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Acoustic Evidence of Hoary Bats (*Lasiurus cinereus*) on Newfoundland, Canada

Darrian P. Washinger[1,*], Raymond Reid[2], and Erin E. Fraser[3]

Abstract - We report 4 occurrences of *Lasiurus cinereus* (Hoary Bat) on the island of Newfoundland, Canada, based on over 50,000 full-spectrum recordings of echolocation calls made at 94 sites, in Gros Morne National Park, between 2013 and 2019. Our detections of few vocalizations by Hoary Bats over multiple years and locations support prior observations that this species is an infrequent vagrant in western Newfoundland and likely not a summer resident.

Introduction

Lasiurus cinereus (Palisot de Beauvois) (Hoary Bat) is one of the most widespread species of bat in the Western Hemisphere, ranging from the mid-latitudes of Canada to South America (Cryan et al. 2014, Harvey et al. 2011, Shump and Shump 1982). This species is non-colonial and tends to roost concealed in the foliage of trees (Cryan et al. 2014, Harvey et al. 2011). While it is challenging to track seasonal movement of bats, all Hoary Bats in northern populations were previously believed to make long-distance seasonal migrations to southern wintering grounds (Cryan et al. 2014). Recent evidence, however, suggests that annual movements of this species are more complicated, with evidence of 3 behaviors: site fidelity, local linear travel, and multi-directional long-distance (>1000 km in 1 month) travel (Morningstar and Sandilands 2019, Weller et al. 2016). Additionally, substantial movements may occur outside the typical autumn and spring migratory periods, including during summer (Morningstar and Sandilands 2019).

As a result of their high mobility, Hoary Bats have frequently colonized remote oceanic islands (Bonaccorso and McGuire 2013). For example, Hoary Bats reside on Hawaii, Bermuda, and the Galapagos Islands, and vagrants have been reported on Iceland, Hispaniola, and Scotland's Orkney Islands (Bonaccorso and McGuire 2013, Cryan 2003, McCracken et al. 1997, Shump and Shump 1982). However, the northeastern extent of the species' geographic range is still not well documented. Records of Hoary Bats exist for Quebec (Faure-Lacroix et al. 2020), but this species has not been detected in Labrador (Burns et al. 2015). In addition, Segers et al. (2013) recently captured the first Hoary Bat on Cape Breton Island, NS, Canada, less than 175 km

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from the western coast of Newfoundland. Hoary Bats, though, can travel more than 175 km in a single night (e.g., Morningstar and Sandilands 2019), making it possible that members of this species are consistently present on Newfoundland.

Nevertheless, there has been little documentation of Hoary Bats on the island. On 18 October 2018, a live Hoary Bat was photographed on an oil-production facility off the east coast of Newfoundland (J. Humber, Department of Fisheries and Land Resources, Corner Brook, NL, Canada, pers. comm.). Previously, Maunder (1988) reported 1 unconfirmed acoustic recording collected near Little Grand Lake on 29 August 1986 and 1 injured individual found in a residential area of St. Johns on 14 August 1984 that died shortly after its discovery. Maunder (1988:728) presumed the species to be a "regular, though probably rare, late summer and fall visitor (or straggler) to the whole Atlantic Provinces region of Canada." In the present study, we document and quantify activity of Hoary Bats on the west coast of Newfoundland, by examining full-spectrum recordings of echolocation calls collected in Gros Morne National Park (GMNP) and the surrounding area from 2013 to 2019, during various bat-monitoring and research projects.

Field-site Description

We conducted acoustic monitoring at sites throughout GMNP, in community enclaves associated with the park, and at 5 locations just outside its boundary (Fig. 1). The park (1805 km^2) spans the ecoregions of Western Newfoundland Forest, Northern Peninsula Forest, and Long Range Highlands and includes a matrix of ecosystems, that vary across altitudes and bedrock types (Damman 1983). While there are alpine communities located at higher elevations, lower elevations are dominated by boreal forest and bog ecosystems (Damman 1983). Due to the region's cool, wet climate (>180 days of precipitation per year), wildfire is rare, and outbreaks of defoliating insects are the principal agent of disturbance, leading to development of forests dominated by *Abies balsamea* (L.) (Balsam Fir) (Thompson et al. 2003).

Methods

We conducted monitoring with acoustic detectors (model SM2BAT+, Wildlife Acoustics, Concord, MA) that were deployed using manufacturer-recommended settings (sampling rate of 384 kHz, maximum trigger length of 20 sec, and 2-sec timeout) and programmed to create WAV files. We set detectors to record from 30 min prior to sunset until 30 min after sunrise, but if equipment malfunctioned, we still analyzed recordings from partial nights. We affixed microphones with a foam windscreen horizontally to a 6-m-tall pole that was set along forest edges, with the microphone oriented towards open areas to maximize the volume of sampled airspace and reduce interference from acoustic clutter (i.e., objects interfering with clear recording of echolocation calls).

We deployed detectors between May and November at a total of 94 sites, although sampling effort and locations varied considerably among years (Table 1).

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From 2013 to 2016 and in 2019, most monitoring sites were accessible by road, and we placed detectors in small forest clearings, by water sources, at campgrounds, along forest trails, and in day-use areas at elevations of approximately 1–450 m. In 2013, recording took place at 29 sites from June to October, for 4–57 nights each.

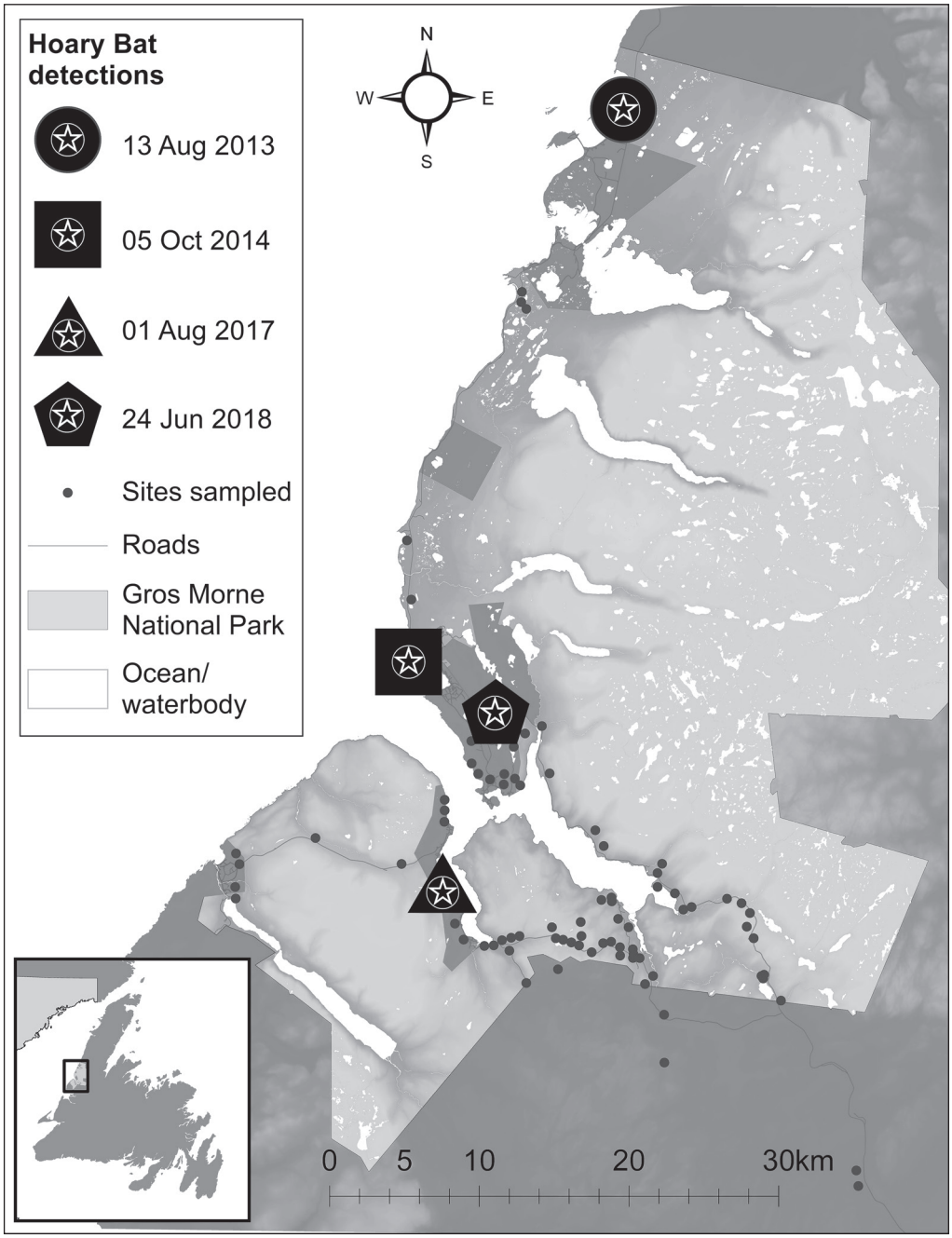

Figure 1. Locations of 4 detections of *Lasiurus cinereus* (Hoary Bat) in Gros Morne National Park, NL, Canada, obtained by acoustic surveys from 2013 to 2019.

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Similarly, in 2014, we monitored 24 locations from June to November, for 1–119 nights per site. From 2015 to 2019, monitoring followed the protocol of the North American Bat Monitoring Program (NABat; Loeb et al. 2015); sampling occurred at the same 12 locations each year, for a minimum of 4 nights during either June or July. In addition to the NABat sites, we monitored 1 site for 117 nights between May and October 2016.

In 2017 and 2018, we recorded at an additional 36 and 63 sites, respectively, for use in a habitat analysis. For this project, we completed acoustic monitoring from mid-June to mid-August in the Western Newfoundland Forest Ecoregion of GMNP and associated enclaves, in 4 different stand types: mature mixed forests,

Table 1. Yearly summaries of the acoustic sampling effort for bats in Gros Morne National Park, NL, Canada. Total number of sites, number of survey nights, total bat passes from each software program (Kaleidoscope Pro 4.3.2 and Sonobat 4.2.1), and the number of automated identifications of *Lasiurus cinereus* (Hoary Bat) are shown for each year and month. Recordings identified as a Hoary Bat by either program were further manually examined and confirmed, as were any recordings containing calls with a minimum frequency of <30 kHz and/or exceeding 9 msec in duration.

				Kaleidoscope		Sonobat		Manually examined	
Year	Month	# of sites	# of survey nights	Total # of bat passes	Total # of *L. cinereus* files	Total # of bat passes	Total # of *L. cinereus* files	Total # of calls examined	Confirmed # of calls of *L. cinereus*
2013	Jun	8	14	4701	47	3477	0	64	0
2013	Jul	18	31	8008	6	7218	0	21	0
2013	Aug	15	25	10,439	11	8508	1	39	1
2013	Sep	7	29	1187	2	817	0	8	0
2013	Oct	6	4	233	0	107	0	0	0
2014	Jun	7	19	2658	1	2311	0	15	0
2014	Jul	11	31	8847	7	6525	0	82	0
2014	Aug	9	31	14,317	5	10,804	0	367	0
2014	Sep	7	25	1750	2	1484	0	82	0
2014	Oct	6	22	396	1	342	1	2	1
2014	Nov	1	1	0	0	0	0	0	0
2015	Jul	12	15	455	0	358	0	11	0
2016	May	1	26	310	0	239	0	0	0
2016	Jun	5	18	3921	0	3355	0	5	0
2016	Jul	7	31	3110	3	2668	0	9	0
2016	Aug	2	27	1868	0	1594	0	2	0
2016	Sep	1	11	71	0	72	0	0	0
2016	Oct	1	4	5	0	8	0	0	0
2017	Jun	3	5	12	2	9	0	2	0
2017	Jul	30	31	859	13	851	0	24	0
2017	Aug	14	12	724	3	618	1	5	1
2018	Jun	22	11	2506	12	1919	0	38	1
2018	Jul	50	31	2750	18	2186	0	29	0
2018	Aug	13	11	279	6	234	0	21	0
2019	Jun	4	14	912	1	668	0	14	0
2019	Jul	10	21	1852	8	419	0	14	0

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mature coniferous forests, regenerating forests, and moose meadows (forested stands that were disturbed by insect defoliation but failed to regenerate due to over-browsing by hyperabundant *Alces alces* (L.) [Moose] and were characterized by grasses, ferns, non-palatable shrubs, and an open canopy [Gosse et al. 2011]). Locations were generally equally distributed among the 4 stand types. We placed detectors in stands that were accessible by foot and located <2 km from a road and >500 m from the nearest neighboring survey site. Within each stand, we placed acoustic detectors >50 m from any water source, hiking path, road, or stand edge to minimize edge effects.

We analyzed each acoustic recording using 2 software packages: Sonobat 4.2.1 (Arcata, CA; www.sonobat.com) and Kaleidoscope Pro 4.3.2 (Wildlife Acoustics, Concord, MA; www.wildlifeacoustics.com). We used the recommended settings for both programs, except that the minimum number of pulses considered by Sonobat for identification was lowered to ≥2, to increase the number of species-level identifications. We used the regional classifiers for both packages, "Bats of North America 4.3.0/NL" for Kaleidoscope and "North-northeastern US" for Sonobat, which allowed identifications of 8 species: *Eptesicus fuscus* (Palisot de Beauvois) (Big Brown Bat), *Lasiurus borealis* (Müller) (Eastern Red Bat), the Hoary Bat, *Lasionycteris noctivagans* (Le Conte) (Silver-haired Bat), *Myotis leibii* (Audubon and Bachman) (Small-footed Myotis), *M. lucifugus* (Le Conte) (Little Brown Myotis), and *M. septentrionalis* (Trouessart) (Northern Myotis), although the latter 2 species are the only ones known to reside on the island (Park and Broders 2012).

After noise was filtered from the recordings, output from each package included a species-level identification of each bat pass, when possible. We considered a recording to be a bat pass if the automated program made a species-level identification or detected characteristics of echolocation pulses without being able to identify to species. Each recording that was labeled as a Hoary Bat by either package was manually examined by 2 experienced operators (D.P. Washinger and E.E. Fraser), using Sonobat. Manual identification of bat passes as being made by Hoary Bats was based on call characteristics reported in the literature (Barclay et al. 1999, Fenton and Bell 1981, Obrist 1995, O'Farrell et al. 1999), as well as comparisons with reference calls. In addition, we manually examined recordings that were automatically identified as a species with call characteristics similar to those of Hoary Bats (i.e., Silver-haired Bats) or that contained calls having a minimum frequency <30 kHz and exceeding 9 msec in duration. The operators considered a recording of echolocation calls to be made by a Hoary Bat if the minimum frequencies of the calls were between 18 and 22 kHz, the duration of the call was >9 msec, and the calls had the flat shape and narrow bandwidth characteristic of the species. Vocalizations of Hoary Bats can be similar to social calls of the Little Brown Myotis and some sounds made by rodents (Kalcounis-Rueppell et al. 2006). These alternative hypotheses, though, were considered unlikely, because we recorded away from known roosts to minimize detection of social calls, affixed microphones to a 6-m-tall pole to avoid rodent vocalizations, and inspected the full call sequence.

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Results

We collected a total of 144,528 recordings during 500 recording nights, in 7 different months, over 7 years. Recordings were made during May (n = 26 nights), June (81), July (191), August (106), September (65), October (30), and November (1). Echolocation calls were detected in 72,170 (Kaleidoscope) and 56,791 (Sonobat) recordings (Table 1). Most calls (95%) were attributed by each program to *Myotis* spp. or were unable to be identified to species. Some calls (5%) were attributed to Big Brown Bats, Silver-haired Bats, and Eastern Red Bats, although manual confirmation of these recordings was beyond the scope of our project. Of the 840 calls manually examined, nearly all (99%) were identified as noise or *Myotis* spp.; only 4 recordings were manually identified as being made by Hoary Bats (Figs. 1, 2). Recordings of Hoary Bat echolocation calls were made on 13 August 2013, 5 October 2014, 1 August 2017, and 24 June 2018. All recordings of Hoary Bats occurred at low-elevation sites (1–52 m).

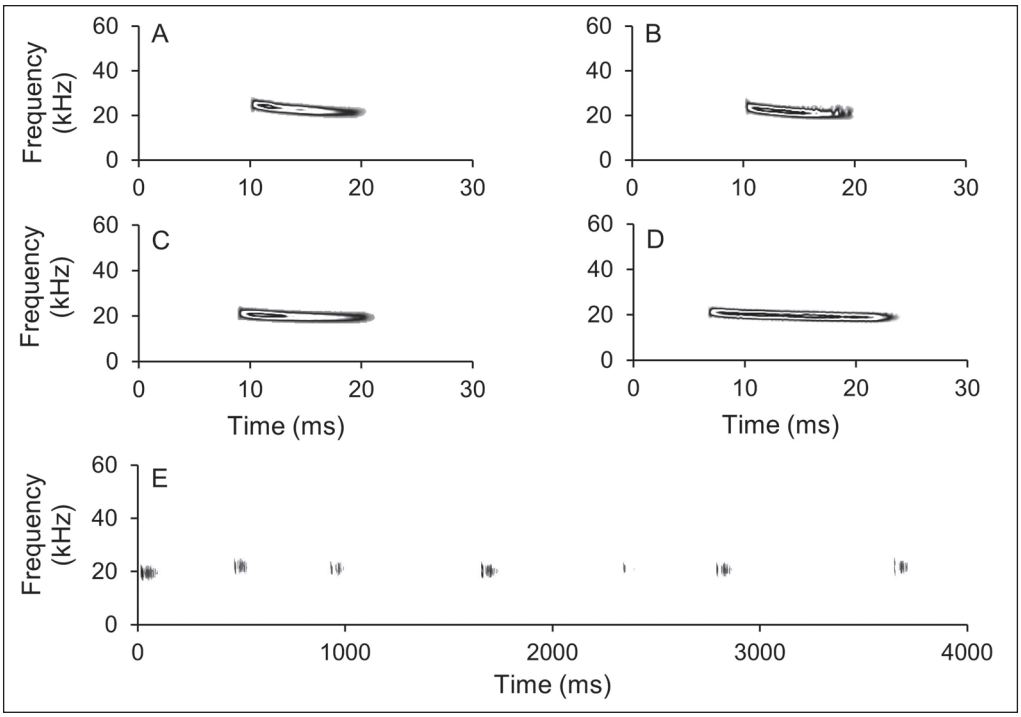

Figure 2. Echolocation calls identified as vocalizations from a *Lasiurus cinereus* (Hoary Bat) in Gros Morne National Park (NL, Canada) from 2013–2019. Call identification was based on automatic identification by at least 1 software package and subsequent manual inspection, including examination of multiple pulses within the sequence. Sonobat 4.2.1 was used to visualize calls and to measure the call parameters. (A) 13 August 2013, mean frequency 21.2 kHz (min–max: 20.7–23.4 kHz), duration 10.3 msec; (B) 5 October 2014, mean frequency 21.1 kHz (20.2–21.3 kHz), duration 9.7 msec; (C) 1 August 2017, mean frequency 19.2 kHz (18.9–20.0 kHz), duration 12.2 msec; (D) 24 June 2018, mean frequency 18.6 kHz (18.3–18.9 kHz), duration 17.3 ms; (E) 1 August 2017, first 4000 msec of the call sequence containing the call featured in (C).

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The Hoary Bat detection on 13 August 2013 had 5 distinct calls over the 4.1-sec recording. The detector was deployed in a clearing surrounded by semi-mature (41–60 years) Balsam Fir-dominated forest in Shallow Bay campground, ~125 m from the ocean (elevation: ~1 m above sea level). The recording from 5 October 2014 included 4 distinct calls over its 4.3-sec duration. This detector was placed in a coniferous scrub (crown closure ≥10%, height <3.5 m), located next to a semi-mature Balsam Fir-dominated forest and ~110 m from the coast (elevation: 21 m). On 1 August 2017, the detection had 16 distinct calls during the 13-sec recording. This detector was situated in a moose meadow surrounded by semi-mature Balsam Fir-dominated forest ~240 m from the coastline (elevation: 42 m). The detection from 24 June 2018 consisted of 3 distinct calls over 2.9 seconds. This detector was located above deciduous scrub at Bottom Brook ~3 km from the coast of Bonne Bay (elevation: 52 m).

Discussion

We detected only 4 Hoary Bats during 500 nights of acoustic monitoring over 7 years (Table 1). Nevertheless, the reliability of automated identification of bat echolocation calls is a contentious issue (Russo and Voigt 2016, Rydell et al. 2017), and our results further demonstrate the potential for disagreement among multiple software packages (Lemen et al. 2015). Our choice to perform manual examination of all potential recordings of Hoary Bat calls and to limit identifications to those showing only highly stereotypical characteristics of the species increases our confidence in identification accuracy, but such conservatism likely resulted in an underrepresentation of the actual number of recordings that included Hoary Bats. Furthermore, our study was not designed specifically to detect Hoary Bats, with microphones potentially not situated high enough to detect this species (Baerwald and Barclay 2009), so our field methods also could lead to underrepresentation of the species.

In addition to our acoustic records, we manually verified 2 other Hoary Bat detections that were obtained in western Newfoundland by the bat-monitoring program conducted by the provincial government (J. Humber, pers. comm.). These additional recordings occurred on 6 August 2018, at Prince Edward Park (50 km south of GMNP, <1 km from the coast of Humber Arm), and 13 August 2018, near a pond in the White Bay area (45 km northeast of GMNP, <15 km from the coast of White Bay). Our 4 verified detections, combined with these 2 acoustic records and the unconfirmed recording at Little Grand Lake (<100 km south of GMNP) on 29 August 1986 (Maunder 1988), suggest that Hoary Bats are only infrequent visitors to western Newfoundland.

Our sampling was restricted to GMNP and adjacent areas, which make up less than 2% of the total area of Newfoundland. Our study area may be particularly likely to have occasional Hoary Bats present because they could be using the western coastline as a migratory pathway (Cryan et al. 2014). All 4 of our Hoary Bat detections were obtained close to the coast (<3500 m; Fig. 1), as were the 2 detections recorded by the provincial government (<15 km). In addition, 3 of our recordings

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occurred in August–October, which coincides with the timing of late-summer/autumn migration (Cryan 2003; Cryan et al. 2004, 2014; Findley and Jones 1964), and the 3 recordings of Hoary Bats made by other researchers in western Newfoundland also were made during the migratory period (August). In aggregate, these observations, along with those by Segers et al. (2013) in Cape Breton, suggest that Hoary Bats are migrating along the coastlines of Nova Scotia and western Newfoundland, although location and frequency of summer residency by this species in northeastern Canada is largely unknown (Segers et al. 2013). Further investigation with monitoring efforts specifically designed to capture Hoary Bat vocalizations is necessary to understand more fully how common the species is in the rest of Newfoundland and, more broadly, to document the presence and activity of Hoary Bats throughout the year in northeastern Canada.

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