP 1-2	06180160.MOV	6/18/2024	0:11:05	0	1		leaves moving
FLPP 1-2	06180161.MOV	6/18/2024	0:11:09	0	1		leaves moving
FLPP 1-2	06180162.MOV	6/18/2024	0:12:45	0	1		leaves moving
FLPP 1-2	06180163.MOV	6/18/2024	0:14:27	0	1		leaves moving
FLPP 1-2	06180164.MOV	6/18/2024	0:16:14	0	1		leaves moving
FLPP 1-2	06180165.MOV	6/18/2024	0:23:57	0	1		leaves moving
FLPP 1-2	06180166.MOV	6/18/2024	0:45:22	0	1		leaves moving
FLPP 1-2	06180167.MOV	6/18/2024	1:14:12	0	1		leaves moving
FLPP 1-2	06180168.MOV	6/18/2024	1:25:42	0	1		leaves moving
FLPP 1-2	06180169.MOV	6/18/2024	1:25:55	0	1		leaves moving
FLPP 1-2	06180170.MOV	6/18/2024	1:33:54	0	1		leaves moving
FLPP 1-2	06180171.MOV	6/18/2024	1:46:45	0	1	insect	insect flying near leaves
FLPP 1-2	06180172.MOV	6/18/2024	1:47:48	0	1		leaves moving
FLPP 1-2	06180173.MOV	6/18/2024	1:51:44	0	1		leaves moving
FLPP 1-2	06180174.MOV	6/18/2024	1:53:12	0	1		leaves moving
FLPP 1-2	06180175.MOV	6/18/2024	1:57:17	0	1	insect	insect flying
FLPP 1-2	06180176.MOV	6/18/2024	2:01:17	0	1		trees moving
FLPP 1-2	06180177.MOV	6/18/2024	2:03:06	0	1		trees moving
FLPP 1-2	06180178.MOV	6/18/2024	2:04:06	0	1		trees moving
FLPP 1-2	06180179.MOV	6/18/2024	2:06:36	0	1		trees moving
FLPP 1-2	06180180.MOV	6/18/2024	2:06:44	0	1		trees moving
FLPP 1-2	06180181.MOV	6/18/2024	2:07:42	0	1		trrees moving

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FLPP 1-2	06180182.MOV	6/18/2024	2:09:11	0	1	insect	moth flying; black at the end; short video
FLPP 1-2	06180183.MOV	6/18/2024	2:10:30	0	1		trees moving
FLPP 1-2	06180184.MOV	6/18/2024	2:11:12	0	1		trees moving
FLPP 1-2	06180185.MOV	6/18/2024	2:18:55	0	1		trees moving
FLPP 1-2	06180186.MOV	6/18/2024	2:19:00	0	1		trees moving
FLPP 1-2	06180187.MOV	6/18/2024	2:33:00	0	1		trees moving
FLPP 1-2	06180188.MOV	6/18/2024	2:33:42	0	1		trees moving
FLPP 1-2	06180189.MOV	6/18/2024	2:34:26	0	1		trees moving
FLPP 1-2	06180190.MOV	6/18/2024	5:02:14	0	1		leaf falling
FLPP 1-2	06180191.MOV	6/18/2024	5:13:54	0	1		leaves moving
FLPP 1-2	06190192.MOV	6/19/2024	21:22:58 PM	0	1		leaves moving; too much light
FLPP 1-2	06190193.MOV	6/19/2024	21:55:40	0	1	insect	lots of insect movement
FLPP 1-2	06190194.MOV	6/19/2024	22:00:41	0	1	insect	insecs moving
FLPP 1-2	06190195.MOV	6/19/2024	22:09:42	0	1	insect	insects moving
FLPP 1-2	06190196.MOV	6/19/2024	22:13:53	0	1	insect	insect, very likely based on wing shape; rain
FLPP 1-2	06190197.MOV	6/19/2024	22:23:11	0	1	insect	likely insect
FLPP 1-2	06200198.MOV	6/20/2024	0:59:15	M	1	likely insect	likely insect, based on flight path
FLPP 1-2	06200199.MOV	6/20/2024	10:52:26	0	1		taking down trail cam
FLPP 1-2	06200200.MOV	6/20/2024	10:53:31	0	1		taking down trail cam
FLPP 1-2	06200201.MOV	6/20/2024	11:31:29	0	1		taking down trail cam
FLPP 1-2	06200202.MOV	6/20/2024	11:33:27	0	1		taking down trail cam
FLPP 1-2	06200203.MOV	6/20/2024	11:34:53	0	1		taking down trail cam
FLPP 1-2	06200204.MOV	6/20/2024	11:35:22	0	1		taking down trail cam
FLPP 1-2	06200205.MOV	6/20/2024	11:41:26	0	1		taking down trail cam
FLPP 1-2	06200206.MOV	6/20/2024	11:46:41	0	1		taking down trail cam
FLPP 1-2	06200207.MOV	6/20/2024	15:34:52	0	1		in office
FLPP 1-2	06200208.MOV	6/20/2024	15:35:23	0	1		in office

FLPP 2-1	07050001.MOV	7/5/2024	10:29:10	0		1			tear down
FLPP 2-1	07050002.MOV	7/5/2024	10:29:27	0		1			tear down
FLPP 2-2	06280001.MOV	6/28/2024	11:42:38	0		1			tear down - Garry
FLPP 3-1	07020114.MOV	7/2/2024	16:32:35	0		1			set up
FLPP 3-1	07020115.MOV	7/2/2024	13:32:54	0		1			set up
FLPP 3-1	07040116.MOV	7/4/2024	21:19:30	0	1				wind blown particles; insects
FLPP 3-1	07040117.MOV	7/4/2024	23:24:04	0	1			insect	indistinguishable particles; moth with antenna
FLPP 3-1	07060118.MOV	7/6/2024	2:55:12	0	1			insect	large gusts of wind; insect
FLPP 3-1	07060119.MOV	7/6/2024	3:00:58	0	1				wind gust
FLPP 3-1	07060120.MOV	7/6/2024	3:25:39	0	1				shadow flying upward - indistinguishable
FLPP 3-1	07100121.MOV	7/10/2024	0:46:19	0	1		1	rodent	Likely a deer mouse (*Peromyscus maniculatus*)
FLPP 3-1	07100122.MOV	7/10/2024	0:54:55	0	1				wind and rain
FLPP 3-1	07100123.MOV	7/10/2024	1:30:05	0	1				wind and rain
FLPP 3-2	07020015.MOV	7/2/2024	17:04:40	0		1			set up
FLPP 3-2	07020016.MOV	7/2/2024	17:05:19	0		1			set up
FLPP 3-2	07020017.MOV	7/2/2024	17:23:10	0		1			set up
FLPP 3-2	07020018.MOV	7/2/2024	17:25:52	0		1			set up
FLPP 3-2	07100019.MOV	7/10/2024	14:46:39	0		1			tear down
FLPP 4-1	07170001.MOV	7/17/2024	10:31:55	0		1			deployment
FLPP 4-2	07050001.MOV	7/5/2024	15:53:11	0		1			deployment
FLPP 4-2	07050002.MOV	7/5/2024	15:53:32	0		1			deployment
FLPP 4-2	07050003.MOV	7/5/2024	15:53:48	0		1			deployment
FLPP 4-2	07050004.MOV	7/5/2024	15:54:04	0		1			deployment
FLPP 4-2	07050005.MOV	7/5/2024	15:54:21	0		1			deployment
FLPP 4-2	07050006.MOV	7/5/2024	15:54:38	0		1			deployment
FLPP 4-2	07050007.MOV	7/5/2024	15:54:57	0		1			deployment

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FLPP 4-2	07050008.MOV	7/5/2024	15:55:14	0		1			deployment
FLPP 4-2	07110009.MOV	7/11/2024	2:33:31	0	1				rain? Something indistinguishable (rain drop?)
FLPP 4-2	07110010.MOV	7/11/2024	2:33:48	0			1	shrew	Shrew, likely masked shrew (*Sorex cinereus*); something with a glowing eye was indistinguishable 02:33:57 (too fast - only one frame)
FLPP 5-1	07260001.MOV	7/26/2024	10:42:19	0		1			tear down - Garry
FLPP 5-2	07220001.MOV	7/22/2024	3:01:08	0	1			insect	no movement noticable (small movement from leaves; insect
FLPP 5-2	07250002.MOV	7/25/2024	22:56:58	0	1				leaves gently moving; insect; this branch at the top was not there in the prior video
FLPP 6-1	07190001.MOV	7/19/2024	13:33:47	0		1			set up
FLPP 6-1	07190002.MOV	7/19/2024	13:33:20	0		1			set up
FLPP 6-1	07190003.MOV	7/19/2024	13:34:41	0		1			set up
FLPP 6-1	07190004.MOV	7/19/2024	13:35:01	0		1			set up
FLPP 6-1	07190005.MOV	7/19/2024	13:35:18	0		1			set up
FLPP 6-1	07190006.MOV	7/19/2024	13:35:36	0		1			set up
FLPP 6-1	07190007.MOV	7/19/2024	13:35:53	0		1			set up
FLPP 6-1	07190008.MOV	7/19/2024	13:36:11	0		1			set up
FLPP 6-2	07190001.MOV	7/19/2024	14:06:47	0		1			set up
FLPP 6-2	07190002.MOV	7/19/2024	14:07:07	0		1			set up
FLPP 6-2	07190003.MOV	7/19/2024	14:07:21	0		1			set up
FLPP 6-2	07260004.MOV	7/26/2024	11:56:46	0		1			pick up
FLPP 6-2	07260005.MOV	7/26/2024	11:57:04	0		1			pick up
FLPP 7-1	08090001.MOV	8/9/2024	13:48:42	0		1			set up
FLPP 7-1	08090002.MOV	8/9/2024	13:49:58	0		1			set up
FLPP 7-1	08090003.MOV	8/9/2024	13:50:15	0		1			set up
FLPP 7-1	08090004.MOV	8/9/2024	13:50:33	0		1			set up

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FLPP 7-1	08090005.MOV	8/9/2024	13:50:50	0		1	set up
FLPP 7-1	08090006.MOV	8/9/2024	13:51:08	0		1	set up
FLPP 7-1	08090007.MOV	8/9/2024	13:51:26	0		1	set up
FLPP 7-1	08090008.MOV	8/9/2024	13:51:43	0		1	set up
FLPP 7-1	08090009.MOV	8/9/2024	13:58:50	0		1	set up
FLPP 7-2	08090001.MOV	8/9/2024	14:35:36	0		1	set up
FLPP 7-2	08090002.MOV	8/9/2024	14:46:08	0		1	set up
FLPP 7-2	08090003.MOV	8/9/2024	14:35:42	0		1	set up
FLPP 7-2	08180004.MOV	8/18/2024	1:45:33	0	1		tree
FLPP 7-2	08190005.MOV	8/19/2024	14:56:05	0		1	pick up
FLPP 7-2	08190006.MOV	8/19/2024	14:56:40	0	1		pick up

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Appendix G. Raw acoustic data from the 14 surveyed sites across all dates surveyed. For each site, all recordings were identified to species or species-group, when possible. When the acoustic data was of insufficient quality to make a species-group identification, the recording was identified based on phonic group: high frequency and low frequency species. All potential Northen Myotis (MYSE) detections were given a confidence level: high, medium/high, medium, low, and very low. Finally, if there was a species that was suspected, it is also indicated in parenthesis after the manual identifiection with the confidence level. Inclement weather is given as 0 (no bad weather events), 1 (sustained rain or winds > 15 km/h), or 2 (sustained rain and winds > 15 km/h). The last three columns give the weather variables in more details.

Site	# Survey Nights	Survey Night	HighF	40kMyo	MYSE (high)	40kMyo (MYSE, med/high)	40kMyo (MYSE, med)	40kMyo (MYSE, low)	40kMyo (MYSE, v low)	EPFULANO	EPFULANO (LANO, med)	LACI	LowF	LowF (LACI, low)	Noise	Total HighF Bats	Total LowF Bats	Total Bats	Inclement weather	Winds > 15km/h	Rain	Rain (mm)
FLPP 1-1	6	14-Jun	28	144	0	0	0	1	0	0	0	0	0	0	109	173	0	**173**	0			
FLPP 1-1	6	15-Jun	1	9	0	0	0	0	0	0	0	0	0	0	217	10	0	**10**	1		x	0.3
FLPP 1-1	6	16-Jun	6	207	0	0	0	2	2	0	0	0	0	0	57	217	0	**217**	0			
FLPP 1-1	6	17-Jun	4	44	0	0	0	0	0	0	0	0	0	0	61	48	0	**48**	1	x		
FLPP 1-1	6	18-Jun	5	92	0	0	0	1	0	0	1	0	0	0	26	98	1	**99**	1	x		
FLPP 1-1	6	19-Jun	0	10	0	0	0	0	0	0	0	0	0	0	37	10	0	**10**	1	x		
FLPP 1-2	6	14-Jun	0	3	0	0	0	0	0	0	0	0	0	0	13	3	0	**3**	0			
FLPP 1-2	6	15-Jun	1	3	0	1	0	0	0	0	0	0	0	0	24	5	0	**5**	1		x	0.3
FLPP 1-2	6	16-Jun	1	112	0	0	0	0	1	0	0	0	0	0	37	114	0	**114**	0			
FLPP 1-2	6	17-Jun	2	56	0	0	0	0	0	0	0	0	0	0	32	58	0	**58**	1	x		
FLPP 1-2	6	18-Jun	1	294	0	0	0	0	0	0	0	0	0	0	18	295	0	**295**	1	x		
FLPP 1-2	6	19-Jun	0	47	0	0	0	1	0	0	0	0	0	0	23	48	0	**48**	1	x		
FLPP 2-1	7	28-Jun	0	1	0	0	0	0	0	0	0	0	0	0	18	1	0	**1**	0			
FLPP 2-1	7	29-Jun	0	3	0	0	0	0	0	0	0	0	0	0	61	3	0	**3**	2	x	x	0.24

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Site	# Survey Nights	Survey Night	HighF	40kMyo	MYSE (high)	40kMyo (MYSE, med/high)	40kMyo (MYSE, med)	40kMyo (MYSE, low)	40kMyo (MYSE, v low)	EPFULANO	EPFULANO (LANO, med)	LACI	LowF	LowF (LACI, low)	Noise	Total HighF Bats	Total LowF Bats	Total Bats	Inclement weather	Winds > 15km/h	Rain	Rain (mm)
FLPP 2-1	7	30-Jun	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	**0**	1	x		
FLPP 2-1	7	1-Jul	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	**0**	0			
FLPP 2-1	7	2-Jul	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	**0**	0			
FLPP 2-1	7	3-Jul	0	2	0	0	0	0	0	0	0	0	0	0	16	2	0	**2**	1		x	8.13
FLPP 2-1	7	4-Jul	0	2	0	0	0	0	0	0	0	0	0	0	26	2	0	**2**	0			
FLPP 2-2	7	28-Jun	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	**0**	0			
FLPP 2-2	7	29-Jun	0	0	0	0	0	0	0	0	0	0	0	0	94	0	0	**0**	2	x	x	0.24
FLPP 2-2	7	30-Jun	0	1	0	0	0	0	0	0	0	0	0	0	7	1	0	**1**	1	x		
FLPP 2-2	7	1-Jul	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	**0**	0			
FLPP 2-2	7	2-Jul	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	**0**	0			
FLPP 2-2	7	3-Jul	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	**0**	1		x	8.13
FLPP 2-2	7	4-Jul	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	**0**	0			
FLPP 3-1	8	2-Jul	0	1	0	0	0	0	0	0	0	0	0	0	3	1	0	**1**	0			
FLPP 3-1	8	3-Jul	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	**0**	0			
FLPP 3-1	8	4-Jul	0	1	0	0	0	1	0	0	0	0	1	0	3	2	1	**3**	1	x		
FLPP 3-1	8	5-Jul	0	3	0	0	0	0	0	0	0	0	0	0	25	3	0	**3**	1	x		
FLPP 3-1	8	6-Jul	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	**0**	2	x	x	6.5
FLPP 3-1	8	7-Jul	0	1	0	0	0	0	0	0	0	0	0	0	2	1	0	**1**	0			
FLPP 3-1	8	8-Jul	0	4	0	0	0	0	0	0	0	0	0	0	7	4	0	**4**	0			
FLPP 3-1	8	9-Jul	0	2	0	0	0	0	0	0	0	0	0	0	285	2	0	**2**	0			

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Site	# Survey Nights	Survey Night	HighF	40kMyo	MYSE (high)	40kMyo (MYSE, med/high)	40kMyo (MYSE, med)	40kMyo (MYSE, low)	40kMyo (MYSE, v low)	EPFULANO	EPFULANO (LANO, med)	LACI	LowF	LowF (LACI, low)	Noise	Total HighF Bats	Total LowF Bats	Total Bats	Inclement weather	Winds > 15km/h	Rain	Rain (mm)
FLPP 3-2	8	2-Jul	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	**0**	0			
FLPP 3-2	8	3-Jul	0	7	0	0	0	0	0	0	0	0	0	0	2	7	0	**7**	0			
FLPP 3-2	8	4-Jul	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	**0**	1	x		
FLPP 3-2	8	5-Jul	0	1	0	0	0	0	0	0	0	0	0	0	11	1	0	**1**	1	x		
FLPP 3-2	8	6-Jul	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	**0**	2	x	x	6.5
FLPP 3-2	8	7-Jul	0	0	0	0	0	0	0	0	0	0	0	1	15	0	1	**1**	0			
FLPP 3-2	8	8-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0			
FLPP 3-2	8	9-Jul	0	0	0	0	0	0	0	0	0	0	0	0	1211	0	0	**0**	0			
FLPP 4-1	6	5-Jul	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	**0**	1	x		
FLPP 4-1	6	6-Jul	0	0	0	0	0	0	0	0	0	0	0	0	1197	0	0	**0**	1	x		
FLPP 4-1	6	7-Jul	0	1	0	0	0	0	0	0	0	0	0	0	2	1	0	**1**	0			
FLPP 4-1	6	8-Jul	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	**0**	1	x		
FLPP 4-1	6	9-Jul	0	7	0	0	0	0	0	0	0	0	0	0	383	7	0	**7**	1	x		
FLPP 4-1	6	10-Jul	0	1	0	0	0	0	0	0	0	0	0	0	1041	1	0	**1**	0			
FLPP 4-2	13	5-Jul	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	**0**	1	x		
FLPP 4-2	13	6-Jul	0	0	0	0	0	0	0	0	0	0	0	0	1187	0	0	**0**	2	x	x	3.4
FLPP 4-2	13	7-Jul	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	**0**	0			
FLPP 4-2	13	8-Jul	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	**0**	1	x		
FLPP 4-2	13	9-Jul	0	3	0	0	0	0	0	0	0	0	0	0	323	3	0	**3**	2	x	x	0.3
FLPP 4-2	13	10-Jul	0	1	0	0	0	0	0	0	0	0	0	0	1721	1	0	**1**	1		x	3.3

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FLPP 4-2	13	11-Jul	0	1	0	0	0	0	0	0	0	0	0	0	1958	1	0	**1**	2	x	x	4.83
FLPP 4-2	13	12-Jul	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	**0**	0			
FLPP 4-2	13	13-Jul	0	1	0	0	0	0	0	0	0	0	0	0	3	1	0	**1**	0			
FLPP 4-2	13	14-Jul	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	**0**	1	x		
FLPP 4-2	13	15-Jul	0	3	0	0	0	0	0	0	0	0	0	0	5	3	0	**3**	1	x		
FLPP 4-2	13	16-Jul	0	1	0	0	0	0	0	0	0	0	0	0	478	1	0	**1**	1	x		
FLPP 5-1	14	12-Jul	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	**0**	1	x		
FLPP 5-1	14	13-Jul	1	0	0	0	0	0	0	0	0	0	0	0	2	1	0	**1**	0			
FLPP 5-1	14	14-Jul	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	**0**	0			
FLPP 5-1	14	15-Jul	1	0	0	0	0	0	0	0	0	0	0	0	3	1	0	**1**	0			
FLPP 5-1	14	16-Jul	0	0	0	0	0	0	0	0	0	0	0	0	335	0	0	**0**	2	x	x	5.2
FLPP 5-1	14	17-Jul	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	**0**	1	x		
FLPP 5-1	14	18-Jul	0	1	0	0	0	0	0	0	0	0	0	0	35	1	0	**1**	1	x		
FLPP 5-1	14	19-Jul	0	1	0	0	0	0	0	0	0	0	0	0	3	1	0	**1**	0			
FLPP 5-1	14	20-Jul	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**0**	0			
FLPP 5-1	14	21-Jul	0	1	0	0	0	0	0	0	0	0	0	0	4	1	0	**1**	0			
FLPP 5-1	14	22-Jul	0	0	0	0	0	0	1	0	0	0	0	0	4	1	0	**1**	0			
FLPP 5-1	14	23-Jul	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**0**	0			
FLPP 5-1	14	24-Jul	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	**0**	0			
FLPP 5-1	14	25-Jul	0	1	0	0	0	0	0	0	0	0	0	0	976	1	0	**1**	1		x	2.4

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FLPP 5-2	1	12-Jul	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**0**	1	x		
FLPP 6-1	7	19-Jul	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	**0**	0			
FLPP 6-1	7	20-Jul	1	3	0	0	0	0	0	0	0	0	0	0	1	4	0	**4**	1	x		
FLPP 6-1	7	21-Jul	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	**0**	0			
FLPP 6-1	7	22-Jul	1	0	0	0	0	0	0	0	0	0	0	0	3	1	0	**1**	0			
FLPP 6-1	7	23-Jul	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	**0**	0			
FLPP 6-1	7	24-Jul	0	0	0	0	0	0	0	0	0	0	0	0	26	0	0	**0**	0			
FLPP 6-1	7	25-Jul	0	0	0	0	0	0	0	0	0	0	0	0	115	0	0	**0**	2	x	x	5.4
FLPP 6-2	7	19-Jul	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	**0**	0			
FLPP 6-2	7	20-Jul	1	4	0	0	0	0	0	0	0	0	0	0	2	5	0	**5**	1	x		
FLPP 6-2	7	21-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0			
FLPP 6-2	7	22-Jul	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	**0**	0			
FLPP 6-2	7	23-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0			
FLPP 6-2	7	24-Jul	0	1	0	0	0	0	0	0	0	0	0	0	7	1	0	**1**	0			
FLPP 6-2	7	25-Jul	0	36	0	0	0	1	0	0	0	0	0	0	30	37	0	**37**	2	x	x	5.4
FLPP 7-1	10	9-Aug	2	42	1	2	2	2	5	0	0	0	1	0	1260	56	1	**57**	2	x	x	4.1
FLPP 7-1	10	10-Aug	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**	1	x		
FLPP 7-1	10	11-Aug	1	9	0	0	1	0	0	0	0	1	0	0	98	11	1	**12**	0			
FLPP 7-1	10	12-Aug	0	10	0	0	0	0	0	0	0	0	0	0	15	10	0	**10**	0			
FLPP 7-1	10	13-Aug	0	18	0	0	0	0	0	0	0	0	0	1	27	18	1	**19**	0			

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FLPP 7-1	10	14-Aug	0	33	0	0	0	0	1	0	0	0	0	0	19	34	0	**34**	0			
FLPP 7-1	10	15-Aug	2	19	0	0	0	0	0	0	0	0	0	0	17	21	0	**21**	0			
FLPP 7-1	10	16-Aug	3	7	0	0	0	0	0	0	0	0	0	1	19	10	1	**11**	0			
FLPP 7-1	10	17-Aug	2	10	0	0	0	0	0	0	0	0	0	0	13	12	0	**12**	0			
FLPP 7-1	10	18-Aug	7	15	0	0	0	0	0	0	0	1	1	0	31	22	2	**24**	0			
FLPP 7-2	10	9-Aug	0	2	0	0	0	0	0	0	0	0	0	0	10	2	0	**2**	2	x	x	4.1
FLPP 7-2	10	10-Aug	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	**0**	1	x		
FLPP 7-2	10	11-Aug	1	4	0	0	0	1	0	0	0	0	0	0	12	6	0	**6**	0			
FLPP 7-2	10	12-Aug	2	1	0	0	0	0	0	0	0	0	0	0	38	3	0	**3**	0			
FLPP 7-2	10	13-Aug	3	5	0	0	0	0	0	0	0	1	0	0	14	8	1	**9**	0			
FLPP 7-2	10	14-Aug	2	10	0	0	0	0	0	0	0	0	0	0	13	12	0	**12**	0			
FLPP 7-2	10	15-Aug	2	10	0	0	0	0	0	0	0	0	0	0	18	12	0	**12**	0			
FLPP 7-2	10	16-Aug	3	6	0	0	0	0	0	1	0	0	0	0	25	9	1	**10**	0			
FLPP 7-2	10	17-Aug	0	2	0	0	0	0	0	0	0	0	0	0	29	2	0	**2**	0			
FLPP 7-2	10	18-Aug	2	5	0	0	0	0	0	0	0	1	0	0	12	7	1	**8**	0			