Inventory Methods for Bats

Standards for Components of British Columbia's Biodiversity No. 20

Prepared by
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Preface

This manual is an updated version of Inventory Methods for Bats, Standards for Components of British Columbia's Biodiversity No. 20. Version 2.0. The manual was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Information Standards Committee (RISC). The objectives of the working group are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series which presents standard protocols designed specifically for a group of species with similar inventory requirements. The series includes an introductory manual (Species Inventory Fundamentals No. 1) which describes the history and objectives of RISC, and outlines the general process of conducting a wildlife inventory according to RISC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The Species Inventory Fundamentals manual provides important background information and should be thoroughly reviewed before commencing with a RISC wildlife inventory. RISC standards are also available for vertebrate taxonomy (No. 2), animal capture and handling (No. 3), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in inventories that involve these activities.

Standard data forms are required for all RISC wildlife inventory. Survey-specific data forms accompany most manuals, while general wildlife inventory forms are available in the Species Inventory Fundamentals No. 1. This is important to ensure compatibility with provincial data systems, as all information must eventually be included in the Species Inventory Database. For more information about the Wildlife Species Inventory and relevant data submission templates, visit the Wildlife Species Inventory homepage (www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information).

It is recognized that development of standard methods is necessarily an ongoing process. Field testing is a vital component of this process, and feedback is essential. Comments and suggestions can be forwarded to the Resources Information Standards Committee (RISCWeb@gov.bc.ca).

Acknowledgments

The Government of British Columbia provides funding for the Resources Information Standards Committee's work, including the preparation of this document. The Resources Information Standards Committee supports the effective, timely, and integrated use of land and resource information for planning and decision-making by developing and delivering focused, cost-effective, common provincial standards and procedures for information collection, management, and analysis. Representatives of the Committee and its Task Forces are drawn from the ministries and agencies of the Canadian and the British Columbia governments, including academic, industry, and First Nations involvement.

The Resources Information Standards Committee evolved from the Resources Inventory Committee, which received funding from the Canada-British Columbia Partnership Agreement of Forest Resource Development (FRDA II), the Corporate Resource Inventory Initiative, and Forest Renewal BC, and addressed concerns of the 1991 Forest Resources Commission.

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For further information visit the RISC website at: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/inventory-standards/terrestrial-ecosystems-biodiversity
or email RISCWeb@gov.bc.ca

Terrestrial Ecosystems Task Force

All decisions regarding protocols are the responsibility of the Resources Information Standards Committee.

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We thank Cori Lausen (Wildlife Conservation Society Canada) for use of her figures throughout this document. Do not reproduce figures without permission from Cori Lausen.

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1 INTRODUCTION

Bats (Chiroptera), as a group, are highly diverse, second only to rodents in terms of number of mammalian species worldwide (Harvey et al. 2011). British Columbia (B.C.) has the most diverse bat fauna in Canada. All species regularly found in the province (i.e., not "Accidental"; Table 1) belong to the family Vespertilionidae, and nearly all feed exclusively on arthropods, most of which are flying insects. Six bat species currently appear on the province's Blue List (special concern) or Red List (endangered or threatened; Table 1), and most of them are near the northern extent of their ranges. Four species are listed federally under the *Species at Risk Act* (SARA; Table 1): Spotted Bat (*Euderma maculatum)*, Pallid Bat (*Antrozous pallidus)*, Little Brown Myotis (*Myotis lucifugus)*, and Northern Myotis (*Myotis septentrionalis*). One additional species, Fringed Myotis (*Myotis thysanodes*), is designated as Data Deficient by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Bats are important to biodiversity conservation and have high ecological and economic value (O'Shea and Bogan 2003; McCracken et al. 2006; Jones et al. 2009; Boyles et al. 2011; Riccucci and Lanza 2014). Scientific study of this group of mammals is vital for:

- monitoring the distribution and status of threatened and endangered bat species;
- informing environmental assessments;
- assessing the success of conservation efforts, including mitigation and enhancement activities; and,
- planning and conducting disease surveillance.

Bats are threatened by disturbance to, and destruction of, their foraging areas, roost sites, and hibernacula; collisions with wind turbines and vehicles; climate change; changes in prey base due to pesticides and toxic chemicals; and direct exposure to toxins. The spread of *Pseudogymnoascus destructans*, a fungus that causes the disease known as white-nose syndrome (WNS), has caused the death of millions of bats in eastern North America and may result in extirpation of certain bat species in many areas (Lorch et al. 2016). White-nose syndrome was discovered near Seattle, Washington in 2016 and is expected to spread into B.C. in the next few years. Most of the province's species have only one young per year (Nagorsen and Brigham 1993); therefore, they have a limited ability to recover from declines in population sizes. The combination of peripheral distribution and vulnerability may have important implications for the biology of the province's bats, and ultimately for their conservation.

Bats are difficult to study. They are small-bodied and mostly cryptically coloured, can travel long distances quickly, are active at night when they cannot be easily observed by humans, and spend the day hidden in sites that are often inaccessible or dangerous to people; most species also echolocate at frequencies that are inaudible to the human ear (O'Shea et al. 2003). Because bats often congregate in colonies, are rarely territorial, and are volant, the distribution of many species tends to be either irregular or clumped. Many techniques and sampling protocols used to assess habitat use or abundance of other wildlife species are therefore inappropriate for bats and very specific, bat inventory techniques are required.

Little is known about many aspects of bat biology, such as the seasonal distribution of species; their lifespans; the timing and nature of their reproduction; the requirements, locations, and mechanisms of overwintering; their migration routes and timing; and their selection and use of habitats (Holroyd et al. 2016). In particular, very poor information exists for winter hibernacula. Knowledge of summer roosts is biased toward studies of females.

Inventory Methods for Bats provides guidance to people who are conducting bat surveys in B.C. This manual is an updated and restructured version of the previous provincial standard inventory manual for bats (RIC 1998a). It provides updated and standardized sampling protocols for assessing bat community composition, relative abundance, and habitat associations of bats. The limitations associated with obtaining absolute abundance estimates for bats are discussed. The use of up-to-date and standardized methodologies will help to ensure that bat inventory projects are well-planned and effective, with results that are comparable among projects.

Use of the methods described in this manual is recommended for surveyors (e.g., qualified professionals) who apply for permits to capture bats, or design survey projects to support environmental assessments, inventory, monitoring and research on bats in B.C. The methods also provide up-to-date techniques to support other government legislation, policies and processes (e.g., *Canadian Environmental Assessment Act* and B.C. Environmental Assessment Office; B.C. Environmental Mitigation Policy and Procedures, B.C. Develop with Care 2014; Wildlife Habitat Areas or Wildlife Habitat Features under the Identified Wildlife Management Strategy, SARA Critical Habitat inventory).

Additional guidance on designing bat inventories to support impact assessments and develop mitigation for specific development sectors is provided in Best Management Practices for Bats in British Columbia. These documents should be consulted for industry-specific guidance regarding the scope and type of surveys to use, the questions that should be asked for particular development types, and the amount and type of data that should be collected to answer those questions. These documents are available at: https://a100.gov.bc.ca/pub/eirs/viewDocumentDetail.do?fromStatic=true&repository=BDP&documentId=12460

2 BAT STATUS AND DISTRIBUTION

Seventeen bat species have been documented in British Columbia, although only 15 are known to occur regularly (Table 1). Details on the biology, natural history, and distribution of the bat species of British Columbia are provided on the BC Species and Ecosystems Explorer website (https://a100.gov.bc.ca/pub/eswp/) and in Holroyd et al. (2016) Nagorsen and Brigham (1993), and van Zyll de Jong (1985). Species distribution maps are also available on the BC Species and Ecosystems Explorer website. Federal and provincial recovery strategies (www.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/species-ecosystems-at-risk/recovery-planning) and COSEWIC status reports (https://www.cosewic.ca/index.php/en-ca/status-reports.html) are available for some species. Table 1 summarizes the provincial and federal status and habitats of each species. The provincial status of three species is Accidental; another is Unknown. It has not been confirmed whether the records of these species are a result of accidental and infrequent incursions into the province or insufficient knowledge. Biologists should be vigilant and collect additional evidence of these species and other bat species that have not yet been recorded in the province.

Table 1. Bats of British Columbia (B.C.) and their status [a].

Species	Code	Provincial Listing	SARA Listing	Identified Wildlife	B.C. Habitat and Distribution
Spotted Bat (*Euderma maculatum*)	EUMA	Blue	Special Concern; Schedule 1	Yes	Arid landscapes of Southern Interior
Townsend's Big-eared Bat (*Corynorhinus townsendii*)	COTO	Blue	NA	No	Broad range of habitats in Southern Interior; few records from Lower Mainland
Pallid Bat (*Antrozous pallidus*)	ANPA	Red	Threatened; Schedule 1	No	Arid landscapes of Southern Interior (Okanagan/Similkameen)
Big Brown Bat (*Eptesicus fuscus*)	EPFU	Yellow	NA	No	Broad range of habitats throughout B.C.
Canyon Bat (*Parastrellus hesperus*)	PAHE	Accidental	NA	No	Arid landscapes; known only from acoustic recordings in extreme south Okanagan (Sarell et al. 2014)
Eastern Red Bat (*Lasiurus borealis*); formerly thought to be *L. blossevilli* (Nagorsen and Paterson 2012)	LABO	Unknown	NA	No	Broad range of habitats; carcass records from Peace and Skagit watersheds; acoustic recordings from Okanagan (see Nagorsen and Paterson 2012); unconfirmed calls and sightings from several other areas (C. Lausen, pers. comm., 2018)
Hoary Bat (*Lasiurus cinereus*)	(LACI)	Yellow	None	No	Broad range of forested habitats; throughout southern half of B.C. and the Peace watershed; appears to be absent from Haida Gwaii
Silver-haired Bat (*Lasionycteris noctivagans*)	LANO	Yellow	None	No	Broad range of forested habitats throughout B.C.

Species	Code	Provincial Listing	SARA Listing	Identified Wildlife	B.C. Habitat and Distribution
Californian Myotis (*Myotis californicus*)	MYCA	Yellow	None	No	Broad range of forested habitats throughout southern half of B.C., including Haida Gwaii
Western Small-footed Myotis (*Myotis ciliolabrum*)	MYCI	Blue	None	No	Arid and semi-arid habitats in Southern Interior; poorly documented in southern East and West Kootenay
Little Brown Myotis (*Myotis lucifugus*)	MYLU	Yellow	Endangered; Schedule 1	No	Broad range of habitats throughout B.C.
Yuma Myotis (*Myotis yumanensis*)	MYYU	Yellow	None	No	Broad range of habitats throughout southern third of B.C. extending up the coast to Alaska Panhandle
Long-legged Myotis (*Myotis volans*)	MYVO	Yellow	None	No	Broad range of habitats throughout B.C.
Long-eared Myotis (*Myotis evotis*) [b]	MYEV	Yellow	None	No	Broad range of habitats; likely throughout B.C.
Northern Myotis (*Myotis septentrionalis*)	MYSE	Red	Endangered; Schedule 1	No	Cool, moist forested habitats in northern B.C., as far south as Trout Lake in the southeast and Hazelton in the southwest; likely more extensive in suitable habitats
Fringed Myotis (*Myotis thysanodes*)	MYTH	Blue	Data Deficient; Schedule 3	Yes	Arid and semi-arid habitats in Southern Interior of B.C. as far east as Creston, and one location in the Lower Mainland; not yet known from East Kootenays
Brazilian Free-tailed Bat, also known as Mexican Free-tailed Bat, (*Tadarida brasiliensis*),	TABR	Accidental	None	No	Broad range of habitats; known from acoustic detections, mainly in southwest B.C. (Ommundsen et al. 2017), but recent acoustic detections elsewhere in southern B.C.

Species	Code	Provincial Listing	SARA Listing	Identified Wildlife	B.C. Habitat and Distribution
Big Free-tailed Bat (*Nyctinimops macrotis*)	NYMA	Accidental	None	No	Arid landscapes; specimen from Lower Mainland (Cowan 1945); suspected call heard from cliff near Kamloops (Sarell and Woodgate 1991); zero-crossing recording confirmed on Sunshine Coast (C. Lausen, pers. comm., 2018)

[a] Source: primarily Nagorsen and Brigham (1993); B.C. Conservation Data Centre (2013).

[b] *Myotis evotis* includes long-eared bats formerly identified as Keen's Myotis (*M. keenii;* Lausen et al. 2018).

3 PERMITTING AND QUALIFICATIONS

3.1 Qualifications

Crew leads for bat capture surveys must be sufficiently experienced in trapping and handling bats to obtain permits. Surveyors who are proposing to use invasive procedures (e.g., PIT tagging, radio telemetry) must also have experience with those techniques.

3.2 Permitting

More than one permit may be needed for bat inventory projects. The requirement for particular permits will depend on the species being targeted, the nature of the research, and the land ownership status of the study area. Land ownership information and parcel boundaries can be viewed and printed through the provincial iMapBC application (https://www2.gov.bc.ca/gov/content/data/geographic-data-services/web-based-mapping/imapbc). Permitting requirements by jurisdiction are summarized below. The time involved in obtaining a permit will vary with the time of year and the number of permits that are proceeding through the review process, so applications for permits should be made as soon as possible, and alternative plans should be considered in case permits are not received in time for fieldwork. Sufficient funding and time should be budgeted to prepare permit applications. Maps of proposed study areas must accompany all permit applications. These can be created through the provincial iMapBC application. Permits must be carried in the field at all times.

3.2.1 Provincial Permits

Surveys that involve capturing, handling, or disturbing bats require a General Wildlife Permit under the BC *Wildlife Act*. Applications for *Wildlife Act* permits are made online through FrontCounter BC (https://portal.nrs.gov.bc.ca/web/client/home). Applicants must ensure they follow the directions on the site and within the forms. They must describe the objectives of the planned project, provide a map of the study area, summarize the methodology, and list the personnel involved and their relevant experience.

The Animal Care Application (ACA) form accompanies the General Permit Application for projects that involve bat capture and handling. The ACA requires similar details as the permit application however it goes into substantial depth in the following areas: investigator experience, animal capture and handling methods, contingency planning and euthanasia. It must contain enough detail that the project and proposed methods can be understood without other supporting documents; its review will be quicker if the applicant completes it using the directions on the form.

Researchers who are proposing to mark bats, attach radio-transmitters, or conduct other more invasive procedures must fully explain their experience, justify the need for the work and describe contingency plans including how any injuries will be managed and how humane euthanasia will be performed in the field (i.e., AVMA Guidelines for the Euthanasia of Animals, 2020, or other relevant protocols). Surveys that involve only acoustic detection do not require a provincial permit at present. If you are unsure whether your surveys require a permit, contact the appropriate regional biologist or provincial small mammal specialist for clarification.

3.2.2 Provincial Parks and Protected Areas Permits

Research conducted within a provincial park or protected area must be authorized by BC Parks, and a Park Use Permit is required for any research activities that are not considered "consistent with public use" (BC Parks 2015). Activities for which a Park Use Permit is needed include animal capture, non-standard access (e.g., helicopter use), and access to restricted areas. Research by a provincial government agency (not including Crown corporations) does not require a Park Use Permit, but notification and liaison with BC Parks must still occur (BC Parks 2015). Research within an ecological reserve requires an Ecological Reserve Permit, which can be issued only for scientific research that is "concerned with any aspect of the ecology of the reserve(s) in question and intends to increase knowledge of that study area using established methods of inquiry based on gathering observable, empirical or measurable evidence" (Province of British Columbia 2018). Applications for provincial Park Use Permits and Ecological Reserve Permits can be made online (https://portal.nrs.gov.bc.ca/web/client/-/research-parks-use-permit). It is recommended to consult with the appropriate Parks Area supervisor prior to submitting an application. Regional office contacts are found on the park use permits webpage listed previously.

3.2.3 SARA Permits

A SARA permit is needed to undertake surveys on federal Crown land that will affect bat species listed as Threatened or Endangered on Schedule 1 of SARA, and that will contravene the general or critical habitat prohibitions of SARA. Federal Crown lands include Indian Reserves, Department of National Defence lands, National Wildlife Areas, federal government offices owned and operated by Public Works and Government Services Canada, federal airports and sea ports, national parks and national park reserves. No SARA permit is needed for passive audio recording surveys if the equipment, equipment deployment or retrieval do not interfere with access to a residence or involve damage or destruction to any part of the residence or critical habitat (i.e., hammering spikes into a cave roost to attach a detector).

SARA permits may be issued for the following purposes (Government of Canada 2018):

- the activity is scientific research related to the conservation of the species and is conducted by qualified people;
- the activity benefits the species or is required to enhance its chance of survival in the wild; or
- affecting the species is incidental to conducting the activity.

SARA permits for research on federal lands that are not within the boundaries of Parks Canada Heritage Areas (e.g., national park, national historic site) can be applied for online (www.dfo-mpo.gc.ca/species-especes/sara-lep/permits-permis/index-eng.html).

3.2.4 Permits for Activities in Parks Canada Heritage Areas

Researchers who are planning to work within a Parks Canada Heritage Area, including surveys not involving bat handling, must apply for a research permit through the Parks Canada website (https://www.pc.gc.ca/apps/rps/index_e.asp). If the proposed activities contravene SARA, additional permitting conditions must be met and a separate SARA permit may be required. Note that possession of VHF receivers to track wildlife is prohibited within some Parks Canada Heritage Areas unless authorized under a permit (Parks Canada 2016).

3.2.5 First Nations Permits

Individual First Nations may have their own permitting systems. Contact the administrative departments of the appropriate bands well ahead of proposed fieldwork to confirm permission requirements, such as a Band Council Resolution. Permission from particular individuals may also be needed to access specific areas within an Indian Reserve, similar to considerations for private land described below. Indian Reserves are considered federal land; therefore, a SARA permit is needed for any survey activities that may affect bat species listed as Threatened or Endangered on Schedule 1 of SARA (see above).

3.2.6 Private Land

Private landowners must be contacted (preferably well in advance of any research activities) to obtain permission to access their land. Biologists who are planning to radio-track bats, in particular, should be aware of relevant property boundaries adjacent to study areas and ensure that field crews do not trespass into other jurisdictions while attempting to locate a tagged animal. Landowners may have individual requirements regarding advance notice, timing of access, check-ins, livestock, gates, vehicle use, entry to buildings, or precautions to avoid the spread of noxious weeds. Tenants and neighbours should also be notified if unusual late-night activities might cause alarm.

4 GENERAL SURVEY STANDARDS

In most instances, investigators are logistically limited in the number of sites they can visit over the 6–8 months of the year that bats are active in British Columbia. Only a small number of closely situated sampling stations can be attended to by a team of three people in one night. It is necessary to repeat sampling several times, but not all nights will be suitable for sampling due to weather constraints (Grindal et al. 1992). Bat activity tends to vary with ambient air temperature, precipitation, humidity, and wind speed, as well as reproductive status and insect availability, all of which change throughout the season. The catchability and detectability of bat species differs, which violates the assumptions of many methods of comparing data over time and space. Few data are available regarding the amount of effort needed to detect the presence of bat species (Weller and Lee 2007).

It is virtually impossible to determine the absolute number of bats present in an area. Statistically valid comparisons of relative abundance either within an area or between areas are also rarely possible (see below). It is difficult to discern real differences within the high degree of natural variation in bat activity and habitat use. Researchers rarely have the resources to acquire the sample sizes needed to meet statistical criteria and assumptions. This makes the use of Before-After Control-Impact designs, often recommended for environmental impact studies, unsuitable for monitoring bats in the province under most circumstances.

There currently is no technique for measuring the absolute abundance of bats, except in extremely localized areas, such as single roosts (Thomas and LaVal 1988; Jung and Kukka 2016). Even those techniques provide only a snapshot of the number of individuals in a roost at the time it was sampled because some species frequently switch roosts (Rasheed and Holroyd 1995; Vonhof and Barclay 1996; Bogan et al. 2003), and the assumption of a closed population is violated (Clement et al. 2015; Jung and Kukka 2016). Power analysis methods have been used on data from emergence surveys of known roosts combined with radio-telemetry to estimate bat abundance (Clement et al. 2015), but these methods are rarely practical. Studies of tropical bat populations have suggested that long-term population monitoring (10 to 20 years) of the most abundant species is needed to reliably detect temporal changes in species abundance (Walsh et al. 2001; Meyer et al. 2010).

Bat "activity" is easiest to document using ultrasonic detectors (Dixon et al. 2014). Indices of "relative activity" are often used to compare bat activity (e.g., Miller 2001) but are typically flawed due to the multiple variables other than population size that affect bat activity (O'Shea et al. 2003).

Adequate sample sizes and repeated sampling of the same study areas (ideally under the same conditions) are necessary to produce an accurate inventory. Therefore, the sampling effort that can be achieved for bats within a project will be more sensitive to variables such as the size of the project area, the number of study areas within it, and the number of nights spent per study area than it may be for other animals. Because the results of an inventory are variable, it is important that plans to survey bats include a means of controlling these factors. However, limited resources often dictate the use of protocols that will maximize the information collected regarding species composition (especially species at risk), locations, and use of summer roost and hibernacula features, and any information about ecology that can be interpreted from those data.

The choice of methods used to sample bats at three intensities (presence/not detected, relative abundance, and absolute abundance) will depend on the species being examined and the question(s) being asked, or the data required. It is difficult to specify the number of study areas that should be established within a project area, or the length of time that should be spent sampling each one. Inventories should focus on key features that could provide bat habitat throughout the study area. This approach relies on the investigators' familiarity with the study area and the ability to recognize suitable habitat features and incorporate these features into an inventory plan that will address the study goals within the project timing and budget. Random or stratified sampling has the potential to miss important bat habitat.

Planning surveys to support environmental assessments should begin with an assessment of the likelihood that bats use habitats within the study area for feeding and/or roosting (security/thermal, reproduction). If there is a potential for use, the baseline surveys needed are determined based on the characteristics of the particular project (size, location, potential to affect bats and bat habitat). There are no prescriptive requirements of effort for proponents and consultants who are conducting bat components of environmental assessments, but it is expected that adequate surveys will be conducted to identify bat species composition, and type and season of habitat use. This baseline inventory is critical for developing effective measures to avoid or minimize impacts on bats and their habitats. Species at risk are usually emphasized in an environmental assessment, so surveys at the presence/not detected level are normally conducted to address knowledge gaps regarding their presence in a study area. Additional survey scope will be added based on the results of the presence/not detected surveys, as well as the risks and consequences of the project, and the level of concern resulting from input from First Nations, regulators, and the public on the project's Terms of Reference or Valued Components document. The use of monitoring programs may be requested by clients or regulators to assess the effectiveness of mitigation. The expectations of environmental assessments are similar whether they are prepared for federal, provincial, or local governments.

Within each project, it is recommended that each study area be visited more than once, even for presence/not detected studies. Limitations of current sampling methods and the high degree of spatial and temporal use of habitat exhibited by bats may lead to an inaccurate representation of species present at a site during any given night (Skalak et al. 2012). The failure to detect a species may reflect its rarity or may be a sampling artifact rather than actual absence of that species. Confidence in results will increase with repeated sampling at the same location. For studies that involve large geographic areas, at least two circuits of the project area should be made during the sampling season to gain information on seasonal variation in bat distribution or activity (i.e., sample at each station, then return and sample all stations again later in the season).

Questions formulated by investigators should be designed with consideration of current limitations in bat census techniques to ensure that results are meaningful and defensible. Questions that can be considered include the following:

- What species (or acoustic groups) are present in a given study area at the time of the survey? Are the individuals that are present primarily male or female?
- At what times of year are bats most active in a given study area? When do they first appear in the spring, and when does activity decline in the fall?
- Which habitat types are being used by bats in a given study area?
- Are there particularly important habitat features (e.g., roosts) in a given study area? Are those features located where they could be affected by development?
- Is a particular feature being used as a roost? Is it a maternity roost or a hibernaculum?
- Are some species detected more often than others in a given study area?

4.1 Survey Design Hierarchy

Bat surveys follow a survey design hierarchy that is similar to all RISC standards for species inventory. Figure 1 clarifies certain terminology used within this manual (also found in the Glossary),and illustrates the appropriate conceptual framework for bat detection and capture surveys. A survey setup that follows this design will lend itself well to standard methods.

1.	**PROJECT**
	May include multiple surveys of different species groups over multiple years.
2.	**SURVEY**
	The application of one RISC method to one taxa group during one season. Must contain one or more study areas that are visited at least once.
3.	**STUDY AREAS**
	Areas that are sampled using one or more methodologies (e.g., different geographic or habitat areas). Each study area may contain one stratum or more strata.
4.	**STRATA** **In cactus cliff study area**
	Provides a framework for focusing effort and minimizing variability. For bats, strata may be based on habitat types where bats are most expected to be found. Each stratum may contain one or more design components.
5.	**DESIGN COMPONENTS** **Trap stations and detectors**
	Trap stations and detectors are placed non-randomly in areas where bats are expected to occur or at locations within each stratum where capture is most likely.
6.	**OBSERVATIONS**
	Encounters with the target taxa at each design component.

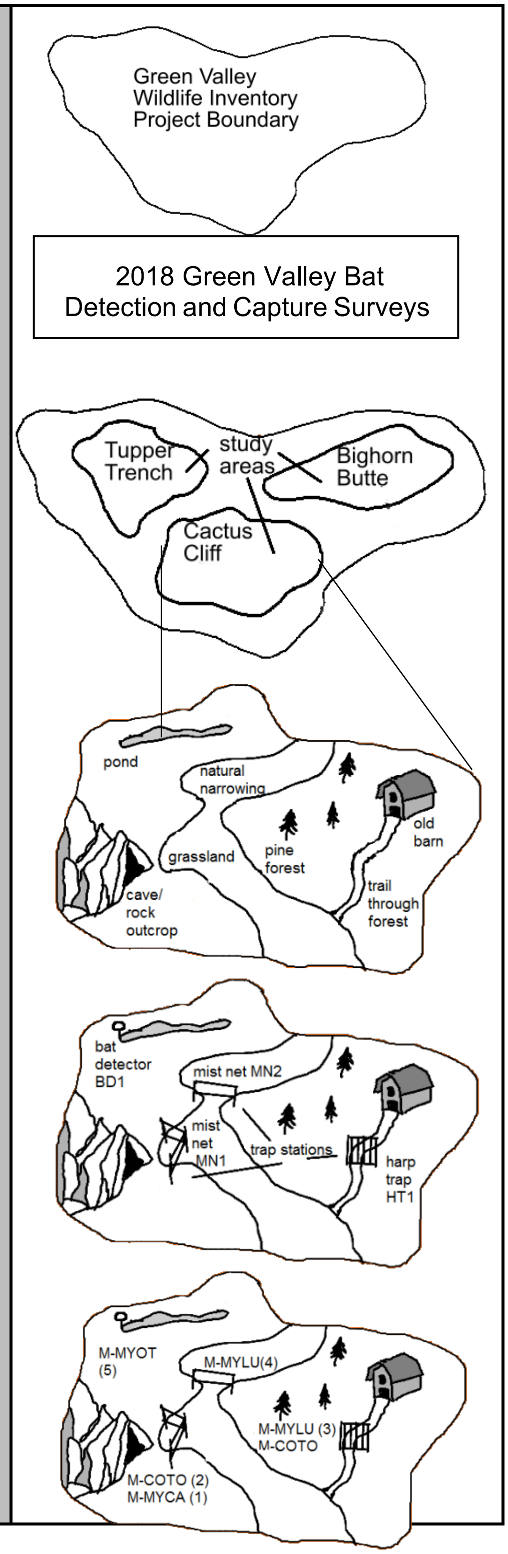

Figure 1. RISC species inventory survey design hierarchy with examples.

4.2 Habitat Data Collection Standards

Habitat data must be collected for each survey type. The type and amount of data collected will depend on the scale of the survey, the nature of the focal species, and the objectives of the inventory. The terrestrial Ecosystem Ground Inspection Form (https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/ecosystems/bec/codes-standards/gif_frm98.pdf) (B.C. Ministry of Forests and Range and B.C. Ministry of Environment 2010) should be used in most cases. However, under certain circumstances, this may be inappropriate, and other RISC-approved standards for ecosystem description may be used. For a generic but useful description of approaches to habitat data collection in association with wildlife inventory, consult the introductory RISC manual, Species Inventory Fundamentals (No. 1) (www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/spifml20.pdf).

Suggested data forms for standard descriptions of roosts, whether located in cliff, caves, trees, or buildings, are available from the BC Small Mammal and Herpetofauna Specialist (LeighAnne.Isaac@gov.bc.ca).

4.3 Choosing Appropriate Survey Techniques

Choosing the appropriate survey technique depends on the scope and objectives of the study. Simply establishing presence of bats may be sufficient for some purposes (i.e., if establishing that a structure is used by bats is all the information that is needed). Assessment of presence at the acoustic group level, at minimum, is required for most environmental assessments. Genetic confirmation of cryptic species (e.g. Little Brown Myotis /Yuma Myotis; Little Brown Myotis /Long-eared Myotis /Northern Myotis) is necessary, if presence at the species level is needed.

Because no one technique can adequately sample all bat species that occur in British Columbia, several techniques often must be used in combination to obtain presence/not detected and relative abundance/activity data (Table 2) at the species level. The same general techniques are used to assess both of these levels of sampling intensity; therefore, data on species presence and relative levels of abundance/activity can be collected at the same time. Reliable comparisons between species are not possible due to differences in catchability or detectability. Absolute abundance estimates generally are not feasible, except for counts undertaken at specific roosts.

In British Columbia, mist nets, harp traps, ultrasonic bat detectors, roost searches, visual counts, and DNA analysis are all techniques that can be used to assess presence/not detected and relative abundance of bats because they tend to complement one another. The species that tend to be underestimated or missed by one method are often better sampled using one of the other methods. For example, the presence of certain species may be difficult to determine due to their low vulnerability to trapping and/or the limited ability to distinguish their echolocation calls. With two to three workers and sufficient equipment, it is quite easy to use multiple methods simultaneously in a study area. However, the emphasis on specific survey methods used will vary for different survey intensities (Tables 2 and 3) and/or target species (Table 4).

Table 2. Recommended combinations of techniques to assess presence/not detected, relative abundance/activity, and absolute abundance of bats.

Objective	Recommended Combination of Techniques
Presence/not detected	• Roost searches (if appropriate for the site) followed by capture techniques (mist netting, harp trapping) with DNA analysis if necessary to confirm species captured, conducted simultaneously with acoustic detector sampling for all species and listening for Spotted Bats. Roost exit or internal surveys for individual sites.
Relative abundance/ activity	• Roost searches (if appropriate for the site) followed by capture techniques (mist netting, harp trapping) with DNA analysis if necessary to confirm species, conducted simultaneously with acoustic detector sampling. Roost exit or internal surveys for individual sites.
Absolute abundance	• Visual counts (exit survey or internal survey); likely in conjunction with telemetry or roost searches (to locate roosts). Listening for emerging Spotted Bats can also provide absolute abundance data.

Table 3. Types of inventory surveys, field data forms available, and level of intensity of the survey.

Survey Method	Field Data Forms Available	Intensity[a]
Capture & Tagging	*Data form:* Bat Capture Form. Available from the BC Small Mammal and Herpetofauna Specialist (leighanne.isaac@gov.bc.ca). *Data submission template:* Bat Capture and Telemetry Template (www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates)	• PN
PIT tagging	*Data submission template:* PIT Tag Data Form Available from the BC Small Mammal and Herpetofauna Specialist (leighanne.isaac@gov.bc.ca).	• PN • RA
Acoustic detection	*Data submission template:* Bat Acoustic Template (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates)	• PN • RA
Roost description	*Data Form:* Roost Tree Data Form. Available from the BC Small Mammal and Herpetofauna Specialist (leighanne.isaac@gov.bc.ca).	• PN
Emergence count	*Data form:* BC Community Bat Program count form (https://bcbats.ca/get-involved/counting-bats/) *Data submission template:* General Survey Using Sample Stations	• PN • RA • AA

Survey Method	Field Data Forms Available	Intensity[a]
	https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates	

[a] PN = presence/not detected; RA = relative abundance/activity; AA = absolute abundance.

Table 4. Recommended sampling methods for British Columbia (B.C.) bats, overwinter strategies, and location of summer roosts (roost information primarily from Nagorsen and Brigham 1993; B.C. Conservation Data Centre 2013; Holroyd et al. 2016).

Species	Overwinter Strategy	Summer Roosting Strategy	Typical Summer Roost	Recommended Sampling Methods
Spotted Bat (*Euderma maculatum*)	Hibernates – unconfirmed in B.C.	Solitary (or very small colonies)	Cliffs	Listen with unaided ear near cliffs (only for people who are able to hear above 8 kHz); acoustic detection set for low-frequency (7 to 12 KHz range) detection; triple-high or quad-high (8–10 m high) mist net (only if capture is needed for telemetry)
Townsend's Big-eared Bat (*Corynorhinus townsendii*)	Hibernates	Colonial	Caves, mines, buildings	Mist net/harp trap at buildings, caves, mines; acoustic detection; roost and hibernacula searches in cavernous features or buildings
Pallid Bat (*Antrozous pallidus*)	Hibernates – inferred by fall telemetry (see Sarell and Haney 2007)	Colonial	Rock crevices	Mist net with bottom tier at ground level; target flyways and rock shelters; listen for audible directive calls at potential roosts during emergence; acoustic detection
Big Brown Bat (*Eptesicus fuscus*)	Hibernates	Colonial (small colonies)	Buildings, tree cavities, rock crevices	Mist net (5–10 m high); acoustic detection; roost searches in buildings
Canyon Bat *(Parastrellus hesperus*)	Hibernates – unknown in B.C.	Solitary/ colonial (small colonies)	Cliff, rock outcrops elsewhere – unknown in B.C.	Acoustic detection, mist net, visual of distinctive flight pattern at dusk (“butterfly-like”)

Species	Overwinter Strategy	Summer Roosting Strategy	Typical Summer Roost	Recommended Sampling Methods
Eastern Red Bat (*Lasiurus borealis*)	Migrates	Solitary	Foliage of shrubs and trees	Acoustic detection; triple-high (8 m high) mist net or canopy net
Hoary Bat (*Lasiurus cinereus*)	Migrates	Solitary	Foliage of shrubs and trees	Acoustic detection; triple-high (8 m high) mist net or canopy net; some evidence to suggest they can be lured into mist nets with ultrasonic playback of Little Brown Myotis distress calls (C. Lausen, pers. comm., 2018)
Silver-haired Bat (*Lasionycteris noctivagans*)	Migrates/ hibernates (see Lausen and Hill 2016)	Colonial/ solitary	Foliage/tree cavities; buildings; rock outcrops	Mist net/harp trap; acoustic detection
Californian Myotis (*Myotis californicus*)	Hibernates	Colonial	Buildings, tree cavities/bark, rock crevices	Mist net/harp trap; acoustic detection limitations due to overlap with Yuma Myotis
Western Small-footed Myotis (*Myotis ciliolabrum*)	Hibernates	Colonial (small)	Rock crevices	Mist net/harp trap (best along cliff faces, or stringing nets closely across trunks of trees in relatively open areas near rock/mudstone crevices; acoustic detection with calls verified by species expert
Little Brown Myotis (*Myotis lucifugus*)	Hibernates	Colonial	Buildings, tree cavities, rock crevices	Mist net (near water or ideally over water at water level)/harp trap; roost searches in buildings; strong evidence to suggest that this species is lured in by distress calls of conspecifics; DNA analysis recommended to distinguish from Yuma Myotis; acoustic detection limitations due to overlap with Long-legged Myotis

Species	**Overwinter Strategy**	**Summer Roosting Strategy**	**Typical Summer Roost**	**Recommended Sampling Methods**
Yuma Myotis (*Myotis yumanensis*)	Hibernates	Colonial	Buildings, tree cavities, rock crevices	Mist net (near water or ideally -over water at water level)/harp trap; roost searches in buildings; acoustic detection limitations due to overlap with Californian Myotis
Long-legged Myotis (*Myotis volans*)	Hibernates	Colonial	Rock crevices, tree cavities	Mist net/harp trap
Long-eared Myotis (*Myotis evotis*)	Hibernates	Colonial	Rock crevices, tree cavities, buildings	Mist net/harp trap (roads and cutlines through trees where undergrowth presents gleaning opportunities; entrances to caves and mines; along rows of vegetation in arid regions); acoustic detection
Northern Myotis (*Myotis septentrionalis*)	Hibernates	Colonial (small)	Tree cavities	Mist net/harp trap (narrow roads and cutlines through trees)
Fringed Myotis (*Myotis thysanodes*)	Hibernates	Colonial	Buildings, caves, rock crevices	Mist net/harp trap, best at rock overhangs and entrances to caves and mines; acoustic detection
Brazilian Free-tailed Bat, also known as Mexican Free-tailed Bat (*Tadarida brasiliensis*)	Migrates/ hibernates – unknown in B.C.	Colonial	Cliffs, buildings, bridges, culverts elsewhere – unknown in B.C.)	Acoustic detection, with targeted guano sampling for genetic analysis

4.4 Survey Planning

Some general considerations are applicable to all survey methods. The initial planning stages should include the following points:

- Review the introductory RISC manual, Species Inventory Fundamentals (No. 1), for direction on general study design.
- Establish a study area boundary that is appropriate to the scale and requirements of the project in order to focus planning on a defined geographic area. The scope of inference for survey results depends on the area that is sampled.
- Planning for surveys conducted to support environmental assessments of proposed development projects should consider the area of influence from both direct impacts (e.g., habitat alterations, hazards to individual bats) and indirect impacts (e.g., noise, light, vibration) within the construction, operation, maintenance, and decommissioning of the project, as it pertains to bats and their habitats.
- In some cases, sampling outside the project study areas may be required (e.g., if roosting habitat or known roosts are present outside the project study area and may be a source of bats that could be affected by development) (Weller 2007).
- Review the provincial bat BMPs for particular development types and activities to obtain specific guidance, if appropriate for the project.
- Obtain and review pre-existing status and background information on bat species and known important habitat features in or near the study area. That information may consist of published information, grey literature, or data available through provincial data sources such as the Species Inventory Web Explorer (http://a100.gov.bc.ca/pub/siwe/search_reset.do), BC Species and Ecosystems Explorer (https://a100.gov.bc.ca/pub/eswp/), EcoCat (https://a100.gov.bc.ca/pub/acat/public/welcome.do) and CLIR (https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/libraries-publication-catalogues/cross-linked-information-resources-clir).
- Environmental assessment reports from existing or proposed nearby projects may be useful sources of information. Provincial government biologists, other bat biologists, and local naturalists and landowners may also provide information that is relevant to survey planning. Review of pre-existing data will help identify data gaps and formulate the survey objectives.
- Basic familiarity with the biology of the species that are expected to occur in the study area will assist in determining the appropriate survey method to use (Kunz 2003). See Section 2 for suggested sources of information.
- Review mapped information in and adjacent to the study area. Useful mapping products (e.g., species locations from the Wildlife Species Inventory Database and Conservation Data Centre, Vegetation Resources Inventory, biogeoclimatic subzone mapping, karst potential, Critical Habitat for SARA-listed species) are available online on through the provincial iMapBC application (https://maps.gov.bc.ca/ess/hm/imap4m/), Habitat Wizard (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/ecosystems/habitatwizard) or CDC iMap (http://maps.gov.bc.ca/ess/hm/cdc/). Sensitive Ecosystem Mapping, Terrestrial Ecosystem Mapping, and Wildlife Habitat Suitability Mapping may be available for some areas and can be obtained through EcoCat or iMapBC applications. The province provides locations of active and inactive mines (www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/british-columbia-geological-survey/mapplace); however, the coordinates provided often are approximate.

Mapping information will assist in determining locations and amounts of potential bat habitat and the scope of surveys needed.

- Examine land ownership status and habitats available within and adjacent to the study area to establish where access is desired and possible. This information can assist in developing survey scope, methods, and budgets, and confirming the type of permits required. Land ownership status can be determined through iMapBC or Front Counter BC Discovery Tool, using Google Earth (https://portal.nrs.gov.bc.ca/web/client/explore).
- Conduct a preliminary assessment of potential bat roosting and hibernacula habitat features. Viewing satellite imagery of the study area (e.g., on GoogleEarth) can be very helpful in assessing access needs and the amount and distribution of potential bat habitat. This could include wildlife tree patches, rock outcroppings, buildings, bridges, and mines (evidence of visible tailings and review of provincial mines data). Key foraging habitat and water sources should also be considered.
- Choose study sampling sites within the study areas where bats are most likely to occur and that can be safely accessed for surveying.
- Each study area should be sampled more than once, and effort should be made to maximize replication. Confidence in the results will increase with repeated sampling of the same study area. For larger geographic areas, it is recommended that at least two circuits of the project area be made during the sampling season to provide some information on seasonal variation in bat distribution or activity.
- Determine the questions that surveys will be designed to answer. Determining the locations of, and potential impacts on, summer maternity roosts and hibernacula is typically the most important need for an environmental assessment project.
- Establish the resources (personnel, budget, and time) available for the surveys, data analysis and reporting.
- Review the Wildlife Species Inventory data submission templates and the customizable data forms available in association with this manual to ensure that data are collected in a format that is easily submitted to the provincial database, and that mandatory data will be recorded in the field.
- Methods that are useful for sampling certain bat species may be inappropriate for others. If the goal of a study is to sample an area for all possible bat species, several techniques will need to be used.

4.5 Time of Year

The timing of sampling will depend on the objectives of the survey and the location of the study area. The active season for bats will be shorter at study areas that are farther north or at higher elevations (see discussion of bat seasonal activity in Holroyd et al. 2016).

General recommendations for survey timing are provided in Table 5. Actual sampling dates will depend on the location and elevation of the study area and on the weather.

Table 5. Sampling periods to document seasonal bat activity.

Seasonal Bat Activity	Definition	Sampling Period (approx.)
Spring emergence from hibernacula	Individuals begin to emerge from hibernacula and move to spring foraging areas. Peak emergences tend to be brief and vary among species. Local climate likely has a great influence on timing.	March 15–May 15
Spring migration	Few data are available for B.C. Bat species that migrate long-distances. Some bats may not necessarily follow the same route as fall migration. Migrating individuals may fly quite high for much of their path and follow geological features like ridge lines, so detection may be difficult.	Unknown but likely April 15–June 1
Summer maternity roosting	Communal roosts where adult females gestate, give birth, and nurse young are often used every year and by many generations.	June 1–August 15
Fall migration	The pattern of fall migration is slightly better known than that of spring migration, and begins earlier in the north and finishes later in the south. Migration routes are very poorly understood.	August 1–September 15
Swarming and fall return to hibernacula	Few data are available for B.C., but swarming events prior to entering hibernacula are readily observed, and often song-like sonograms are recorded in conjunction with high levels of bat activity. Actual swarming activity may be brief, but general activity around hibernacula is often prolonged until cold weather drives the bats into hibernation.	September 7–October 31
Winter emergences	Winter emergence is poorly known, but individuals of some species may emerge every couple of weeks, whereas other species appear to arouse very infrequently or not at all. Local climate appears to also influence arousal.	October 15–March 15

- Although there are records of winter activity for several species in British Columbia (Nagorsen et al. 1993; Sarell et al. 2012; Burles et al. 2014), the infrequency of winter arousal usually makes capture or emergence surveys impractical during the winter (C. Lausen, pers. comm., cited in Holroyd et al. 2016). There are additional concerns about handling bats in winter, such as causing them to deplete energy stores that are still needed for hibernation. The use of acoustic methods should be considered, and acoustic surveys are generally the first step to determining patterns of activity for effective subsequent capture.

- Surveys that involve entry into hibernacula or roost sites in order to map them or install monitoring devices should be conducted at times of the year when those sites are unoccupied by bats in order to minimize disturbance impacts.
- Deep snow, unmaintained roads, or high water may prevent access to some sites during some seasons.
- Observations of multiple bats outside a single site during the winter may indicate the effects of WNS, and should be documented and reported immediately to the provincial wildlife veterinarian or provincial wildlife disease surveillance program.
- The time of year or stage of the reproductive cycle will influence sampling in several ways (Thomas and West 1989):
    - Lactating females typically make at least one return trip to the maternity roost to nurse their young before returning to foraging areas to feed (to meet their increased energy demands). This may result in higher levels of bat activity than during other stages of the reproductive cycle, even though there may be no actual change in the number of bats present.
    - Bats may congregate at particular sites during late summer (usually at hibernacula) in a behaviour known as “swarming”, during which they circle repeatedly, dive, and chase other individuals (Fenton 1969; Veith et al. 2004). Very high levels of activity have been recorded at swarming sites.
    - An increase in the number of bats present and, correspondingly, in the levels of bat activity will occur when young-of-the-year become volant and leave the roost. In addition, because males and females have different energetic requirements during the breeding season, they may use different habitats (Barclay 1991) or different roosts (D. Nagorsen, pers. comm., 2018). This may result in a bias in relative abundance estimates or a failure to identify important habitats for males.

4.6 Time of Day

- Bats are generally inactive during daylight hours, except in rare circumstances, and will be found only in roosts. Distinct periods of high activity during the night occur for most species (Thomas and West 1989). The first of these occurs when bats first leave the roost to drink and forage. This usually occurs near sunset, but some species, such as the Spotted Bat, tend to emerge later.
- Activity by most species typically decreases over the course of a night, which results in a trough of activity around 2400 to 0100 hours, often followed by an increase in activity again just prior to dawn as bats often obtain another drink of water, then return to roost sites.
- Generally, the species for which activity is not depressed in the middle of the night are the “long-eared” species. These remain active throughout the night due to their ability to glean when insects settle on vegetation during cool parts of the night (Chruszcz and Barclay 2003). Because long-eared bats that are capable of both gleaning and aerial hawking are more likely to forage closer to the ground during the cool, middle part of the night, these species, unlike most, may targeted with mist nets during the middle of the night (C. Lausen, pers. comm., 2018). Nightly activity patterns will vary depending on if the sampling sites is a day roost, night roost, commuting or migration route, or foraging area.

4.7 Environmental Conditions

- Environmental conditions influence bat activity (e.g., Grindal et al. 1992). Precipitation, strong winds, or temperatures below 10°C all tend to cause a decrease in bat activity. Therefore, sampling should be conducted on nights with minimal or no precipitation and when the ambient temperature at sunset is above about 10°C; otherwise, bat activity will be limited, and sampling will be relatively unproductive. However, in northern areas (including Haida Gwaii) or at higher elevations where temperatures at sunset are generally lower, bat activity has been regularly documented (S. Grindal, pers. obs., cited in RIC 1998a; D. Burles pers. comm., 2018). In these areas, a lower temperature threshold at sunset (e.g., 5°C) can be used.
- Capturing bats that are active in winter is very labour-intensive and is not practical for most inventory purposes. However, conducting acoustic surveys during winter can confirm the presence of nearby hibernacula for some species.
- Typically, sampling is unsuccessful before snow has melted and local lakes are free of ice.
- Increased levels of moonlight may reduce capture success because some bats can easily detect nets and may not fly during lighter conditions.
- Billowing mist nets in moderate to high winds are less likely to capture bats.
- Heavy rains may raise water levels and flood sampling sites (and submerge remote detectors) near creeks, rivers, and bridges.

4.8 Human Safety

The most serious safety concern when handling bats is the potential for rabies transmission. Rabies is a viral infection that is transmitted via the saliva or cerebrospinal fluid of an infected mammal, and is almost always fatal once symptoms have appeared. Bats are the only known reservoir of rabies in the province (BC Centre for Disease Control 2021). It is estimated that infection rates in wild bat populations is less than 0.5% (BC Centre for Disease Control 2021).

Bat biologists are considered to be at "very high" risk of contracting rabies (WorkSafeBC 2015). Any person handling bats must have pre-exposure immunizations against rabies. Titre testing should then be done every 2 years to confirm the presence of protective levels of antibodies. All members of the field crew, whether vaccinated or not, should take precautions to avoid being bitten by using protective gloves. If a bite or scratch occurs, the wound should be washed thoroughly with soap and water, and the injured person should see a healthcare provider as soon as possible for post-exposure prophylaxis (WorkSafeBC 2015). Abbreviated post-exposure prophylaxis is recommended for people who have had pre-exposure vaccination (World Health Organization 2013). All personnel on bat survey field crews (including volunteers) must be provided with information on rabies and measures to prevent worker exposure.

Bat surveys are often conducted in remote and rugged terrain. Accessing and working in these environments at night can be hazardous. Handheld two-way radios can be used for communication among crew members. Satellite Global Positioning System (GPS) messaging devices are very useful for crews working in remote locations because aid can be summoned quickly in case of emergency. Hiking routes into remote sites can be marked with white flagging tape so a safe route out can be retraced at night. Recording a track of the route on a handheld GPS receiver will serve the same purpose.

Bat surveys that are subject to WorkSafeBC regulations (www.worksafebc.com/en) must comply with all applicable safety standards as legally required by the Occupational Health and Safety regulation. Equipment carried on all field surveys should include, at a minimum, a Level 1 first aid kit, and at least one person should hold WorkSafeBC Level 1 first aid certification, depending on the number of people in the field crew.

Bats often roost and hibernate in sites that can be very dangerous for people to enter (Tuttle 2003). Safety training (e.g., Confined Space, H2S Aware, Fall Arrest) may be required for particular surveys (e.g., caves, mines). Surveys on industrial sites may potentially expose surveyors to hazardous chemicals, electrical hazards, asbestos, or moving machinery (Mitchell-Jones 2004). Special care must be taken for work on ladders and in unmaintained structures. Hantavirus and pneumonic plague may be risks in structures where rodents are present (WorkSafeBC 2006).

Entry into caves and mines and work on cliffs is particularly dangerous; therefore, properly trained workers with appropriate safety gear must be employed. Bears, abandoned explosives, and rotting support structures have been reported in mines, as well as the ever-present danger of rockfall and tunnel collapse (M. Sarell, pers. obs.). No worker should ever go underground alone (Mitchell-Jones 2004). A hazard assessment should be done before field surveys are conducted to establish training and personal protective equipment needs for each site, as well as rescue and evacuation plans.

5 INVENTORY TECHNIQUES

Inventory techniques for bats are described in detail below. All bat inventory projects must be conducted in accordance with the most recent provincial SOPs for minimizing the risk of introduction or spread of the fungus that causes WNS.

5.1 White-nose Syndrome Decontamination

The Standard Operating Procedures (SOPs) for white-nose syndrome decontamination include procedures for:

- decontaminating field gear, equipment, and clothing;
- reducing the risk of introducing *Pseudogymnoascus destructans* into B.C.;
- reducing the risk of disease transmission among sites within B.C., and
- reducing the risk of disease transmission among individual bats within a site.

Specific recommendations in the SOPs are frequently updated, so be sure to regularly visit the Canadian Wildlife Health Cooperative webpage (http://www.cwhc-rcsf.ca/). The general principles within decontamination SOPs include not moving equipment and gear between sites unless it has been thoroughly cleaned and decontaminated, using a fresh set of disposable gloves to handle each animal (unless they are captured within the same roost), and either decontaminating all processing equipment that has touched a bat's body before using it on another bat or using methods that prevent contact between the bats and the processing equipment.

5.2 Roost Searches

Location and assessment of suitable roost sites may be a critical component for effective inventory of bats (Kunz 1982). Roosts include night roosts (sites used temporarily between feeding bouts during the evening), day roosts (sites that bats use during the day), or hibernacula (sites where hibernation occurs during the winter). Roosts also serve as maternity colonies where adult females congregate to raise young. Bats tend to be faithful to maternity day roost sites and hibernacula because they have stringent thermal requirements for these types of roosts (Brigham et al. 1997). Roost searches may be used as a preliminary assessment of whether a feature needs to be further investigated to determine if it is a potential "Residence" of a SARA-listed bat species; this is important information for projects at a variety of scales from large developments to site-specific building maintenance and demolition (Gano et al. 2011).

The advantage of roost monitoring is that colony roosts tend to be relatively permanent and logistically easy to study (Thomas and Laval 1988), but roosts must first be located. Radio-telemetry can be used to locate roosts, but it is expensive and time-consuming. Reconnaissance searches of roosting habitat are used to locate roost structures and assess their suitability and use. The goal is to assess all natural features and anthropogenic structures that could be used by bats, and then use additional survey methods at the most promising sites.

5.2.1 Office Procedures

- Review Section 4.4 on Survey Planning.

- Consult Holroyd et al. (2016) and Table 4 for information on summer roost and hibernaculum preferences of bat species that are likely to be encountered in the project area.
- Check permit dates and conditions. Note that mist net suppliers may request proof of permit before shipping nets.
- Obtain suitable maps of the project area. Typically, a larger scale, such as 1:20 000, is most useful.
- Based on the maps and other knowledge of the project area (previous reports, local resource specialists), identify strata that are of most interest. It may also be useful to identify specific study areas (i.e., sites) at which sampling will be conducted. The use of properly identified objectives will hasten this process.

5.2.2 Field Procedures

- Use a crew of at least two to conduct roost searches (USDA 2006).
- In general, abandoned mines should not be entered due to extreme safety concerns, but they can be surveyed externally using exit counts, acoustic recordings or video cameras. Note the presence or absence of open portals, their dimensions, and the air temperature of outward airflow (Hendricks 2003).
- Move slowly and quietly to minimize disturbance to bats.
- Roost access points can often be identified from staining on the surrounding material where oils from the bats’ fur have accumulated over time. Guano or urine staining may also be present.
- Visually scan structures, holes, cracks and crevices as thoroughly as possible, using headlamps and flashlights to look for roosting bats, urine and body oil stains, dead bats, and guano.
- Crevice-roosting bats are most likely to be found in dark areas away from human disturbance, such as attics, corners, or behind shutters or beams, if using buildings.
- Pay particular attention to areas where guano may accumulate (e.g., on tops of roof beams, windowsills, and ledges) (Walsh and Catto 2004).
- Use a red filter over lights, if safety permits, as bats do not see well in the red spectrum (C. Lausen, pers. comm., 2018). Use white light for searching and travelling, and red light to examine any bats located (USDA 2006).
- Use of a fibre-optic scope is helpful for inspecting crevices.
- Some bat species use trees as roosts, particularly larger, older trees, stumps, and snags with cavities, exfoliating bark, or deep crevices in the bark (Kunz 1982). It may be possible to identify roost trees by signs such as urine stains on trunks, accumulations of guano on the ground, or by hearing bat sounds using human hearing or ultrasonic detectors (Mayle 1990).
- Foliage-roosting bats are likely to be among foliage close to the trunk of trees. Once a search image is developed, they can be spotted (B. Klug, pers. comm., 2018); however, visual surveys for foliage-roosting bats are practical only for small study areas with small trees.
- Sometimes bats may be detected by the odour of guano or the sound of their vocalizations. A handheld bat detector may assist in detecting ultrasonic bat sounds (USDA 2006).

- Record locations of bats or bat sign, as well as the amount and freshness of the sign. Guano deposited in locations where there is foot or vehicle traffic is easily crushed, so complete pellets in traffic areas indicate recent use.
- Take photographs if this can be done without disturbing the bats. Infrared cameras are recommended because they do not require white lights or camera flash.
- Recording a GPS track of the surveyors' route can be very helpful for later assessing the amount of area searched.
- Roost searches should be used in combination with acoustic detection and exit surveys.

5.3 Visual Counts

Visual counts can be used to confirm the use of a roost site that has been previously identified (i.e., via a roost search). Multiple visits to a roost during multiple seasons will fully evaluate its use (Neubaum et al. 2017).

Two types of visual counts (Kunz 2003) are applicable to the province's bat species: internal counts (or surveys) and exit surveys (also called emergence counts or emergence surveys). Internal counts involve physically entering a roost or hibernaculum (building, cave, mine) or looking into a bat house to count the number of bats inside. Exit surveys involve counting the number of bats that emerge from a roost around sunset.

Usually only one roost exit can be monitored per night per observer during exit surveys unless cameras or automatic counting systems are used. Data should be collected on more than one night to estimate variation over time. Counts of emerging bats provide an estimate of population size for that specific roost (Thomas and LaVal 1988).

Roost counts can provide a fairly accurate estimate of colony size for a given roost on a given date, but further research is necessary to assess their ability to provide accurate population monitoring data (Jung and Kukka 2016). The numbers of bats at an individual roost could diminish even though the population overall is increasing (Hayes et al. 2009). To extrapolate the information to larger geographic areas or populations, a researcher must:

- establish the geographic limits of the study or project area;
- determine the number and size of all roosts in the project or study area;
- determine how far individuals disperse on a daily or seasonal basis compared to the size of the project or study area; and
- determine whether other individuals disperse into the study or project area.

In practice, this is logistically and economically impossible. Due to these constraints, population estimates should be limited to individual roosts.

If large colonies or winter hibernacula are identified and are accessible, they can be periodically monitored with internal counts (up to every 2 years for hibernacula [Kunz 2003]) by experienced individuals to assess if changes in population size are occurring. However, disturbance should be kept to a minimum.

An accurate count of bats in hibernacula or summer roosts may be possible where numbers of bats are not extremely large (as in B. C.), where all parts of the hibernacula or roost are accessible to researchers, and where there are few places for bats to hide (Tuttle 2003).

Mark-recapture programs have been unsatisfactory, likely because assumptions of a closed population and equal capture probability were violated (Kunz 2003; Kunz et al. 2009b; Jung and Kukka 2016). Mark-recapture techniques may also require repeated recapture of animals (unless automatic detection systems such as PIT-tagging are used), which is rarely possible or practical (Clement et al. 2015).

5.3.1 Exit surveys

Exit surveys at roosts provide a reasonably accurate count of the total number of bats that are using a roost at the time of the count, provided that all exits from the roost are identified and monitored, and that any bats that re-enter the roost are accounted for (Thomas and LaVal 1988). Even then, exit surveys seldom provide a complete count of the population that is using the roost (see below). Counts on multiple nights are usually required to obtain a reasonable estimate of the number of bats that are using a roost.

Exit surveys have the following advantages:

- They can be conducted without specialized equipment or permits, and by volunteers who have a minimum of training.
- No particular decontamination protocols are needed if the roost is not entered.
- They are easy to replicate over time, and reasonable sample sizes and estimates of variation can be obtained.
- They can document seasonal occupancy and relative use of particular habitat features, and the success of artificial roosts (e.g., bat houses).
- They can be used at sites that are physically inaccessible.
- They can be conducted without disturbing the bats or affecting their likelihood of using the site in the future.
- Timing of exit surveys may be varied to obtain counts of reproductive adult females (before parturition) or counts of females and young-of-the-year after the young are volant.

Exit surveys have the following disadvantages:

- They require a priori knowledge of roost locations and exits. It may take a night or two of observations just to ensure that all exits are being monitored.
- There may be a large sampling error because counts made by different observers may be highly variable (D. Nagorsen, pers. comm., 2018).
- Usually only one roost exit can be monitored per night per observer (unless cameras are used), so attempts to compare numbers among different roosts by conducting counts at different sites on the same night require many observers.
- Additional inventory methods such as capture, acoustic sampling, or DNA analysis of guano samples may be needed to obtain positive species identification. More than one species may use a roost.
- Exit surveys at maternity colonies will usually count only females and their juveniles because males often roost elsewhere.
- Individuals in some colonies may leave and re-enter the roost several times at sunset, which can make conducting counts difficult (Jung and Kukka 2016). This is especially true after parturition as reproductive females emerge to feed and return to feed young.

- Not all individuals may leave the roost every night, and not all members of the colony may use the roost every day, so multiple counts are required to provide more accuracy.

Use of night-vision equipment may be helpful in conducting counts, but observer fatigue may pose problems if observation periods are > 30 minutes (Grandison et al. 2002). Using a voice recorder rather than taking notes manually will ensure that the observer does not have to look away from the exit being monitored.

Electronic counting devices such as photo-electric beam splitters, which record each flying bat that interrupts the light beam, have also been used to census bat roosts (e.g., Voute et al. 1974). Video recordings by infrared cameras and cameras with infrared illuminators are useful for automatic or backup counts of exiting bats, or to record bat behaviour (Britzke et al. 2014). The recorded video is played back at a later date, and observers tally the bats going into and out of the roost (Sedgeley 2012). Camera systems may have a high initial cost, and require ongoing maintenance as well as constant and reliable battery power (Kunz 2003; Sedgeley 2012). Multiple cameras must be used if there are multiple exits from the roost, but analysis of the video can be time-consuming (Kunz et al. 2009b). The use of cameras in sampling bats in British Columbia has been limited because there are relatively few known roosts where bats occur in sufficient numbers to make these methods more practical and cost-effective than using human observers.

5.3.2 Internal Counts

Internal counts can be used at hibernacula or summer roosts. Bats in B.C. use a variety of sites for hibernation, including caves, mines, buildings, human-made tunnels, talus slopes, rock crevices, root wads, and trees (Nagorsen et al. 1993; Blejwas et al. 2017). At present, relatively few hibernacula are known in B.C., compared to observed numbers of bats in the province during summer (Holroyd et al. 2016). The largest estimate for a single mine hibernaculum in B.C. is 1,198 to 3,748 (Isaac and Lausen 2015).

Most other hibernacula are thought to hold relatively few bats. Most bats in B.C. are thought to hibernate in small numbers in features such as rock crevices, crevices in karst features, boulder fields, and tree cavities, where internal inspection is not possible. Even bats roosting in buildings during winter can be very difficult to locate due to their tendency to nestle into insulation or other areas that will minimize water and heat loss. Identification of these lesser known hibernation sites is important for improving our understanding of bat habitat use and for protecting important hibernacula.

Entry of occupied hibernacula, even if bats are not handled, should generally be avoided because disturbance to the bats may lead to their mortality or to abandonment of the site (Thomas et al. 1990; Sheffield et al. 1992; Speakman et al. 1992; Thomas 1995; Kunz 2003; O'Shea et al. 2003; Hayes et al. 2009). Although bats naturally arouse periodically during hibernation, human disturbance can cause them to arouse more frequently and use up fat reserves, which can reduce overwinter survival. Researchers who propose to enter occupied hibernacula must provide, in their permit applications, justification of how the value of the data obtained will outweigh the risk to the bats (Reeder et al. 2016; Boyles 2017).

Some hibernacula are located in features that are physically inaccessible to surveyors (e.g., rock crevices, partially collapsed mines); others may not be accessible during the winter due to deep snow. Surveys inside accessible roosts and hibernacula are typically conducted to obtain direct counts of bats, to install monitoring equipment such as temperature loggers, to collect site information to assist in planning later surveys, and to collect samples for WNS surveillance. Monitoring equipment can be installed while bats are not present, but bat counts and surveys that require handling bats to obtain samples must occur while roosts and hibernacula are occupied.

Occupied hibernacula should be entered only once (between November and March), preferably when the maximum number of bats is present. The peak in occupancy probably occurs during January or February, although there is likely variation among sites and species in British Columbia. Surveys should last for only short periods in order to minimize disturbance to bats from noise, heat, and light. Surveyors should plan the surveys before entering the hibernacula so verbal communication inside is minimized.

Caves and mines should be carefully examined for any signs of bats, including guano, skeletons, and skulls. It is important that surveyors have an accurate search image for bat guano: it resembles mouse droppings but is rounder on the ends and easily crushes into a powder that contains shiny pieces of insect carapaces or dusty moth scales. Take care not to confuse rodent droppings with bat guano; when in doubt, a sample should be taken. Bats are likely to defecate very little during the winter, and some caves flood/wash annually, which makes hibernacula difficult to recognize during summer inspections (C. Lausen, pers. comm., 2018). Acoustic monitoring during the fall, winter and spring should be considered as an alternative.

Some summer roosts can be accessed to conduct internal surveys. They are located primarily in buildings but could also be in caves, mines, or bridges. As with hibernacula, minimizing disturbance is important.

Guano and odor are the primary search cues for bat presence, especially because bats may be absent at the time of the survey or hidden in crevices. Scattered guano may just indicate the presence of bats flying through the site, whereas small piles may indicate night roosting. Large accumulations of guano are usually signs of summer roosts, even when bats are not present.

5.3.3 Office Procedures

- Review Section 4.4 (Survey Planning).
- Obtain suitable maps of the project area. Typically, the largest scale available is most useful.
- Based on the maps and other knowledge of the project area (previous reports, local resource specialists), identify strata that are of most interest. It may also be useful to identify specific study areas (i.e., specific locations) at which sampling will take place. The use of properly identified objectives will hasten this process.
- For building or underground searches, review building site drawings, obtain access (keys, ladders), and prepare required safety protocols (safety plan, equipment, personal protective equipment, ladders, special training).

5.3.4 Preliminary Fieldwork

- Identify potential roost sites such as suitable wildlife trees, cliffs, buildings, caves, and mines (using roost searches, acoustic detection and/or exit surveys, or radio-telemetry).
- Once a potential roost site is located, determine whether an exit survey or an internal count is most appropriate.
- During the day, the field crew should visit the study area to check out access, and when applicable, locate suitable viewpoints for conducting counts, locate areas of potential hazard to the field crew (e.g., electric fences, unsafe floors of buildings), set up equipment, and ensure detectors are working.

- Check the time of sunset for the date and location of the survey.

5.3.5 Personnel

When conducting internal counts:

- All crew members who enter roosts and hibernacula must have up-to-date rabies and tetanus vaccinations.
- When relevant, all crew members must be familiar with safety procedures for entering potentially hazardous structures (e.g., mines, caves, old buildings) and have appropriate training, certifications, and equipment.

5.3.6 Field Procedures

5.3.6.1 Exit surveys

- Identify potential roost sites such as suitable wildlife trees, cliffs, buildings, caves, and mines (using roost searches, acoustic detection, or radio-telemetry).
- Conduct exit surveys at maternity roosts after pregnant females have congregated but before pups are volant (generally June 1–21) to obtain an estimate of the number of adult females using the roost. Also conduct exit surveys after pups have become volant but before bats move to hibernacula (generally July 21–August 15 for the province north of Kamloops and Revelstoke, and July 11–August 5 for coastal and southern B.C.) to obtain an indication of reproductive success (B.C. Community Bat Program 2016; M. Kellner, pers. comm., 2018).
- Exit surveys that are intended to monitor year-to year numbers at an individual roost should be conducted at the same times each year.
- Conduct exit surveys when air temperatures are above 12°C, no rain is falling, wind speeds are < 4 on the Beaufort scale (B.C. Community Bat Program 2016; Vermont Fish and Wildlife 2016) and there is no full moon.
- Collect emergence data on multiple nights to assess the degree of variance in numbers of bats emerging.
- Choose a viewpoint where emerging bats can be seen against the sky (preferably to the west, if possible, to maximize bat silhouette visibility). This may mean having the observer stationed inside the structure.
- Observers should take up a comfortable position 30 minutes before dusk and should use a handheld counter. Observers should remain quiet, refrain from smoking, and minimize the use of lights. Do not shine lights on the roost exit or stand directly beneath it (USFWS 2017). Ensure that all exits from the roost are identified and monitored, and that any bats that re-enter the roost are accounted for.
- Using multiple observers at each exit (if possible) will permit assessment of observer error.
- Count all bats exiting the roost, and record a separate tally of any re-entering the roost. Two handheld counters can be used to record exits and entries separately.
- Record the date, weather conditions (temperature, cloud cover, wind speed, precipitation), start time and end time of the survey. Year and month should be written out completely (e.g., 2018 July 6, not 18-6-7) because all-numeric codes are easily misinterpreted.
- Record the number of bats entering and exiting during the observation period, the time the first bat was detected, and the time the last bat was detected.

- Surveyors should continue to watch the exit for at least 10 minutes with no bat activity or until it is too dark to see.
- It may be necessary to capture bats at or near the roost to examine their physical features, obtain acoustic recordings, or collect guano samples to identify species by DNA analysis.

5.3.6.2 Internal Counts

- Caution! Roost sites and hibernacula should only be entered with extreme care and preparation, and for a worthwhile purpose. Entry can disturb the bats, may lead to abandonment of the site, and may facilitate the spread of the fungus that causes WNS. Entering these features may also cause structural damage to the site (e.g., abandoned mines, old buildings).
- Identify potential roost sites and hibernacula such buildings, caves, and mines (using roost searches, exit surveys, acoustic detection, or radio-telemetry).
- Ensure that the process for conducting an internal count at a particular site is clearly communicated to all participants before the site is entered so that surveyors work efficiently and quietly, and minimize the time they spend inside a site.
- All discussions should be held away from the roost.
- Record the start and end time, temperature and water vapour pressure during each internal count.
- Red light should be used within a summer roost.
- Attempt to identify bats to species if this can be done without disturbing the animals.
- Handling a roosting bat is discouraged.
- **Direct counting**: Within the roost, it may be possible to directly count roosting bats that are in conspicuous locations, without causing substantial disturbance. A red filter over the headlamp causes less disturbance to bats. In some cases, it might be easiest to take a photo of clusters of bats and count them later. Clearly document the location of bat observed within the structure.
- **Surface area and packing density:** To count bats that hibernate or roost in densely packed clusters, estimate the surface area and mean packing density within a 30-cm (12-inch) square and then extrapolate to the roost site. Alternatively, photograph each cluster and count the bats in the photographs later, once the survey has been completed. This latter method minimizes time spent in the roost or hibernaculum.
- Confirm species identification using DNA analysis by collecting guano samples and any dead bats found during an internal survey.

5.3.7 Visual Count Data Reporting

Data analysis and reporting will vary according to the project’s purposes. General recommendations are provided here. Any estimation of absolute abundance should include a discussion of the assumptions that are implicit in the methods used (e.g., closed populations, constant and equal detectability over multiple counts/ capture sessions) and the likelihood of those assumptions being confounded (Kunz et al. 2009b; Ingersoll et al. 2013).

Data reporting for exit surveys should include:

- weather conditions at the time of sampling;
- number of each species, sex, and age class (if known and applicable) for each roost site;

- total time monitored and number of exits monitored;
- number of bats emerging, and the time of emergence of the first bat and last bat; and
- minimum number of live bats (for simple counts; does not include confidence intervals).

Data reporting for internal counts could include:

- description of the proportion of the site that was searched, and the total time it was searched;
- internal temperature of the site;
- number of each species (if known and applicable) for each site entered;
- distribution, location, and cluster size of bats;
- observations of whether bats were changing locations during the survey;
- minimum number of live bats (for simple counts; does not include confidence intervals); and
- estimate of count accuracy by comparing simultaneous counts from two observers.

Submission of all visual count data should be done using the General Survey template found here: www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates.

5.4 Acoustic Surveys

Bats are a cryptic species. It is sometimes challenging to detect them visually, capture them or identify them to species level with confidence. Acoustic sampling methods that are used to study bats "remotely" by recording their echolocation calls are non-invasive, efficient, and cost-effective. Acoustic inventory of bats may facilitate sampling over a much longer time frame and/or simultaneously over a wider geographic area than capture methods can, for the same cost. Automated or autonomous recording units and other types of bat detectors are extremely versatile and, when used properly, can quantify bat species diversity and activity patterns in a localized area.

This manual is not intended to be a bat acoustic identification guide. It is the responsibility of individual researchers to use guidance in this manual in addition to the most recent information available on bat species ecology, range, and acoustic classifications. It is important to realize, however, that even the most recently available information may not be comprehensive because knowledge about bat communities, species distributions, ecology, and acoustic repertoire is continually evolving.

5.4.1 Principles of Acoustic Survey

Unlike sound produced by some other animals, such as bird song, bat echolocation is not intended primarily to communicate species or courtship information between individuals (Barclay 1999). Bats echolocate to orient themselves when navigating, detect prey when foraging (Griffin 1958), and for communication and social recognition (Voigt-Heucke et al., 2010). Bats with similar ecology/morphology that feed on similar sized insect prey often have similar echolocation calls. In fact, call variability between individuals of the same species can be greater than the variability between species (Parsons et al. 2000; Russo and Voight 2016).

Species identification from recorded calls is often impossible, whether manually analyzing call sequences or using automated identification software. Poor quality or "noisy" recordings, absence of diagnostic call features, absence of search-phase calls, and substantial overlap between species' call repertoires frequently confound species classification. Instead, classification to broader species groups is often more feasible and appropriate. For this reason, any classifications produced by auto-identification software should be verified by a qualified professional to increase confidence that recorded calls are correctly assigned to a species or species grouping.

Neither acoustic sampling nor capture methods have perfect detectability rates. As such, neither method is sufficient to determine species absence, but with effort and appropriate study design, a reasonable understanding of bat diversity and relative activity, and even relative abundance in some cases, within a localized study area can be obtained.

Echolocation research is a continually evolving field of practice (e.g., automated species identification [Frick 2013]; detector technology [Loeb et al. 2015]). Practitioners are strongly advised to consider taking formal training, either generalized or system-specific, to conduct acoustic sampling. Given the complexity of acoustic analysis, formal training should be supplemented with substantial practice and feedback from experts. Formal training provides current information on bat echolocation, acoustic recording (detector) equipment, and advances in software technologies for processing and analyzing acoustic data. It is the responsibility of every practitioner to:

- be familiar with the ecology and acoustic characteristics of bats in the region of interest and/or to seek advice from experts in the field;
- maintain current knowledge of the advantages and disadvantages of available recording equipment and be familiar with equipment deployment;
- understand the limitations of acoustic data analysis approaches (e.g., manual or automated species identification); and
- be conscientious and rigorous in drawing inferences from acoustic data, particularly with call classification.

Using acoustic survey methods in conjunction with other survey methods (e.g., capture or genetic analysis of guano) will provide a more accurate estimate of bat occurrence and/or activity[1] in a given study area than will a single sampling method used in isolation. For example, if calls ending at approximately 40 kHz are recorded in an area where Long-legged Myotis (*Myotis volans*) and Little Brown Myotis (*M. lucifugus*) might occur (based on understanding of current distribution), other inventory methods (e.g., live capture or DNA analysis of guano if available) can be used to confirm the occurrence of either or both species in the study area.[2] Often a combination of sampling methods (acoustic techniques paired with capture/telemetry) is required to provide a more accurate estimate of species richness
(O'Farrell and Gannon 1999; MacSwiney et al. 2008).

5.4.2 Fundamentals of Echolocation

Bat echolocation calls, or pulses, are single, continuous vocalizations separated from other calls by a short period of silence (Fenton, 1970). Each call has a time (milliseconds [ms]), frequency (kilohertz [kHz]), and amplitude (decibels [dB]) component. Two or more calls

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[1] For example, local breeding activity could be confirmed if high acoustic activity is recorded and lactating females are captured; if numerous "feeding buzzes" are recorded, the area is likely important for foraging.

[2] This is because these two species' echolocation calls are very similar, and while low-clutter recordings of Little Brown Myotis can help establish the presence of this species, few diagnostic call features are known for Long-legged Myotis; generally, mist netting or genetic analysis is required to confirm presence.

separated by at least two seconds are termed a bat pass (henceforth “pass”) (Loeb et al. 2015) (Figure 2). The succession, or pattern, of calls is a call sequence.

A call sequence generally changes in predictable ways: the frequency of each call (kHz) and the repetition of each call (also known as pulse periodicity) will change over time as a bat approaches an object (also referred to as “clutter”) in its environment (Figure 3). Three distinct phases of a call sequence, based on the activity of the bat, can be observed in acoustic data (Figure 4): search phase (while the bat is not yet detecting an object), approach phase (as an object is detected), and terminal phase, also known as the “feeding buzz” (when the object is approached closely and, as in the case of an insect, is captured by the bat).

The frequency range of a call is a function of the prey type and size (Schnitzler et al. 2003) and the maneuverability of the bat; use of low frequencies has evolved as a necessary adaptation for fast-flying, less maneuverable species (Norberg and Rayner 1987). The type of habitat within which a bat forages or commutes also influences characteristic call frequencies (Obrist 1995): bats echolocate using lower frequencies in open, “low-clutter”, environments, whereas species travelling or foraging in densely vegetated, “high-clutter”, habitats emit calls more often and at higher frequencies.

High-frequency sounds attenuate (i.e., lose energy [see acoustic attenuation in the Glossary]) more rapidly than low-frequency sounds. The advantage of producing higher frequency calls is the increased resolution that the returning echoes provide; thus, most bats tend toward using a rise in call frequency when approaching objects that they are trying to resolve. Higher frequencies (including harmonics [see Glossary]) allow bats to detect smaller objects or greater detail; a wide range of frequencies allows better localization of an object (distance measure) (Simmons and Stein 1980). Low-frequency sounds cannot detect small objects or provide fine-scale resolution; however, low-frequency sounds travel farther (attenuate less) and thus are advantageous in open habitats for detecting objects at greater distances (Jacobs and Bastian 2016).

The echolocation calls of bats in B.C. range from 8 to 120 kHz. Spotted Bat calls emitted in low-clutter environments are typically between 8 and 12 kHz, and can be detected with the unaided human ear (most humans, especially when young, can hear sounds up to ~20 kHz); however, it is important that all surveyors test their hearing range to ensure these frequencies are audible. Surveyors who have excellent high-frequency hearing may be able to hear the Hoary Bat (*Lasiurus cinereus*), which emits calls as low as 15 kHz when commuting in open habitats. The other bat species in B.C. can be “heard” only with the assistance of ultrasonic acoustic detectors (henceforth referred to as detectors).

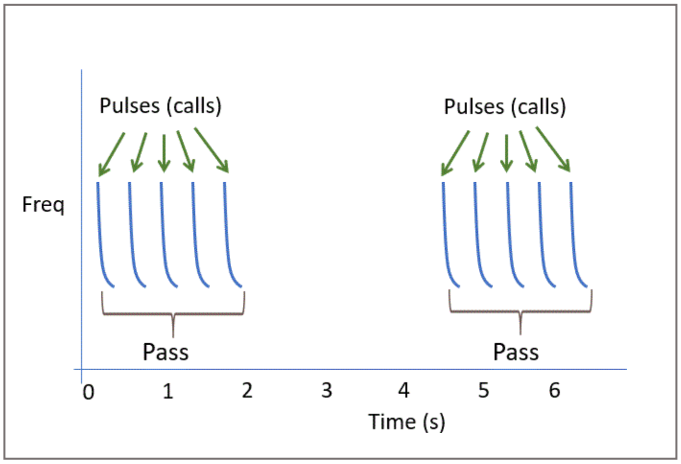

Figure 2. Several calls, or pulses, separated by at least two seconds, form a call sequence, or pass. In this case, two passes are shown. Each pass contains five pulses illustrating the shape typical of a pulse as it "sweeps" through a range of frequencies over time. Copyright 2018, C. Lausen. Reproduced with permission of C. Lausen.

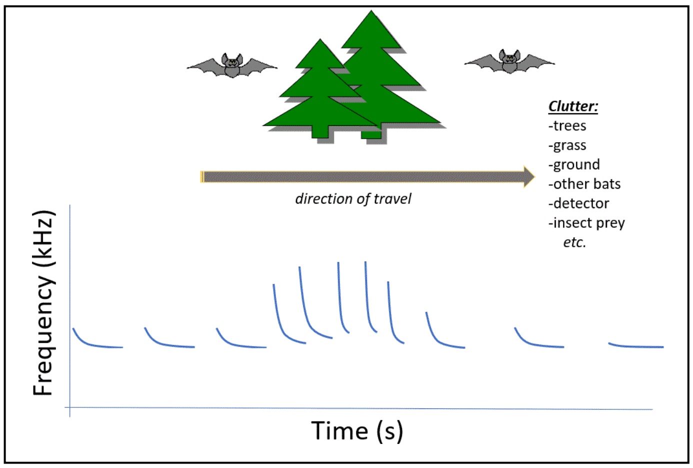

Figure 3. Diagrammatic representation of the clutter continuum—the progression of variability in echolocation frequency (kHz) and pulse periodicity over time in response to obstacle density. Shown are search phase calls as a bat approaches and flies beyond environmental obstacles (clutter). Copyright 2018, C. Lausen. Reproduced with permission of C. Lausen.

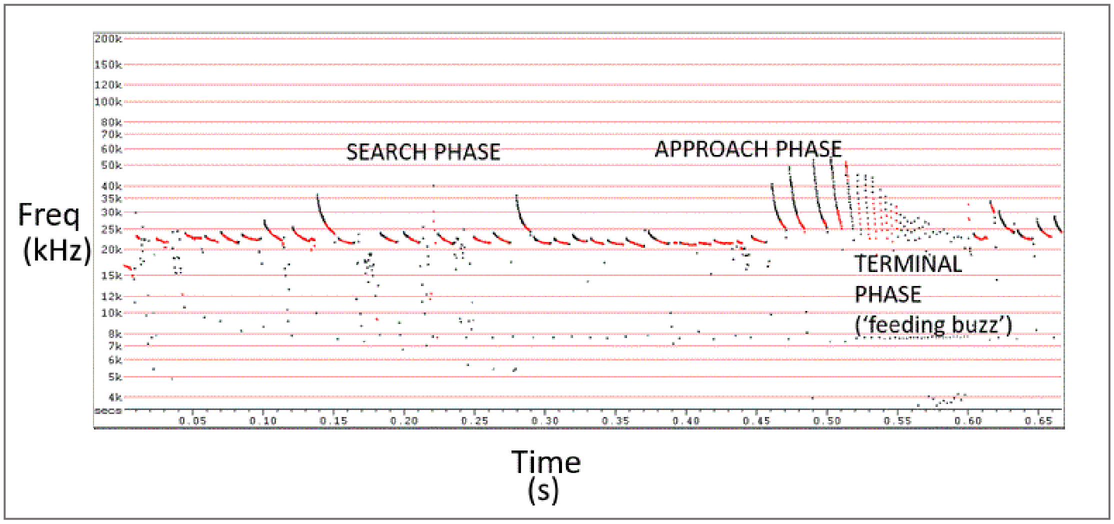

Figure 4. A sonogram (frequency vs. time) illustrating the search, approach, and terminal phases of a call sequence. Copyright 2018, C. Lausen. Reproduced with permission of C. Lausen.

The following factors will affect the detection of echolocation calls:

- Call frequency – is the number of cycles per second of a sound wave measured in kHz. Higher frequency calls (i.e., 40 kHz and above) will attenuate (or dissipate) more quickly, which will limit the detection zone. As a result, the likelihood of detecting species that emit high-frequency calls is lower. Conversely, low-frequency calls (i.e., 25 kHz) travel farther, which increases the detection zone and the likelihood of detection.
- Barometric pressure – or air pressure, is the force exerted by the Earth's atmosphere at a given location. At low barometric pressures, sound waves are more refracted and therefore attenuate more (Bass et al. 2007). As a result, detection zones become smaller when barometric pressure is low (i.e., a detection zone at 3000 m above sea level could be 50% smaller than at sea level).
- Periodicity of echolocation – periodicity refers to how often a bat echolocates; this depends on the species. A bat that echolocates infrequently may fly into and through the detection zone without producing a single call (and thus not be detected). For example, the Pallid Bat may not echolocate very often because it can forage by sight or passive listening (C. Lausen, pers. comm. 2017). The probability of detecting a bat that echolocates often is greater because it may call several times while passing through the detection zone.
- Position of the bat – calls have the greatest amplitude closest to the source (i.e., the bat's mouth). The distance, direction, and angle of a bat's head relative to the microphone will therefore influence the detectability of a call (Broders 2003). Calls will be more easily detected if the bat is close to, facing, or in front of, the microphone (see Section 5.4.2: Fundamentals of Echolocation).
- Recording equipment – even when produced by a single manufacturer, the slightest difference in component materials, dimensions, or construction will result in inherent variation within the recording equipment (e.g., microphones and detectors). This could include variation due to the electronics and configuration parameters of

detectors and minor variation in microphone sensors (Agranat 2014). As a result, the detectability of a call will be affected.

- Intensity (amplitude; i.e., how loud the sound is) – some species such as Townsend's Big-eared Bat (*Corynorhinus townsendii*), Long-eared Myotis (*Myotis evotis*), and Northern Myotis are considered “whispering” bats; they use low-intensity and/or high-frequency calls, which attenuate rapidly (Faure et al. 1990; Szewczak et al. 2011). Other species, such as Hoary Bat, are “louder”; they use high-intensity, low-frequency calls, which attenuate relatively slowly (Murray et al. 2009). As such, the “louder” calls have a larger detection radius and are more likely to be recorded; therefore, they may ultimately be over-represented.

5.4.3 Methodological Considerations for Acoustic Sampling

Appropriate acoustic survey design must consider a variety of factors, including but not limited to research objectives, focal species, sampling equipment and setup, habitat heterogeneity, weather, accessibility, and budgetary considerations.

Research objectives will influence the selection of equipment, the number of detectors used, the timing and duration of the study, and the placement of detectors. For example, a study to determine bat behaviour around a potential maternal roost will be designed differently than a study to determine larger scale bat habitat use and movement patterns for a potential wind energy project. It is important to stratify relevant habitat types to ensure that representative habitats within a given study area are sampled sufficiently. This approach will add rigour to conclusions about species habitat associations, species richness, and habitat use. An experienced bat biologist should determine the acoustic sampling design, and a statistician should be consulted where necessary. The study design should adhere, where relevant, to the latest versions of the Best Management Practices for bats: (https://a100.gov.bc.ca/pub/eirs/viewDocumentDetail.do?fromStatic=true&repository=BDP&documentId=12460) (e.g., Holroyd and Craig 2016a, b, c).

Different bat species may have different detection probabilities, different habitat preferences, and different behavioural characteristics (e.g., migratory versus non-migratory bat species). These differences must be considered when designing a study (including during the selection of sample methods).

The quality and number of acoustic recordings captured in a study will be influenced by the choice of equipment, selected recording settings, and habitat attributes during deployment (e.g., distance to clutter, elevation, orientation). In addition, species detectability (i.e., the probability of detecting a species) will also vary depending on these choices. Finally, it is also important to ensure that acoustic sampling be conducted during appropriate weather conditions, during the appropriate season(s), and over a time frame that is sufficient to provide a reasonable chance of detecting a given species if it is present (see Section 5.4.3: Methodological Considerations for Acoustic Sampling).

Acoustic surveys can be used to confirm species occurrence and compare relative activity. When used in conjunction with direct observation and/or capture methods in very specific circumstances, acoustic surveys may also be used to infer absolute abundance. Regardless of the acoustic sampling method used, the absence of a recorded call cannot be interpreted as the absence of a bat (species or individual), only that it was not detected (O’Keefe et al. 2014). In order to address specific survey objectives, it is important to understand the advantages and limitations of the various acoustic sampling methods.

5.4.3.1 Survey Intensity

Detailed Best Management Practices (BMPs) are available to guide bat survey design when surveys are used to inform various industrial developments (e.g., wind energy, mining). Consult applicable BMPs for additional, sector-specific guidelines (https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/best-management-practices). Sampling methods should follow these BMPs when relevant.

Methods should maximize replication during sampling. Replication is particularly important when the objectives include documenting bat species richness in an area and/or when comparing relative activity across habitats. For example, to compare relative activity across sites, Hayes (1997) suggests a minimum of seven nights of acoustic sampling per site to account for temporal variation in bat activity; Broders (2003) found that 14 to > 20 nights of sampling (based on riparian and forest-edge habitat types, respectively) were required to account for temporal variation. Greater sampling efforts (more locations or longer duration) are required to increase detection probability for species that are rare or difficult to detect (Weller 2008; Skalak et al. 2012). Sampling at multiple sites within a habitat type is required if statistically robust comparisons between habitat types are desired. Consult with a statistician to determine the appropriate number of sites and ensure the study design is adequate.

The following paragraphs discuss survey intensity in relation to acoustic sampling.

Presence/not detected: Presence/not detected surveys are designed to inventory or document the occurrence of bat species (or species groups) at a specific location and time (e.g., Ford et al. 2006). Determining bat abundance (i.e., the numbers of bats present in an area) is not an objective of this type of survey. Presence/not detected survey intensity simply provides an estimate of potential species richness in the study area. The ability to detect more species increases with improved sample design and, in particular, with increased sampling effort. Increased sampling effort may be achieved by increasing the number of detectors and/or the number of recording nights (e.g., Skalak et al. 2012).

Relative abundance: Relative abundance surveys are designed to quantify the number of bats relative to temporal or spatial variations (e.g., at different times or in different locations or habitat types). Relative abundance measures may also be used to quantify abundance of sympatric species (or species groups) in relation to the total number of bat species present in an area. Because it is not possible to reliably detect and therefore count all bats (because bat detection methods and rates are imperfect), relative abundance can at best be inferred using indices, such as relative bat activity given a certain level of quantified and described effort. Typically, the number of call sequences per species (or species group) per unit of time (e.g., per detector or per survey night) is accepted as a basic measurement of bat activity based on acoustic data analysis (Broders 2003; Frick 2013). For the purposes of this document (acoustic component only), relative bat activity refers to the number of passes per detector night of a species or species group relative to other sampling locations or sample timing. When comparing recorded bat activity levels between spatially discrete study areas, it is important to compare locations for which survey effort is similar (i.e., similar timing and duration). When comparing recorded bat activity levels between discrete temporal periods (e.g., seasons), it is important to compare activity levels at the same (or, at the very least, similar) sample locations.

In general, acoustic surveys are less suited than some other methods to providing a measure of relative abundance because it is not possible to differentiate unique individuals based on recorded calls. For example, one bat could be recorded multiple times in a finite period of time; this could mistakenly be interpreted as many bats in an area at that time, or it could be attributed to repeated recording of calls from the same individual. In addition, not all bat species are equally detectable. This will also influence accurate measurement of relative bat abundance (based on recorded acoustic activity levels) of species or species groups. For example, species abundance may be overestimated for “louder” species relative to “quieter” species. Differential habitat selection between sympatric (co-occurring) species due to niche partitioning also confounds accurate estimates of relative abundance. For example, bats that specialize in foraging in interior closed canopy forest conditions will be under-represented when detectors are placed in open environments.

Some issues related to relative abundance sampling can be addressed if acoustic data are collected using mobile transects (see Section 5.4.4: Acoustic Survey Type). During these surveys, the detector is mobile and travelling at a speed generally considered faster than the speed of bat flight (30 km/h). Under these conditions, it can be assumed that each call sequence is a different individual. Repeated mobile sampling along a transect may provide a reasonable estimate of relative abundance over time or between areas as long as other influential covariates (e.g., weather) are quantified and normalized. For example, if Little Brown Myotis represents 50% of 200 call sequences based on a 2-hour mobile transect, the transect can be subsequently repeated under similar conditions (e.g., time, weather, season) to document changes in bat activity levels recorded between different surveys.

Absolute abundance: Absolute abundance surveys claim to quantify the total number of a species present in an area. For many of the reasons described above, acoustic surveys are not capable of accurately measuring absolute abundance of bats. Despite these limitations, however, acoustic methods can be useful in determining absolute abundance of bats emerging from roosts that have a single access point (Kloepper et al. 2016; C. Lausen, pers. comm., 2018). It must be noted that the time of year when this approach can be used must be carefully considered, especially during periods when females are making multiple visits to the roost throughout the night (i.e., when raising young) and double counting is possible. It is recommended that simultaneous visual counts also be conducted to compare and correlate detector results with visual results.

5.4.3.2 Survey Timing

Survey timing will be dictated by the project objectives. Some studies may need to determine nightly activity patterns of migrating bats, which generally comprise most turbine-related fatalities at wind energy facilities; therefore, surveys must include the relevant migratory periods (see Holroyd and Craig 2016c for more details on survey methods for wind energy developments in B.C.). Other studies may focus on identifying maternal colonies or hibernacula. Understanding species-specific ecology is crucial to designing a successful sampling program in these examples.

5.4.3.3 Survey Location and Detector Deployment

Site selection, equipment types and settings, and microphone height and orientation have a significant effect on the number and quality of calls recorded. Efforts should be made to maximize the number of low-clutter calls that the detector will record, especially if species-level identification is an important objective of the study. The use of a handheld detector to pre-sample potential detector placement sites prior to deployment may be useful if there are concerns regarding interfering ultrasonic noise. The following are additional recommendations for site selection and equipment deployment:

- For general inventories, deploy detectors in locations that are representative of the habitats that are available to the bat community.
- For general inventories, deploy detectors within the detection distance (as determined by the manufacturer specifications for the microphone) of where bats are likely to be found.
- If the study objectives are species-specific, deploy detectors near key habitat features or within targeted habitat types that are important to the focal species (e.g., roosting, foraging, commuting, hibernating, and migrating).
- Orient microphones to avoid potential sources of echoes (i.e., nearby reflective surfaces such as buildings, asphalt, ponds, weatherproof housing, solar panels). A set-back of at least three to four metres from such surfaces may be required to reduce the recording of reflections. If possible, sample recordings should be made before finalizing where a detector is deployed.
- Spatial and temporal variation may be required to properly inventory bat species richness and diversity.
- Remember that other organisms can affect the detector (e.g., wasp nests built in microphone housings; porcupine chewing on cables); therefore, it is important to think ahead to reduce risks and to check equipment frequently to reduce potential data loss.

5.4.4 Acoustic Survey Type

Three broad types of bat acoustic sampling methods are explained in this section: active sampling, mobile transect surveys, and passive sampling.

5.4.4.1 General Acoustic Sample Methods

5.4.4.1.1 Active Acoustic Sampling

Active acoustic surveys are completed with a surveyor present for the duration of the survey, who controls microphone direction relative to bat location in order to optimize recordings of echolocation calls (C. Lausen, pers. comm., 2017). Active acoustic surveys can result in high-quality recordings because the direction and position of the microphone relative to the flight path or behaviour of a bat is adjusted by the observer (Britzke 2002; Milne et al. 2004). Active acoustic sampling may involve surveyors walking (with detector continuously sampling) and/or surveying from fixed location(s) with the detector turned off between sampling locations. Handheld detectors (particularly those with directional microphones) are advantageous for this purpose.

Conducting active acoustic surveys with the aid of a spotlight can improve species identification (e.g., an ambiguous Big Brown Bat (*Eptesicus fuscus*) versus Silver-haired Bat (*Lasionycteris noctivagans*) sequence can be identified to species if the bat can be seen because colour of pelage is generally discernable in white light spotlights) and can document a species' vocal repertoire in relation to clutter (e.g., as a bat approaches clutter, it can be followed visually and recorded). Spotlighting (see Section 5.4.5: Reference Recordings) should be done cautiously because some bats are deterred by light (C. Lausen, pers. comm., 2018).

5.4.4.1.2 Mobile Acoustic Transect Surveys

Mobile acoustic transect surveys record calls as the bat detector is continuously moved along a transect (e.g. road, trail, and lake). Mobile acoustic transect surveys can be conducted using cars, bikes, boats or all terrain vehicles, with the microphone attached to a fixed point on the survey “vehicle.” Recent research suggests that mobile acoustic surveys can under-represent species richness of rare species (Skalak et al. 2012; Braun de Torrez et al. 2017); however, mobile surveys are useful when surveying for common species. Mobile acoustic surveys are also useful for investigating changes in bat diversity or activity indices over time if standardized methods are employed (Loeb et al. 2015). Caution should be used if mobile acoustic transects are being used as the sole measure of species richness (Tonos et al. 2014), and many transects with substantial repeated sampling may be required to draw statistically valid conclusions. Similar to active acoustic sampling, use of a directional microphone is recommended to reduce noise in the recordings and reduce the likelihood of recording multiple bats at a time, which can confound species identification.

Guidance on using mobile acoustic transect surveys, including details on suitable detector types and requirements, are provided by the North American Bat Monitoring Program (NABat) (www.nabatmonitoring.org/).

5.4.4.1.3 Passive Acoustic Sampling

Passive acoustic sampling refers to the automatic recording of echolocation calls from a fixed location (including fixed microphone orientation) without the presence of a surveyor. Recording occurs at a fixed point or points (if more than one detector is used), according to the programmed recording schedule. Passive sampling methods are more cost-effective than active sampling based on per hour of data collection (Coleman et al. 2014). Passive acoustic survey can be a suitable technique, particularly for rare or declining species that produce some diagnostic echolocation calls, because survey time can be increased with relatively little effort to account for species with low detection probabilities. Coleman et al. (2014) posit that acoustic technology advancements, including lower cost, have resulted in a trend toward increased use of passively deployed detectors.

Despite obvious cost-savings, there are limitations associated with passive surveys, such as potentially lower call sequence quality. Passive surveys may produce lower quality recordings because the detector and the direction of the microphone are in fixed positions, which may not be optimal to record some of the bats flying through the detection zone of a given microphone (Coleman et al. 2014). Recording quality will affect the number of passes that are identifiable to species or species group.

It is recommended that multiple detectors be used to passively sample different habitats within a study area, preferably simultaneously, to capture spatial variation in species presence and activity (Stahlschmidt and Brühl 2012). Additionally, recording should be conducted for the entire night, particularly for studies that report activity levels (Hayes 1997; Skalak et al. 2012). Where a single site or a few sites are monitored over a large spatial scale, detectors should be left in place for a minimum of 6 nights (Hayes 1997). The NABat protocol (Loeb at al. 2015) suggests that a minimum of 4 nights is required for passive monitoring in sampling areas (referred to as grid cells); however, cumulative species curves support sampling for at least 6 nights or more (C. Lausen, pers. comm., 2017) to increase the opportunity to detect species with low detection probabilities.

5.4.4.2 Acoustic Survey of Specific Habitat Features

Many studies (e.g., assessments for industrial projects) aim to assess bat species presence and identify specific habitat features of importance to bats. Acoustic surveys (passive, active, and mobile) are a valuable tool for identifying habitat features. Equipment selection (including microphone type and directionality) and setup will vary with the behaviour being investigated and/or the type of habitat feature of interest.

5.4.4.2.1 Maternity Roosts

Maternity roosts are locations that female bats use in the summer to give birth to, and care for, pups. Maternity roost habitat and use varies considerably by species. Detecting maternal roosts of non-colonial species (i.e., foliage-roosting bats) and Northern Myotis by using acoustic survey alone is not effective. However, identifying likely maternal colonies of some *Myotis* species (e.g., Little Brown Myotis, Yuma Myotis [*Myotis yumanensis*]), Big Brown Bat, and other colonial species is feasible; suspected maternal colonies can then be confirmed through observation, capture, and/or guano sampling.[3]

Relatively high acoustic activity at a suitable habitat feature may indicate a potential maternal colony. Bats may emit different echolocation/interaction calls ("social" calls) when entering/exiting roosts, which can help confirm the presence of a roost. Some studies (D. Burles., pers. comm., 2018) have reported a high correlation between acoustic activity and visual exit counts, though it appears that acoustic activity alone tends to underestimate bats. Generally, nightly activity at a maternity roost will have a bimodal pattern early in the season prior to parturition, as bats leave the roost to forage (early peak of activity near roost) and return later in the night or near dawn, sometimes after night-roosting away from the maternity roost (late night peak). Once pups are born, this bimodal pattern of activity may break down, as females return throughout the night to nurse pups. Once pups are volant, there is generally increased acoustic activity. Adult females may switch roosts (once pups become volant), and choose a cooler site that is more conducive to using torpor to build up fat stores for the winter.

If presence of a maternal roost is suspected, visual counts and additional acoustic sampling (and potentially, capture or guano sampling) are recommended to provide abundance estimates, confirm the species present, and quantify reproductive rates. In the case of colonies in anthropogenic structures (e.g., buildings), observers can often monitor egress/ingress from outside the building and/or directly access the colony (e.g., through an attic).

5.4.4.2.2 Commuting and Foraging Areas

The repetition rate at which calls are given varies in relation to objects/surfaces, and provides a means of discriminating between different behaviours (Thomas and West 1989). Commuting bats or bats searching for prey emit approximately 1–25 calls per second (varying widely with species). This rate increases to ≥ 100 calls per second when a potential prey item has been detected and the bat closes in to capture the prey. The recording of this characteristic "feeding buzz" (see Section 5.4.2: Fundamentals of Echolocation) makes it possible to classify areas used for foraging.

Bats have species-specific foraging preferences. For example, Little Brown Myotis and Yuma Myotis are likely to produce substantially more feeding buzzes in an open water environment because they typically hunt prey while skimming over open water. Species such as Long-eared Myotis or Northern Myotis tend to feed on insects in more cluttered environments, gleaning prey off vegetative surfaces, yet they approach water to drink on the wing (as all bat species do). Bats tend to produce steeper, more broadband calls when confronted by a cluttered environment than they would in a more open environment. This makes species identification difficult, and in some cases, it is impossible to classify echolocation calls beyond species groupings (see Section 5.4.2: Fundamentals of Echolocation).

[3] Experimental work to locate bat roosts using guano-sniffing dogs may be an alternative tool (e.g., University of Washington, Dr. Sam Wasser Conservation Canines -- Rochelle Kelly, pers. comm., 2014). The use of Conservation Canines in finding bat carcasses is also possible.

5.4.4.2.3 Hibernacula

Confirming the presence of hibernacula is species-specific and challenging. Pairing acoustic survey with capture and telemetry can be an effective way of finding/confirming hibernacula. Acoustics should be used to initially identify an area where bats are detected in substantial numbers immediately before and after the hibernation period, or in some cases, during winter (some species in some areas leave their hibernacula to fly mid-winter) (Lausen and Barclay 2006; Lausen et al. 2017 a,b). To confirm where bats are hibernating, late fall or winter capture and radio-tracking may be necessary but are associated with substantial challenges (see Section 5.5.8: Marking Bats).

Detectors may be placed inside suspected or known hibernacula. The Anabat Roostlogger (Titley Scientific) is a special type of zero-crossing (ZC) detector for use primarily in roosts such as caves or mines (maternity or hibernacula). It is a weatherproof (for deployment and decontamination), compact programmable recorder with a sealed microphone and built-in temperature datalogger. A Roostlogger provides long-term sampling with temperature recording for time periods in excess of 1 year[4] with the use of internal batteries. Microphone peak sensitivity is ~42 kHz, so only portions of the original call may be rendered (e.g., second harmonics may be more apparent than the fundamental parts of the call). The limited detection distance (only capable of recording bats that pass within ~10 m of the microphone) ensures that only bat activity associated with the roost or hibernacula is recorded. Roostloggers are not, however, intended for species identification. Bat calls in the high clutter environment of a roost or hibernacula may be atypical and often converge to similar forms, even for different species. Roostloggers should be decontaminated prior to, and following, deployment.

Winterized acoustic detectors may be placed outside hibernacula. Bats exhibit species-specific winter behaviours that greatly influence detection probability outside, and potentially within, hibernacula. Big Brown Bat, Silver-haired Bat, and/or Californian Myotis (*Myotis californicus*) are regularly recorded on acoustic detectors outside hibernacula in winter throughout the province and specifically the Pacific Northwest as far north as Alaska (Falxa 2007; Blejwas et al. 2014; Lausen and Hill 2016; Lausen et al. 2017a, b; Paterson et al. 2020, Paterson 2021). Other *Myotis* species, including the federally endangered Little Brown Myotis and Northern Myotis, generally cannot be classified beyond species group based on acoustic detections, especially at roosts in high-clutter recording environments. Winter activity of these species has not been definitively recorded, possibly due to acoustic limitations or to lack of, or limited, flight behavior in winter.

Due to the challenges inherent in detecting bats acoustically or visually in hibernacula, acceptable criteria for identifying these features have been revised for Little Brown Myotis and Northern Myotis, listed as endangered by SARA, in relation to critical habitat (ECCC 2018). Given the presence of suitable habitat for wintering bats, as assessed by a qualified professional, late fall detections and/or early spring acoustic detections may represent sufficient data to classify a feature as a hibernaculum (ECCC 2018). Therefore, if presence of a hibernaculum is suspected, acoustic survey covering the fall swarming period (August and September), extending into late October or early November, and spring survey starting in early March to the end of April, is recommended to support the classification of a feature as a hibernaculum, for critical habitat designation. Deploying a detector at a suspected hibernaculum in winter is highly recommended if the roost type is a rock crevice because

[4] This sampling duration is accomplished by an automated farming process that subsamples each 5-minute period, an appropriate amount to ensure monitoring lasts for the entire specified deployment period. For more intensive sampling durations, battery life and recording time periods will be reduced (i.e., less than 1 year).

there is growing evidence to suggest that bats may hibernate in crevices and some species may emerge to fly in winter (e.g., Lausen and Barclay 2006; Klug-Baerwald et al. 2016; Lausen et al. 2017b). Many hibernacula identified in B.C. do not support large numbers of bats, so acoustic activity patterns can be quite variable. Careful interpretation of recordings by a qualified professional, along with other lines of evidence, including exit counts, capture, and possibly radio-telemetry or video photography, are necessary to confirm the presence of hibernacula, especially if industrial (or other) developments have the potential to affect the suspected hibernaculum or its use by bats.

Provincial BMP documents that provide guidance to researchers who are trying to monitor bat activity at known or suspected hibernacula are available for mines and caves.

5.4.4.2.4 Migration Corridors

Bat migration is species-specific and may involve short (10s–100s of kilometres) or long distances (100s–1000s of kilometres) between summer and winter habitats. Outside of B.C., there is evidence that the three species of tree bats (Hoary Bat, Eastern Red Bat, and Silver-haired Bat) undertake long distance seasonal migration; however, there is little information about what these species do in western Canada. Winter recordings of Silver-haired Bat in B.C. (Lausen and Hill 2016, Paterson 2021) and along the coast as far north as Alaska (Blejwas et al. 2014), plus regular observations of hibernating individuals in woodpiles (BC Community Bat Program unpublished data), suggest this species may not undergo the same degree of migration as in eastern parts of its range. Information about tree bat migration in North America has increased because tree bats generally constitute most of the operational wind turbine-related fatalities. Acoustic monitoring at wind energy facilities has provided good information on migration timing in some parts of tree-bat range, but wind energy facilities in B.C. are not geographically widespread enough to provide the same level of information across the entire province. Tree bats typically migrate north in spring (April–May) and south in late summer and fall (August–September).

Surveys that are focused on migrating tree bats should consider sampling landscape features such as ridges, river valleys, and edge habitat that could concentrate migrating bats. Additionally, microphones should be elevated to increase the chances of recording migrating bats, which can fly hundreds of metres above the ground. Often, bat activity across a season will show several nightly peaks in activity, probably influenced by weather and moon phase, with a general trend of increasing activity toward the peak of migration; therefore, migration surveys should sample the entire migration period to account for seasonal variation and poor weather.

Acoustic detectors are the primary tool used to assess migration. Provincial BMPs (www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/best-management-practices) that were recently developed to provide guidance in conducting these surveys for wind energy projects.

5.4.4.2.5 Swarming Sites

Fall swarming at hibernacula generally peaks near the end of August (Showalter 1980). Traditionally, swarming has been described as a time in the fall when summer bat colonies have disbanded, and male and female bats gather and mate, often outside of, or near, hibernacula. Swarming activity can be indicative of the presence of important roosting and hibernating habitat. Although swarming sites are not specifically considered Critical Habitat for species at risk, if they are also used as hibernacula, the sites could qualify as Critical

Habitat. If swarming activity is recorded in late summer via a peak in acoustic activity, further acoustic survey in fall, winter (if possible), and spring should be conducted.

5.4.5 Acoustic Sampling Equipment

The three main components of ultrasonic acoustic detection equipment are the detector, microphone, and power supply (see Appendix C). Numerous technologies are available from various manufacturers (e.g., Titley Scientific Ltd., Wildlife Acoustics Inc., Pettersson Elektronik, Alta.) for detecting, transforming (into frequencies audible by humans), and recording bat echolocation calls (see Appendix D). As with inventory methods, the choice of bat detection equipment will depend on the ecology of the focal taxa, the goals and objectives of the research project, and budgetary constraints.

5.4.5.1 Detector Types

Traditionally, all detectors allowed the observer to listen to bats while recording. Some current models, however, do not come equipped with headphone jacks or speakers, and are intended for passive recording only. Detectors vary in the power supply required (i.e., internal versus external) and recording capability (i.e., direct to hard drive/tablet or to internal memory cards). Currently, an increasing number of detectors are being designed to resist the elements (i.e., do not require protective housings); however, water-resistance may be an important consideration when purchasing a detector and may dictate whether accessories are needed.

Detectors are classified based on the way they detect or record incoming ultrasonic calls (i.e., heterodyne, frequency division, time expansion, or full spectrum). Many modern detectors are multi-functional and capable of listening and/or recording in multiple formats, as described below:

- **Heterodyne** – Heterodyne detectors are tunable to a narrow range of frequencies and allow the listener to hear bats echolocating within that narrow range in real time. This is made possible because the incoming frequency is mixed with an internally generated ultrasound signal (from the detector, and generally controlled by the user with a tuning dial) to produce an audible frequency. Heterodyne detectors are of limited use beyond listening to bats in real time for two reasons: (1) frequencies outside the tuned frequency will not be heard by the user unless the bat produces audible calls, and (2) species-level classification is often impossible because any signals captured by the detector cannot be saved and analyzed with sound software to observe call parameters that may permit species identification.
- **Time expansion** – Time expansion detectors can record a broad range of frequencies and preserve original call structure (frequency and duration of call). An incoming frequency is transformed (i.e., processed, by expanding it over time); processing occurs after this frequency is received, which results in a time delay. Because of this, these detectors do not record or allow listening in real time. Commonly, a 10-fold time expansion is employed; for example, a 1.7-s signal captured by a time expansion unit would take 17 s to record/play back. During this 17-s playback/recording period, the detector is unable to capture new signals, which results in a "deaf period." Because recording is not continuous, these detectors are often not recommended for surveys where activity rates are of interest or missed recording time is of concern.
- **Frequency division (also known as zero-crossing)** – These detectors can detect and record a broad range of frequencies in real time. However, only the most intense

(loudest) sounds (i.e., dominant harmonic) are recorded because the sound must exceed the ambient noise threshold. As a result, many low-intensity calls (e.g., while the bat is flying far away from the microphone) will be missed. The incoming sound wave is essentially divided by a preset amount (division ratio, *n*; often 8 or 16), which results in the time and frequency of an incoming echolocation call being sampled at 1/nth the frequency of the incoming signal. In other words, the detector counts each time the loudest sound wave passes the zero point (crossing) on an oscillogram (sound waveform) as specified by the division ratio. Therefore, a lower division ratio, such as 4, will sample an incoming call twice as many times as a division ration of 8. Using ZC recording, information about duration and frequency are retained, while amplitude information is not. The incoming signal is recorded as an x (time) versus y (frequency) data set, which enables the plotting of a sonogram.[5] This is generally enough information to enable species identification where differentiation based on frequencies relative to time in a single harmonic is possible. If amplitude or harmonic information is also needed to differentiate a species, then ZC recordings are not sufficient, and recording in full spectrum is recommended. Calls recorded directly using ZC are termed "native ZC." Although less information is recorded by ZC detectors, smaller file sizes require much less power, and sampling can occur for extended periods (see extended discussion in text box).

- **Full spectrum** – Full spectrum (FS) detectors can detect and record a broad range of frequencies, as well as amplitude or energy associated with echolocation calls. Some FS detectors can also be programmed to record in native ZC. All sounds within the sampling volume are digitized in real time, including ambient noise. As a result, all call structure details such as frequency sweep, harmonics, and relative amplitude are retained. Unlike ZC, FS detectors sample and record all sounds, including loud and soft signals, target and non-target signals, and multiple frequencies occurring simultaneously. Sampling rates (i.e., how often a signal is digitized) (see Glossary) should be suitable for the signal that is being targeted (e.g., for ultrasound, a high sampling rate is required, and 256 kHz is commonly used to avoid clipping high-frequency echolocation calls). Full spectrum sampling rates[6] of current detector models range from 192 to 768 kHz (i.e., sound is sampled 192,000–768,000 times per second (kHz). Full spectrum detectors make detailed recordings and can be essential to confirming species identification (for some species), but they require greater data storage capacity and power than ZC recordings, which may limit deployment time. Full spectrum files can be converted (processed) into ZC files, but the reverse is not possible.

[5] In general, when analyzed a posteriori in specialized software (e.g., Analook, Titley Scientific), a zero-crossing recorded call sonogram is seen as a series of plotted frequencies (dots) over time (e.g., a 7-ms long call ranging in frequency from 56 to 28 kHz typically contains ~60 data points/dots when recorded at a division ratio of 8).

[6] The higher the full spectrum sampling rate used, the larger the file sizes and the greater the power consumption of the detector will be.

Zero-crossing (ZC) versus Full Spectrum (FS)

The two most frequently used detector types are ZC and FS; thus, it is important to understand the difference between these sampling formats. The selected format will generally depend on survey objectives, budget, and personal preferences.

The lower power and memory requirements of ZC recording (relative to FS recording) are especially useful in situations where remote, long-term deployments are required and where regular maintenance/download is not possible. Advances in recording technology have reduced the amount of power required, even for FS recording, and large capacity memory cards are affordable and easy to find, which results in fewer power and data storage advantages of ZC over FS.

If call measurements are a goal, some researchers will gravitate to ZC format. ZC files contain fewer sampling points relative to FS recordings, which creates a simplified representation of the frequencies used by a bat over time. Interpreting ZC calls can be challenging, however, because data points in the sonogram may seem out of place. For example, if calls from multiple bats overlap exactly in time, data points can appear to jump between frequencies because only the loudest frequency will appear as a dot on the sonogram at that point in time. This also applies to multiple harmonics. Generally (but not always), the fundamental (first) harmonic is dominant; if a higher harmonic were to have greater perceived amplitude, the sonogram would show a jump from one harmonic to the next. For example, bats of the genus *Corynorhinus* typically produce calls such that similar energy is perceived between first and second harmonics, which results in both harmonics being displayed in the sonogram in what is called a "split harmonic" (Figure 5). This is not always present in ZC files generated from FS data because some conversion software (e.g., Wildlife Acoustics Inc. Kaleidoscope Pro Software) piece split harmonics back together and display them in the first harmonic only (e.g., Wildlife Acoustic's advanced signal enhancement).

The main disadvantages of the ZC format are the (1) loss of amplitude (energy) information in the call, (2) inability to record more than one harmonic simultaneously, and (3) reduced total number of calls recorded (especially for low amplitude sounds). An argument can be made that while FS recordings include more calls (above and below the noise threshold), the low amplitude calls are embedded in the ambient noise and are not easily recognized as bat calls by automated software. It should also be noted that most users engage triggered FS recordings (see Section 5.6.4: Sampling Settings), such that a recording is not initiated until a signal that exceeds the noise floor in amplitude is detected. Once the signal is loud enough, both FS (e.g., recording to triggered wav files) and ZC detectors are triggered to record. However, if the bat becomes quiet part way through a recording (e.g., during a feeding buzz when the amplitude of calls plummets momentarily), the FS recording will continue for a specified trigger window, recording all detectable sounds, but the ZC detector, due to its inherent nature of recording only sounds louder than the noise floor, often result in some "missed" low-intensity calls, such as those in a feeding buzz. At some point, any sound can become too low in amplitude to be recorded by any detector, but in general, FS detectors record more feeding buzz calls and other lower amplitude sounds, which may or may not be an advantage in downstream analyses.

Material contributed by C. Lausen, 2018.

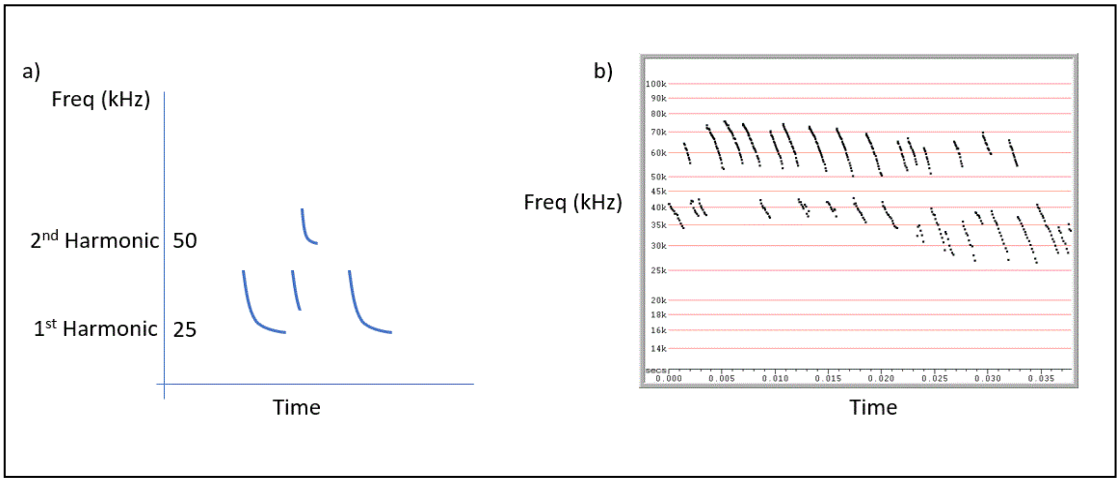

Figure 5. Graphic representation (a) and sonogram (b) of a split harmonic (frequency vs. time); these sound characteristics may be useful in acoustically identifying bat species (e.g., diagnostic for identifying *Corynorhinus* genus). Copyright 2018, C. Lausen. Reproduced with permission of C. Lausen.

5.4.5.2 Microphones

Whether external or integrated into a detector, a microphone will have some degree of directionality,[7] ranging from relatively non-directional (omni-directional[8]; e.g., Wildlife Acoustics' SM series of microphones), more sensitive in one plane (hemi-directional; e.g., Wildlife Acoustics' Echometer Touch 2), or most sensitive in an area surrounding the axis of the microphone (directional; e.g., Pettersson detectors with built-in microphone funnel; polaroid microphones used on Anabat SD1 and SD2 and Binary Acoustic Technology detectors). Directional microphones, as implied, sample only a volume of space in front of the microphone (in three-dimensional space around the axis that passes directly through the centre of the mic); thus, only bat calls, echoes, or noise coming from one main direction will be detected at any significant range. Depending on the microphone housing, there may be a "back-lobe" where sounds are detected, but only at close range. The detection volume realized will depend on a variety of factors, as discussed in Section 5.1.2 Fundamentals of Echolocation. Directional sensitivity makes it possible to reduce unwanted echo or noise in recordings by strategically positioning the microphone. Echoes and noise coming from multiple directions in any acoustic deployment will be recorded if within the detection "sphere"; positioning omni-directional microphones to minimize these unwanted recordings is somewhat more challenging than for directional microphones. The choice of microphone may be limited by compatibility with the detector (by manufacturer or model).

Microphone placement relative to bat flight paths can greatly affect detection distance and the proportion of bats recorded (Frick 2013). Microphones should be placed as far from clutter but as close as possible to anticipated flight paths or areas of activity if maximizing the number of bats detected is the goal.

It is important to keep moisture (e.g., rain, snow) from entering the microphone. Damage from moisture may reduce microphone sensitivity or render it useless; this may go unnoticed

[7] Some manufacturers sell accessory housings that can be used to increase the directionality of their microphones.

[8] No microphone is ever truly omni-directional; the detection volume of "omni-directional" microphones approaches a spherical shape, but because of cable attachment and element housing, there is a loss of sensitivity along the back axis.

unless routine testing is conducted. If a housing is used to protect the microphone, echoes may be generated by the housing, which could interfere with the signal of interest and compromise the quality of the recording. In some cases, manufacturers sell specially designed microphone covers that reduce interference of reflections. Testing homemade housings and analyzing subsequent acoustic recordings produced (looking for echoes as well as good quality signals of interest) prior to deployment in your project is advisable.

Sensitivity (electrical output in response to sound waves), frequency response (microphones are more sensitive at certain frequencies than at others), and noise floor (self-generating inherent noise over a wide range of frequencies) are specifications that should be considered when choosing a microphone.

Microphones should be tested[9] frequently (at a minimum before each field season) to ensure functionality and a minimum level of sensitivity. Ensure you are buying a microphone that has been calibrated (by the manufacturer) to be within a small range of sensitivities. Note that while the word "calibration" is often used when referring to microphones, no models currently support microphone calibration. Such a procedure would require microphones to be rebuilt by the manufacturer. Some manufacturers allow settings on detectors to be changed to "equalize" sensitivities among detector–microphone units (e.g., Titley Scientific); others sell a testing unit misleadingly referred to as a "calibrator" (i.e., Wildlife Acoustics). Even the most precise microphones have an inherent sensor variance due to minute sensor imperfections (e.g., ± 4 dB sensitivity is common), but the difference in detectability of bats among units is much more likely to be due to differences in placement.

5.4.5.3 Power Supply

The choice of power supply will depend on site conditions, length of deployment, and ease of access to the detector site. If deploying detectors in cold conditions, battery life will be limited because batteries do not work as well when cold. Insulating the battery from cold winter temperatures may increase battery performance. Always follow the manufacturer's recommendations for protecting detectors from temperature extremes.

- Internal – Adhere to the manufacturer's instructions regarding the type (e.g., alkaline, lithium) and voltage of batteries that a detector can accommodate; there is a wide range of models with very different requirements. Some types of detectors can be powered using only internal batteries.
- External (including solar power) – Some types of detectors may be powered by external batteries (6–12 V); combining an external battery with a solar panel allows long-term monitoring[10] with significantly less maintenance. Charge controllers are recommended if the unit is deployed in an area that is subject to high light levels. A charge controller with a low voltage disconnect will also prevent battery damage in case of charge depletion below a usable level or during freezing temperatures.

[9] Some manufacturers sell devices that enable the user to test whether the microphone sensitivity remains within manufacturer's specifications.

[10] Using solar panels and external 12-V batteries can permit longer deployments; however, long deployments are risky due to variables that could result in loss of data (e.g., animals damaging cables, microphones, or other hardware).

5.4.5.4 Sampling Settings

Comparisons of acoustic activity should be made only for detectors that are of the same type (manufacturer and model), are equalized (as per manufacturer instructions), and are deployed with the same settings. Environmental variables should also be controlled for, to the extent practicable. Some variation between detectors can be accounted for by user-controlled settings to ensure that units are providing comparable data; however, there are inherent differences between detector types and microphone types, and microphones can degrade over time, which can result in changing sensitivities. Even slight differences in angle of microphone deployment, which is inherent in any study where detectors are deployed side-by-side, can skew comparisons.[11] Detector settings should reflect the target species, recording format selected, recording environment, and power and memory limitations of the detector.

5.4.5.4.1 Sampling frequency of full spectrum detectors

The sampling frequency for FS recordings can be set within the unit, typically with values of 192 kHz, 256 kHz, 384 kHz, and up to 768 kHz in newer units. Based on the Nyquist Theorem,[12] these sampling rates enable recording of frequencies as high as 96–384 kHz. Because calls of B.C. bats are never above 150 kHz, a 768 kHz sampling rate is not necessary for surveys conducted in this province. While a sampling rate of 192 kHz is appropriate for many bats in B.C., recordings of species that echolocate above 100 kHz[13] may be truncated at 96 kHz, especially when approaching close to the microphone (i.e., when high frequency sounds are most likely to be within range); this can reduce the ability to differentiate some *Myotis* species. When recording higher frequency bats in FS, a higher sampling rate such as 256 or 384 kHz is recommended. Note that higher sampling rates will result in larger files sizes and greater power consumption.

5.4.5.4.2 Division ratio of zero-cross detectors

The lower the division ratio in zero-crossing recordings, the more zero-crossing data points are collected over a given time interval. For instance, a division ratio of 8 will record twice as many data points as a division ratio of 16. For ZC recording of most bat species in B.C., a division ration of 8 is sufficient; however, for short duration and low frequency calls (such as those produced by Spotted Bat), a division ratio of 4 is recommended.

5.4.5.4.3 Gain and sensitivity

Sensitivity refers to how easily a detector is triggered. This is not to be confused with gain, which is how much a sound is amplified by the detector. Some FS detectors have no internal adjustments available and rely solely on the sensitivity of the microphone with default settings; however, most FS detectors let the researcher adjust both sensitivity and gain.

High gain will amplify incoming signals, which will allow the detector to trigger on, and record, fainter sounds (thus, more bats from farther away can be recorded); you do, however, risk clipping (see Glossary) loud calls (from nearby bats). Clipping occurs when a sound wave is louder than the detector's capacity to process it. In such a case, incoming frequencies

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[11] Scientifically rigorous comparisons of detectors are done in sound labs under controlled conditions with microphones compared temporarily allowing for exact spatial replication.

[12] The Nyquist Theorem dictates that sampling rate must be at least twice the highest frequency of the original signal in order to be correctly represented in the digitized recording.

[13] Particularly *Myotis* species: Northern Myotis, Long-eared Myotis, Western Small-footed Myotis, and Californian Myotis.

cannot be properly represented, and artifacts called aliases (aliasing [see Glossary]) can be seen in the recordings. Aliasing in recordings can be falsely interpreted as sounds produced by bats (e.g., "false social calls"), or they can simply obscure the actual echolocation call, and thus compromise species identification. A signal that has been clipped is recognized by a square waveform (oscillogram [see Glossary]) and generally should not be used for species identification. Clipping can be avoided by (1) moving the detector farther from the source of calls (e.g., move it away from a roost entrance), (2) reducing the gain settings, or (3) both.

Many FS detectors also allow adjustment of the detector sensitivity, which controls how loud a signal has to be in relation to the ambient (background) noise to trigger a recording. This is called a signal to noise ratio ([SNR] measured in dB); i.e., how well the bat signal separates from the background noise. The SNR (also known as trigger sensitivity) can be set to reduce the number of poor quality recordings. Requiring a high SNR functionally means that a bat must approach a microphone closely before a recording is triggered. Once the recording begins, it will contain the entire soundscape, but the calls will be a strong signal, easily differentiated from background noise by auto-ID software. A higher SNR will result in fewer total calls recorded; however, calls will be of better quality, which will enable a higher percentage of files to be labelled (classified) using auto-ID software.

Because ZC detectors inherently record only the loudest sounds over the noise floor, a gain setting does not apply to these types of detectors. On ZC detectors, the noise floor has to be defined; besides using different styles of microphones, this is the only sensitivity setting that ZC detectors offer. Some ZC detectors auto-detect and frequently auto-adjust[14] for the ambient noise floor (e.g., Wildlife Acoustics SM4Bat). Others require this threshold to be manually set (e.g., Anabat SD1/2[15]); this setting will remain the same throughout the deployment, regardless of changing ambient noise levels (e.g., rain or wind noise). If few calls are recorded on a ZC unit, usually a threshold set too high relative to the noise floor is to blame. If too many noise files are recorded, the detector's threshold has been set too low, residing in the noise floor for at least part of the deployment time.

Gain and sensitivity settings should be set depending on sampling conditions and project objectives. Some manufacturers recommend gain/sensitivity options for various deployment scenarios. For example, an array of detectors monitoring a wind energy development should have the same gain/sensitivity settings to permit comparisons between units. Monitoring specific features for bat presence/use should employ gain/sensitivity settings that are suitable to the sampling location. If deploying near the edge of a large lake that is likely to have lapping waves on windy days, sensitivity settings should be set low. On FS detectors, this means setting a higher SNR; on ZC units, this means lowering the threshold (or turning the sensitivity dial up on Anabat, for example). If the detector is being deployed in a location where bats may approach closely (such as at a roost), then the gain should be lowered to reduce clipping in recordings. Remember that an increase in gain causes all sounds to be amplified, including signal, noise, echoes, etc. A lower gain might be desirable to achieve

[14] While this can be a useful feature for passive detectors because it reduces the number of noise files and files without bats, it does mean that the sensitivity of the detector is changing (i.e., the volume of detection is changing) through the survey session according to environmental conditions, such as wind, rain, traffic, etc. This could be undesirable if volume of detection is a variable that is being controlled for in the study design, such as is generally the case in mobile monitoring where numbers of bats are being compared over time and space.

[15] On an Anabat, the noise threshold is set by turning the sensitivity dial, and will remain the same even if the noise in the environment changes (e.g., the wind dies down and the noise floor lowers), so now the manually set threshold is high relative to the ambient noise level.

"cleaner" recordings, thus increasing the percentage of recordings that are likely to be given an auto-ID label in auto-ID software.

While many detectors allow internal gain/sensitivity adjustments, the sensitivity of the microphone is built into the microphone itself and cannot be adjusted. Microphone sensitivity can degrade over time (see Section 5.4.5 Acoustic Sampling Equipment) and should be checked (as per the manufacturer's instructions) prior to every deployment to ensure that it is operating within the appropriate specifications. Most manufacturers have a system available to check microphone sensitivity.

5.4.5.4.4 Frequency filters

High and low pass filters are available on some units and function to filter sound either above (low pass) or below (high pass) a given frequency (kHz). Low pass filters are typically not used for recording bats. A high pass filter (HPF) of 16 kHz is appropriate for many areas in British Columbia; however, if surveying audible bats, such as Spotted Bat, a lower HPF is required (HPF set to 1 kHz on current detectors).

5.4.5.4.5 Trigger window/maximum time between calls

These terms refer to essentially the same feature but are named differently depending on the manufacturer.

Trigger window (Wildlife Acoustics, Inc. and also used in Titley Scientific's Anabat Swift) refers to the amount of time that passes following the end of a triggered event before a recording should end. For example, if a bat is echolocating loudly and then flies away from the detector, the signal weakens. At the point where the signal no longer meets the criterion for trigger (i.e., in a FS detector, the signal's relative intensity drops below the SNR setting), a certain amount of time must pass before the file is ended. This "wait time" is referred to as the trigger window in many FS detectors, and has ranged from 1 to 5 s in North America. Not all FS detectors have trigger window settings (e.g., Pettersson d500x employs absolute file lengths only). Note that triggered events will record up to a maximum time length (trigger length; see below) set by the user. This value is programmed prior to deployment but to some extent can be altered once data have been recorded.[16]

Maximum time between calls (TBC) has been used in Anabat ZC systems to define this same "wait time" after a signal no longer exceeds the noise floor. This setting is adjusted at the time of data extrapolation (interpolation) via CFCRead (see Glossary). The MaxTBC feature of CFCRead allows the user to specify the time in seconds between the start of one call and the start of the next call. Five seconds for TBC, and 15 s maximum file length has been the default values long used for Anabat recordings. The maximum file length of 15 s is not adjustable in Anabat, but the TBC setting is (in CFCRead).

Standards for recording bats are changing, and Loeb et al. (2015) recommend for NABat monitoring that trigger windows and TBCs are set to 2 s. This is done largely to ensure that extremely low duty cycle bats (e.g., Hoary Bat), which may produce calls as infrequently as once per 1 or 2 s, are not sectioned into individual calls per file. When comparing acoustic activity between sites, it is important that TBC settings are the same; detectors set with different TBC will significantly affect the perceived relative bat activity.

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[16] For example, long files from Wildlife Acoustics detectors can be cut into shorter time periods in Kaleidoscope. Sonobat has traditionally accepted 8-s long files but can accommodate files up to 16 s long; longer files can be loaded into the software, but a smaller subsection of the file must be specified for viewing.

5.4.5.4.6 Trigger length

Also referred to as max length or maximum file time, this feature specifies the maximum length of time that a triggered event will record. Note that triggered recordings in most detectors can amount to less than this maximum file length based on trigger/recording window or TBC settings that specify the amount of "silence" following a triggered event before a recording ends. (See trigger window section above for more details.) This is not true of the current Pettersson detectors, which record the maximum file length regardless of the disappearance of a trigger.

Loeb et al. (2015) recommend a new North American standard of 15 s maximum file lengths.[17] Max lengths of 15 s allow an ample number of calls to be recorded in the same file, which provides more information to auto-ID software upon which to base identification. File lengths longer than 15 s are not recommended due to the increased likelihood of recording more than one bat species in the same file; currently, auto-ID software applies a label to only one species of bat per file. Note that Pettersson detectors currently do not offer a 15 s file length option.

5.4.5.5 Reference Recordings

Reference recordings are acoustic recordings of calls from a known bat species; they can be used for comparison with recorded calls of unknown species identity. A compilation of reference calls (call library [see Glossary]) can be created for specific geographies, and may aid in species classification of acoustic data. Reference recordings are particularly useful for species that are rare or are otherwise under-represented in call libraries.

Sites chosen for recording reference calls must be safe for both bats and personnel, and must be in locations where interruptions during recording are unlikely (e.g., a road rarely travelled). Consider both the natural flight tendencies of the bat and the placement of recording personnel when selecting a site; choosing an open area away from clutter will increase the likelihood of recording "free-flying" calls. Choose a location where a tethered bat is most likely to want to travel (e.g., along a narrow road lined on both sides with trees, or toward water) with no overhead obstacles. Recording reference calls requires the capture and handling of bats, and must follow all protocols, including the decontamination and care guidelines outlined in the capture portions of this document (Section 5.4.5. Reference Recordings). The following are additional ethical and handling considerations:

- Tethering and light tagging should be conducted only by personnel who have experience handling bats, and ideally only by those who have experience with the method(s).
- Several attempts can be made to record reference calls from a tethered bat, but if the bat is not warm enough or is uncooperative, it should be released, regardless of whether a successful recording has been made (C. Lausen, pers. comm., 2017).
- Hand release (without a light tag or spotlight) is the **only** appropriate method for collecting reference call recordings from volant juveniles, late-stage pregnant females, females with pups attached, and lactating females.

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[17] Standards developed to determine potential risk to migratory bats from wind energy facilities in Alberta are based on 5-s MaxTBC and 15-s file length. Recording bats using a shorter trigger window would result in more files (which may be interpreted as call sequences), and comparisons to the standards developed for Alberta would be invalid.

Calls recorded using any reference call method may not be representative of the species' typical calls because bats are recorded close to the ground, and they may be reacting to capture, tagging, bright lights, etc. (Parsons and Szewczak 2009). Calls produced by bats that are echolocating in, or just out of, someone's hand should not be used in reference libraries. Similarly, it is important to document the conditions under which a reference recording is made, such as level of clutter and method used (e.g., spotlighting) so that an appropriate context can be associated with the call shapes in call libraries during future interpretation.

Methods for Collecting Reference Calls

Zipline tethering: Ziplining involves tethering a bat, using elastic sewing thread with a loose-fitting fixed loop around the bat and another around the line, to a length of line (similar to a laundry line) stretched between two fixed objects (Szewczak 2000; Parsons and Szewczak 2009).

BatKite tethering: In BatKiting, the bat is tethered using a loose-fitting loop of elastic thread; the other end of the cord is a spool of thread that is handheld and reeled out as the bat flies higher or farther while still being subtly directed (Lausen et al. 2009). BatKiting is preferable for manoeuverable species (e.g., Western Small-footed Myotis, Californian Myotis, and all long-eared species) versus ziplining which is better for less manoeuverable species, like Hoary Bat (Lausen et al. 2009).

Light tagging: This method involves affixing a miniature light tag to the lower sternum or belly fur of a bat by using water soluble glue (Parsons and Szewczak 2009). For each species light tagged, the use of different colour light tags can facilitate identification of that species if it is re-sighted later in the night. However, not all colours can be well differentiated; therefore, one might restrict tagging to one species per night (C. Lausen, pers. comm., 2017). Szewczak et al. (2011) consider this the best method for acquiring reference recordings because free-flying bats produce the most representative calls. Light tagging should be used at sites where safety concerns or habitat preclude tether deployment (e.g., steep or uneven terrain, dense vegetation). It is not unusual for bats to land in a nearby tree and immediately groom a light tag off; thus, a researcher may put out many light tags to achieve a few good reference calls per night (C. Lausen, pers. com., 2017).

Spotlighting: Rather than affixing a light tag, spotlighting involves visually tracking a bat by using a spotlight (high-intensity flashlight). This method is ideal for collecting reference calls in steep or uneven terrain, or from free-flying species whose pelage makes them readily distinguishable when spot-lighted. It also offers an advantage over other methods because the behaviour of the bat and any potential "intruders" (bats that are not releases and are thus of uncertain identification) can be observed; therefore, notes can be appended to the reference recordings, which may direct their application in libraries.

Hand release (without light tag or spotlight): Certain bat life stages are incompatible with the methods mentioned above; this includes volant juveniles, late-stage pregnant females, lactating females, and females with pups attached. For individual bats within these life stages, hand release without light tags or spotlighting is the **only** appropriate method of collecting reference calls. Personnel should anticipate the most likely direction of travel and orient themselves and the detector(s) accordingly.

Material contributed by C. Lausen, 2018.

5.4.5.6 Analysis of Recordings

Analyses of acoustic recordings may be completed manually with user-developed filters and scans (Analook and Anabat Insight software) or by using auto-ID software. Generally, using a minimum of two methods of classification for each call are recommended: manual verification of classification based on filters and scans combined with an auto-ID program, or two auto-ID programs.

Manual analysis involves an analyst manually scrolling through recorded files and classifying call sequences to species or phonic groups based on objective classification criteria. The use of filters and scans can expedite this process for large data sets by "sorting" the files according to user-specified criteria. The use of filters and scans takes considerable practice, and formal training is recommended. Scanned or filtered files should be manually verified to ensure appropriate classifications.

Analyses of acoustic data may also be completed using a variety of commercially available, automated software programs[18] (i.e., auto-ID program). The format of the original recording (ZC or FS) may dictate the software that can be used (e.g., Analook processes only ZC files, Kaleidoscope Pro allows users to view ZC or FS files, but auto-ID considers only ZC parameters, and Sonobat processes only FS files), unless files are converted prior to analysis. Several software packages for conversion are available, but it is important to understand that not all converters are the same; calls in a file can appear dramatically different when converted with different software.[19] For example, Kaleidoscope removes poor calls during conversion (using advanced signal enhancement to "clean" a file); the resulting sequence may not represent the true call produced by the bat. Due to the differences in file conversion, it is important to use the same software and methods for recording analysis within a given study.

Much debate surrounds the need for FS data (i.e., inclusion of call amplitude information) to differentiate some species of North American bats. In the past, this parameter (amplitude) has confounded Sonobat's ability to differentiate some species, in large part due to discrepancies between response curves of microphones used to collect reference calls underpinning the auto-ID process versus microphones used to collect passive data. This is because frequencies interpreted as loudest on one microphone may not be loudest on another microphone with a different sensitivity response curve.

Automated software makes it possible to analyze large volumes of data efficiently, but it is important to be aware that despite recent advances in this technology, significant limitations in species identification from acoustic data still exist. Awareness of the limitations will prevent erroneous conclusions about species distributions, abundance, or management/conservation needs.

[18] For example, zero-cross recordings can be analyzed in software applications, including Kaleidoscope Pro (Wildlife Acoustics Inc.), Analook (Titley Scientific), and the recently developed Anabat Insight (Titley Scientific). Full spectrum recordings can be analyzed in applications such as BatSoundPro, Sonobat, Kaleidoscope Pro (Wildlife Acoustics, Inc.), and Anabat Insight (Titley Scientific). Currently, the only auto-identification software package that analyzes full spectrum sounds is Sonobat.

[19] For example, Analook (Chris Corben), Bat Call Identification (Ryan Allen), and Kaleidoscope (Wildlife Acoustics) all offer batch conversion of wav to zero-cross files, but depending on the settings used, resulting files can dramatically differ.

5.4.5.7 Call Parameters

Familiarity with call parameter terminology is important when describing calls or attempting to classify them to species (manually or verifying auto-ID). The most common call parameters used in the process of identifying species when ZC recordings are analyzed are illustrated in Figure 6 (maximum frequency, minimum frequency characteristic frequency, duration), and Figure 7 (characteristic slope). Relevant parts of a call are the body, knee, and toe/tail (Figure 8). Additional call features may be useful in some cases, including time between calls (TBC) and initial slope. Full spectrum calls are generally analyzed with consideration of three additional parameters: peak frequency (the loudest frequency in the call—sometimes called peak energy), call amplitude (energy as seen in an oscillogram), and harmonics.

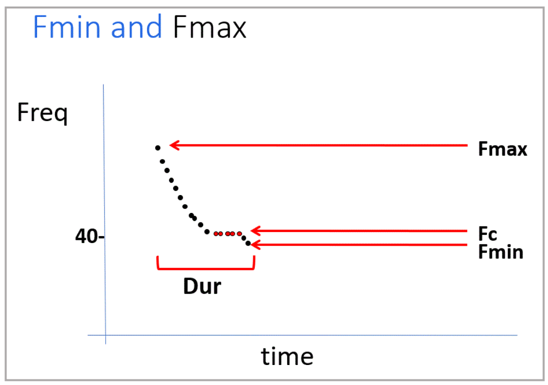


Figure 6. Frequency vs. time graphic representation of four common call parameters: maximum frequency (Fmax), minimum frequency (Fmin), characteristic frequency (Fc), and duration (Dur). Copyright 2018, C. Lausen. Reproduced with permission of C. Lausen.

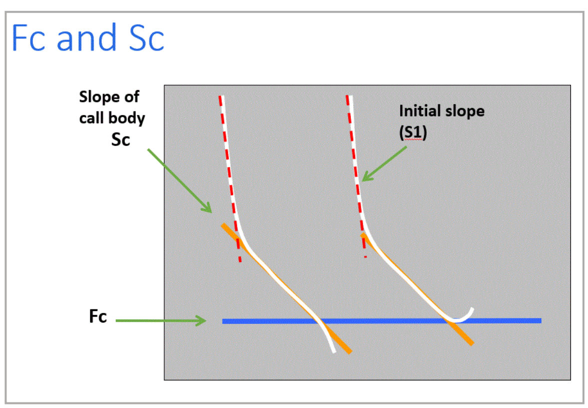


Figure 7. Graphic representation of characteristic frequency (Fc), characteristic slope (Sc; solid orange line) of call body and initial slope (S1; dashed red line) call parameters. The time between calls (TBC) would be the time (ms) elapsed between the start of one call and the start of the next call. Copyright 2018, C. Lausen. Reproduced with permission of C. Lausen.

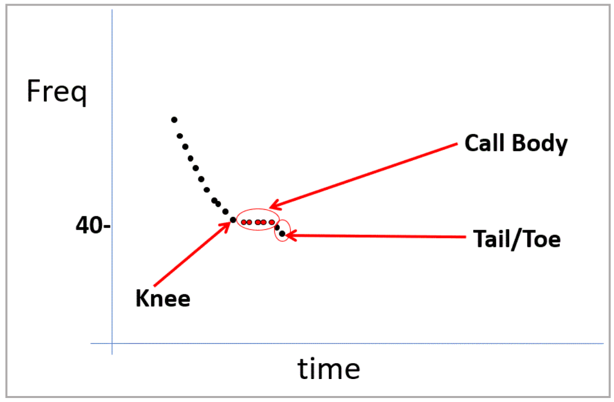


Figure 8. Frequency vs. time graphic representation of knee, call body, and tail (toe) parameters of a bat call. Copyright 2018, C. Lausen. Reproduced with permission of C. Lausen.

Characteristics of calls:

Characteristic frequency (Fc): also referred to as the call frequency. This is the frequency (kHz) at the end of the flattest part (lowest slope) of the call body (Figure 6**)**.

Characteristic slope (Sc): the slope of the call body between the knee and the characteristic frequency. Sometimes referred to as the lower slope (Figure 7).

Duration: the time from start to finish of a single echolocation call, measured in ms (Figure 6).

Fmax (maximum frequency): the maximum frequency (kHz) of the call as recorded; also referred to as *f*high (Figure 6).

Fmin (minimum frequency): the lowest frequency (kHz) of the call as recorded; also referred to as *f*Low (Figure 6).

Peak frequency: applicable only to full spectrum recordings, this is the frequency with the maximum power, or the loudest frequency.

Time between calls (TBC): the time between the start of each call (ms). This is not to be confused with TBC or trigger window settings (for recording call sequences) when programming and or downloading call files (Figure 7).

Parts of calls:

Initial slope (S1): also referred to as the upper slope. This is the slope of the call between Fmax and the knee (Figure 7).

Knee: the frequency (kHz) at which an echolocation call shifts from frequency modulated toward a more constant frequency (i.e., the call changes from more vertical to more horizontal). Some calls may not have a discernible knee (also called an “elbow”), but if it is present, an abrupt angle versus a gentle curvature (“quality of the knee”) can also aid in species differentiation. For example, Little Brown Myotis in low clutter can have a very abrupt/obvious knee, but Long-legged Myotis in low clutter will have only a gradual curvature to its calls (Figure 8).

Body: the flattest part of the echolocation call, which generally occurs between the knee and the end of the call. This can be very difficult to determine for *Myotis* species with steep calls (Figure 8).

Tail/toe: the final part of a call, occurring immediately after the call body; this portion of the call may not be pronounced or distinguishable from the call body characteristic frequency (Figure 8).

5.4.6 Species Classification of Acoustic Recordings

Classification of recorded calls to species is possible for those species that have unmistakable, unique call characteristics (diagnostic). For many species, however, call characteristics overlap; therefore, classification must be limited to phonic group (Table 6). Figure 9 is a generalized illustration of the overlap in minimum frequencies for B.C. bat species. Some bats will alter echolocation characteristics based on insect noise (Gillam and McCracken 2007), the presence of other bats (Obrist 1995), and the amount of structural clutter (Figure 10). Reference calls, usually collected from bats that are hand-released or kited, are calls that are purposefully free of background noise and other bat calls (Section 5.4.5 Reference Calls). While useful, calls obtained from bats that have been captured and released or kited are not representative of the full vocal repertoire of free-flying bats (Parsons et al. 2000). The ambient noise and multiple calls of free-flying bats that may be present on recordings collected in the field can also confound auto-identification analyses.

Search, not approach, phase echolocation calls (Section 5.4.2. Fundamentals of Echolocation) should be used for species classification. Approach phase calls generally do not contain recognizable diagnostic parameters (i.e., Kalko and Schnitzler 1993, Broders et al. 2004). Generally, only high-quality sequences (i.e., at least three good quality, unbroken calls with a good range of recorded frequency) should be identified to species. This is subjective (e.g., a single search phase call produced by the Hoary Bat may be diagnostic); however, experienced analysts will know when a species identification should not be attempted for a particular file.

Bat species acoustic identification has advanced tremendously with the ongoing development of recording technology and the compilation of call libraries from collected reference calls across North America. Several manufacturers have used reference (call) libraries to create auto-identification programs with different algorithms that provide species classifications where possible.

Some programs compare measured parameters of unknown calls with a library of reference calls by using techniques such as discriminate function analysis (e.g., Sonobat), whereas others use underlying libraries of calls to develop algorithms that rely on patterns of calls (e.g., KaleidoscopePro). The accuracy of auto-ID programs is affected largely by the comprehensiveness, size, and quality of their underpinning call library (Russo et. al. 2017). Automated bat call classification is a highly desirable goal for bat researchers; however, these programs and the reference libraries that they rely on are not yet capable of accurately identifying the species present in many recording scenarios and/or in certain regions where call libraries have not been adequately developed (Russo and Voight 2016).

Given the functional nature of echolocation and the similar acoustic reactions that bats share when they approach objects (see Section 5.4.2. Fundamentals of Echolocation), it is likely that differentiating between some species of bats will remain difficult no matter how sophisticated the software and how thorough the reference call libraries become.

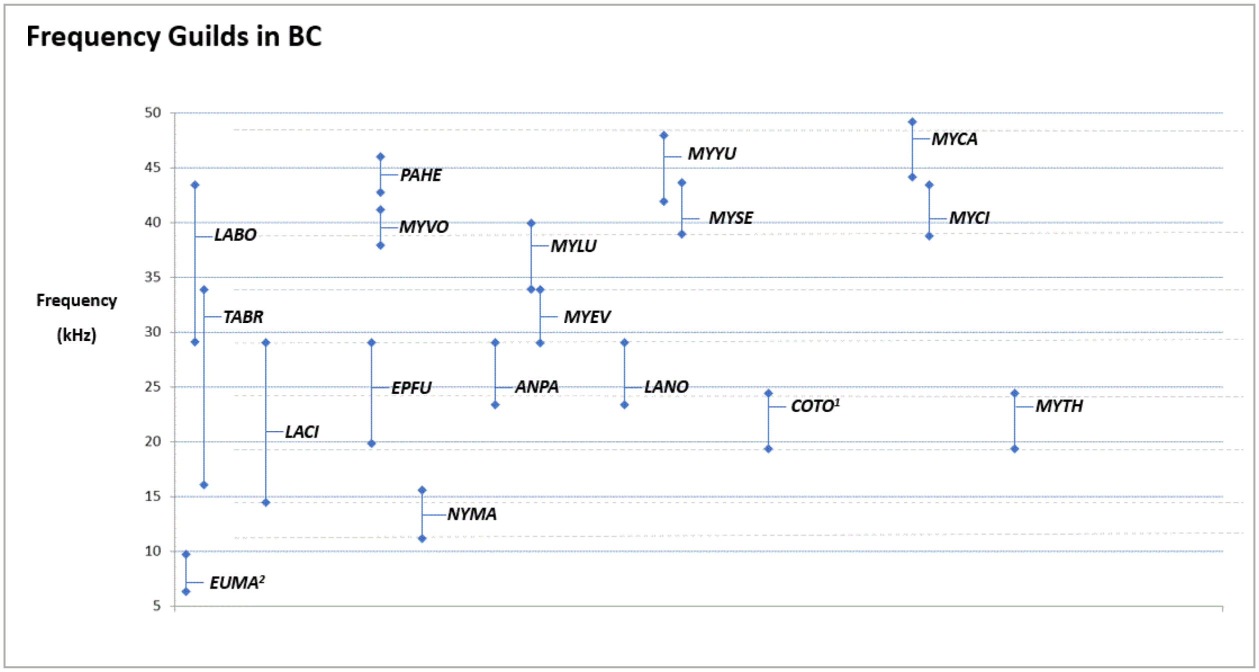


Figure 9. Generalized range of minimum frequencies produced by bat species that occur in British Columbia. This does not necessarily reflect the entire repertoire of the species across their ranges. [1]Refers to fundamental harmonic only; in zero-crossing spectrogram, a diagnostic split harmonic pattern is generally observed. [2]Audible bat, echolocating < 12 kHz. Copyright 2018, C. Lausen. Reproduced with permission of C. Lausen. Species codes are defined in Appendix A.

Table 6. Common labels for species–group identification based on the minimum frequency (Fmin) of a recorded call. British Columbia bats can be grouped into one of these basic acoustic identification categories.

Common Labels	Fmin (kHz)	Possible Species (by Species Code[a])
EUMA	7–12	EUMA (also possibly NYMA)
LowF	< 30	EPFU, LANO, LABO, MYEV, MYTH, ANPA. LACI, TABR, NYMA
EPFU/LANO	25	EPFU, LANO
25K	20–30	COTO, MYEV, MYTH, ANPA
40K Myotis	35–40	PAHE, MYCI, MYVO, MYLU, MYSE
LABO/MYLU	40	LABO, MYLU, PAHE
50K Myotis	41–50	MYCA, MYYU

[a] See Appendix A for species codes and scientific and common names.

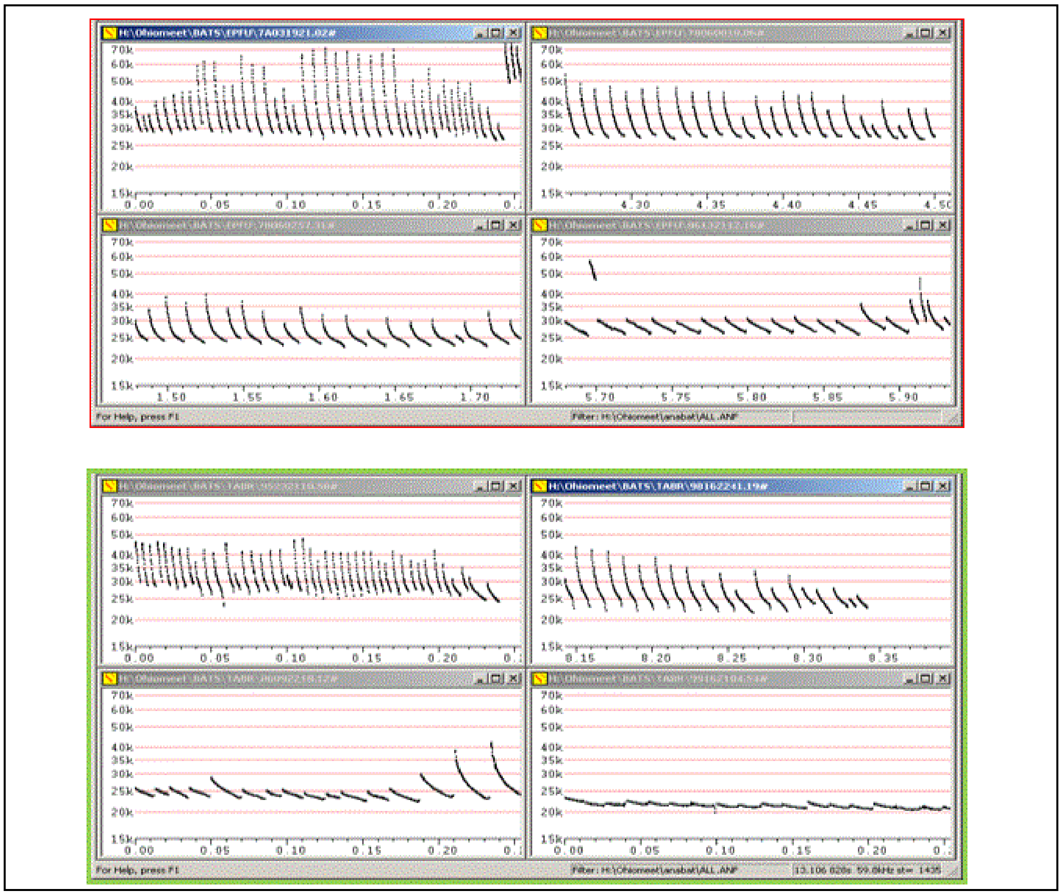


Figure 10. Sonograms depicting the highly variable and converging form of high frequency calls from two species in response to environmental obstacles (i.e., the clutter continuum). Calls in the upper sonogram were produced by Big Brown Bat; the lower sonogram calls are of Mexican Free-tailed Bat. Copyright 2018, C. Lausen. Reproduced with permission of C. Lausen.

5.4.7 Social Calls and Other Acoustic Identification Challenges

Not all sounds that bats make are for spatial orientation. Audible sounds associated with communication (e.g., audible squeaking in maternity colonies, self-defense, or mating) and other sounds that may be communicative but are not understood are categorized as “social calls.” Social calls may be a single call or a series of calls (e.g., Figure 11 illustrates a Spotted Bat social call sequence). More commonly, social calls are a feature added to a functional echolocation call. Social calls can sometimes aid in species identification but should be used cautiously because social call production by bats is poorly understood (C. Lausen, pers. comm., 2018).

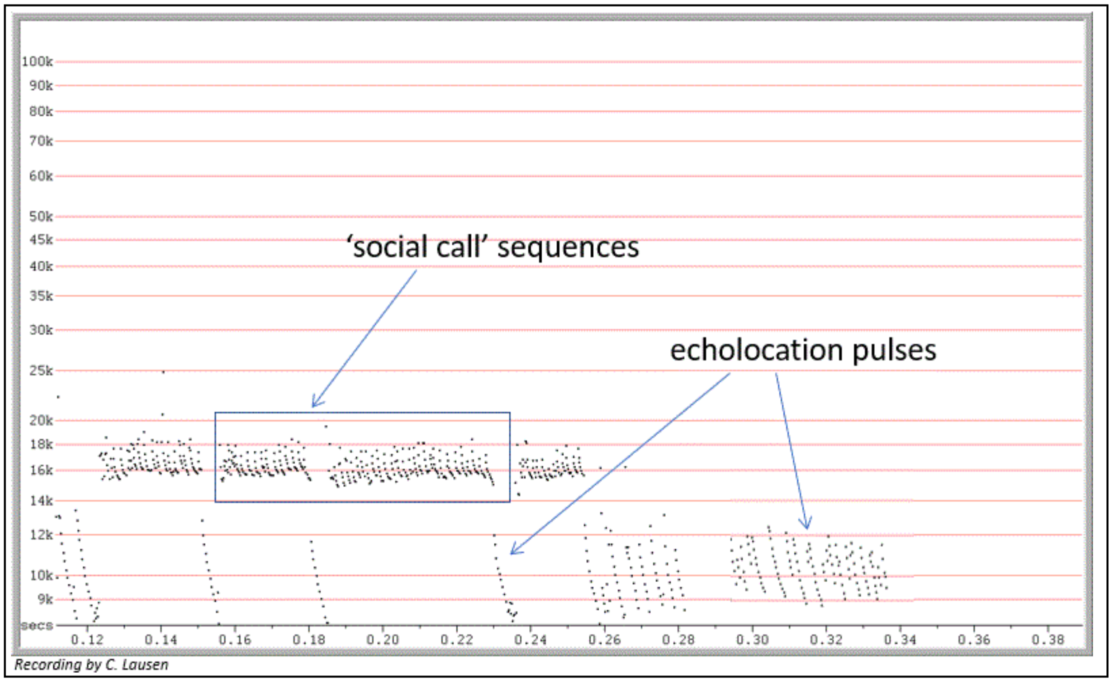


Figure 11. Sonogram of a Spotted Bat call sequence illustrating the series of short, steep social calls at higher frequency than (and interspersed with) their functional echolocation calls. Copyright 2018, C. Lausen. Reproduced with permission of C. Lausen.

It is also important to remember that other animals can produce ultrasound. Some birds and rodents generate ultrasonic calls that can be confused with bat calls. Flying squirrel ultrasonic calls (Murrant et al. 2013), in particular, can resemble calls produced by Hoary Bat.

Due to difficulties inherent in auto-identification programs, non-critical acceptance and reliance on auto-identification as a sole means of classifying bat species presence is not recommended (Rydell et al. 2017). Classification to species group rather than to species is recommended when call characteristics overlap. The ability to identify species from calls recorded in the field will depend a great deal on site selection, deployment details, and the subsequent quality of recordings. Recording in an open environment without clutter can improve species identification; however, such a setup is not always possible when investigating certain landscape/roosting features and habitats, and there can still be substantial overlap between species. Without the presence of diagnostic call parameters and a good understanding of regional bat vocalizations, identification to species may be impossible. It is much better to assign call sequences to a phonic group (Table 6) than to erroneously make assumptions about species-level identification. This would include accepting assignations from auto-identification programs that may have no call samples from species in the study area. This is an important consideration because there can be considerable variation in calls of conspecifics across their range (Thomas et al. 1987; Brigham et al. 1989; Hayes 1997).

Therefore, it is essential that auto-identification outputs are vetted by a qualified professional with experience in bat call classification for the species that are likely to be present in the sampling area. Species verification should be based on objective criteria (such as measurable call parameters), checked against known species distributions, and compared against other species for call overlap. For at-risk or rare species, including those outside their normal or known ranges, multiple expert verifications are recommended.

5.4.8 Office Procedures

Prior to the field season, ensure that:

- project objectives, scope, and logistical/budgetary considerations are well defined to guide selection of the survey method
- detector internal batteries (clock batteries) are charged, or replace as necessary; update detector firmware if needed
- detectors are tested and, if appropriate, equalized (if using multiple detectors)
- microphones are tested and, if appropriate equalized; faulty equipment repaired/replaced
- all other equipment (cables, weatherproof housings, etc.) are in good repair
- all necessary capture/handling permits, vaccination updates, and decontamination supplies are procured (if bat capture and handling is part of the project scope)
- the most current references for bat species (including ecology and distribution) west of the Rocky Mountains have been consulted
- the research team is familiar with the call characteristics and habitat use of the various bat species expected to be present or may occur in the study area

5.4.9 Personnel

- Personnel must be familiar with the programming, use, and deployment of detection equipment.
- Personnel who are conducting formal acoustic data analyses must have previous training and/or experience.
- At least one member of the field team must have previous experience tethering bats (e.g., Zipline, Batkite) or affixing light tags; otherwise, use only hand release for obtaining reference calls.
- For Spotted Bat surveys, surveyors must be able to hear Spotted Bat calls. Recordings are available online to test hearing capability.

5.4.10 Field Procedures

Consult most recent protocols for decontamination supplies/protocols if detectors are deployed in known (or potential) roosts or hibernacula, or if reference calls are to be recorded.

5.4.10.1.1 Spotted Bat sampling

- Listening for Spotted Bat should commence 30 minutes after sunset and continue for at least 1 hour at known or suspected roost sites. In potential foraging habitats, listening should continue all night.
- Detectors may be deployed to record calls remotely throughout the night without the need for attending personnel; however, the detector limitations and settings must be appropriate to detect low frequency and potentially distant Spotted Bat calls. For example, the default HPF of 16 kHz (on some detectors) must be turned off, and if recording in ZC, the division ratio should be set to 4.
- Survey large cliffs by stationing observers about 300 m apart along the toe of the cliff (Sarell and Haney 2000).

- Record start time, end time, temperature, wind, cloud cover, elevation, aspect, location of survey station (using GPS), size of cliff, and qualitative descriptions of the surrounding habitat.
- Two-way radios are useful for communicating detections to other observers so that bats are not counted more than once.
- Each observer should record their survey station location and the time and direction of Spotted Bat calls, and sketch roost locations and annotated flight paths of emerging Spotted Bats.

5.4.10.1.2 Ultrasonic detection of other bat species

- Detectors should be programmed to record the entire night, starting 30 minutes prior to sunset and ending 30 minutes after sunrise.
- Detectors, microphones, and cables should be protected from the elements (rain, snow, wind), damage (by humans or wildlife), or theft, as appropriate.
- Directional microphones should be oriented away from clutter unless contraindicated by survey objectives.
- All microphones should be several metres away from clutter and elevated as high as is practicable to increase the effective volume of airspace sampled. The goal is to reduce sources of noise, and reduce recording of reflected sound, or at least delay its arrival substantially enough (ideally > 2 ms after the end of the call) that it does not compromise recording of a call.
- Daytime reconnaissance is advisable for active survey and mobile transects to gain familiarity with the survey route and habitats being sampled.
- Passive detection equipment (including external power supply if applicable) should be deployed, secured, and tested; taking photographs of the detector and microphone setup is highly recommended.
- The GPS location of the detector, site conditions, and pertinent habitat data should be collected (see Section 5.5.5 Capture Procedures).
- Double-check the detector settings, memory card storage availability, and power supply prior to leaving the site, particularly for long-term deployments.

5.4.11 Acoustic Reporting (Minimum Standards)

Several authors have suggested there is a need for accurate documentation of variability during all phases of acoustic surveys (planning, conducting, analyzing data) (Biscardi et al. 2004; Frick 2013; Clement et al. 2014). Standardized methodologies and reporting will allow greater confidence in inferences drawn from acoustic data.

Reporting should provide enough detail for the project to be repeatable, and should adhere, where relevant, to the latest BMPs for bats (e.g., Holroyd and Craig 2016a, b). Suggested covariates to note for acoustic recording are provided in Loeb et al. (2015).

To promote robust, consistent, and repeatable studies, minimum reporting for acoustic inventory or survey projects will include details about:

- manufacturer and model of detector(s) and microphone(s) employed;
- detector geographic location (Universal Transverse Mercator [UTM] or latitude/longitude) and elevation. For mobile transect surveys, the start and end location of each transect must be reported as well as the distance travelled (GPS tracks of the entire route should be recorded);

- detector settings and power source;
- microphone height, orientation, and weatherproofing (as applicable);
- general habitat type(s) being sampled, and a site description of the detector placement (estimated or measured distance to clutter [e.g., trees, shrubs]);
- length of detector deployment and number of detector nights (nights that the detector was functioning properly). Detectors failures may occur, especially during long-term deployments; this must be considered when determining mean bat passes per detector night over a given time;
- if possible, record nightly temperature, cloud cover, wind speed, and precipitation during acoustic deployment;.
- moon phase, time of moonrise/moonset, time of sunset and sunrise;
- number of call sequences (bat passes) per detector night;
- method of call analysis (manual or automated) used to classify call sequences to species or species group, including type and version of auto-ID program software;
- manual verification of automated classifications;
- filter/auto-ID parameters used for species/phonic group identification of calls;
- species or phonic groups (e.g., *Myotis*, migratory versus non-migratory.) inferred to be present; and,
- name of analyst(s) who completed the call classification.

5.4.11.1 **Data Summary**

For each detector deployed, the number of call sequences per detector night should be tabulated. If pertinent to the study objectives, the number of feeding buzzes per detector night should also be tabulated.

Any estimation of absolute abundance should include a discussion of the assumptions that are implicit in the methods used (e.g., closed populations, constant and equal detectability over multiple capture sessions, and that indices such as catch-per-unit-effort are proportional to the actual population) and the likelihood of those assumptions being confounded (Kunz et al. 2009b; Ingersoll et al. 2013).

Data are required to be entered into templates from, and submitted to, the Wildlife Species Inventory database (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information). This database is maintained by the B.C. Ministry of Environment and Climate Change Strategy.

All data received on listed species are copied to the Conservation Data Centre. Placing inventory data in the Wildlife Species Inventory database ensures its long-term availability and may help improve management practices for bat species. Each Wildlife Species Inventory data set must have an associated report that provides details on methods.

5.5 Capture Surveys

Capture allows for species identification via physical characteristics or DNA sampling, age and gender determination, collection of morphometric data, and determination of reproductive condition (Anthony 1988; Racey 2009). Capture is also necessary to attach radio-transmitters or marks to individuals. However, capture obviously requires some handling of, and disturbance to, the animal. Not all species or genders are equally catchable. Acoustic surveys or visual counts address some questions; thus, capture may not be needed if confirmation of species identification is not necessary. Multiple nights of netting or trapping are needed for adequate sampling based on the size and habitats of the study area, and the weather.

Bats quickly learn where nets are located and to avoid them. If sites must be revisited, capture sessions should not be conducted on two consecutive nights and should be spaced at least 5 nights apart if the nets are placed at the same locations (C. Lausen, pers. Comm., 2018). Exceptions to this include large sites with many netting opportunities (e.g., an abandoned industrial complex with multiple accessible buildings and flyways).

Mist nets and harp traps are most commonly used to capture bats (see Appendix C for equipment). Several other methods (e.g., hand nets, funnels) have been used in the past (e.g., LaVal and LaVal 1977; Youngson and Mckenzie 1977; Fenton and Bell 1979; Kunz et al. 2009a). Many of those other techniques require sampling at or in roost sites, and are not normally recommended because they tend to be disruptive (Hayes et al. 2009). Capturing bats at night roosts may be possible with the use of hand nets, and disturbance at night roosts may have less impact than at maternity roosts or hibernacula. Capture and handling of bats within day roosts or hibernacula should be considered justifiable only if the resulting data are crucial (Reeder et al. 2016).

5.5.1 Personnel

- All crew members who handle bats must have up-to-date rabies and tetanus vaccinations.
- The crew leader for capture surveys must have experience in mist netting, handling bats, and identifying local bat species.
- The crew leader must have previous experience taking wing punch biopsies and attaching tags, bands, or transmitters before attempting those procedures.
- Traditionally, at least two crew members have been considered necessary for capture surveys. Now that many more procedures are being required to prevent the spread of WNS, it is advisable that three crew members be present for surveys so that two individuals can process the bats while the other person checks nets and calls for assistance when needed to lower nets or extract bats.
- All personnel should thoroughly review the Animal Capture and Handling manual and the most current WNS SOPs (https://www.whitenosesyndrome.org/static-page/decontamination-information) before commencing with a RISC wildlife inventory survey that requires capture and/or handling of bats.

5.5.2 Preliminary Fieldwork

- All personnel should visit the study area during the day to check access and communicate with landowners, scout suitable areas for nets (trap stations), note any features that may be hazardous to the field crew (e.g., electric fences or unstable rock), set up equipment, and complete habitat descriptions.
- Record a habitat description of the study area (Ground Inspection Form [B.C. Ministry of Forests and Range and B.C. Ministry of Environment 2010]) and take habitat photos.

5.5.3 Mist Nets

Mist netting is the most common method used to capture bats (Kunz et al. 2009a). Success depends on selection of netting sites (Figure 12) as well as weather conditions. Productive netting sites (i.e., areas of high bat activity) can be determined by direct observation of bats or by using bat detectors (see Section 4 Acoustic Surveys).

The major advantages of using mist nets are that they are relatively inexpensive, highly portable, and easy to set up and use. The disadvantages are that they are associated with biases in terms of which species are caught. Certain species are adept at avoiding mist nets or they fly at heights that make capture difficult, even though they may be present in a study area. For example, Hoary Bats, Eastern Red Bats (*Lasiurus borealis*), Spotted Bats, and Big Brown Bats tend to fly higher than the tops of most mist nets unless the nets are stacked two or three high. Highly manoeuvrable gleaning species such as Long-eared Myotis, Northern Myotis, and Townsend's Big-eared Bat seem better able to detect and avoid mist nets. Juveniles, which are less skilled at manoeuvering, and very pregnant bats may be more susceptible to capture, which can create a biased interpretation of population composition.

Mist nets require constant monitoring to ensure that bats do not become badly entangled or chew their way out. Larger species are the most likely to free themselves (Niver et al. 2014). Environmental factors influence the effectiveness of mist netting. Wind causes mist nets to billow and thus become more detectable and less likely to capture bats that are flying in either direction (Nyholm 1965). Water droplets in rain or fog adhere to mist nets, which renders them more "visible" to bats, and mist nets in open locations may be more detectible to bats on moonlit lights.

5.5.3.1 Mist Net Specifications

Standard mist nets are usually black and 2–3 m high, and consist of four shelves supported by horizontal trammel lines (Figure 14) (Kunz et al. 2009a). Each trammel line has a loop at each end, and the top loop is usually a different colour so it can be identified. The nets most commonly used to capture 5–30 g species have a mesh size of 36–38 mm and are constructed from 50 or 70 denier/2-ply nylon. Fine monofilament nets are also available; they work well but are more easily damaged than braided nylon.

Net lengths of 2.6, 6, 9, 12, and 18 m are common, but other sizes are available. Nets less than 12 m in length tend to be easier to handle, especially for one person, and are the most versatile. Shorter nets can be set up sequentially end-to-end to span wider gaps. Very short nets (e.g., 2.6 m) are ideal for narrow forest trails or building doorways. Multiple mist nets of the same length can be "stacked" on the same set of poles. Multiple mist nets of different lengths can be "stacked" one above the other on different poles to create a larger effective netting area; in this case, it is extremely important to not have the two nets so close together that a bat could become captured in the bottom tier of the top net and subsequently become entangled in the top tier of the bottom net. If this happens, great care must be taken to lower the two nets at the same time to avoid potential injury to the bat (C. Lausen, pers. Comm., 2018).

Nets that are suspended within the tree canopy can increase the success of capturing high-flying species. Numerous designs for canopy nets in a variety of sizes are described by Kunz et al. (2009a). Designs usually consist of a net suspended in or stretched across a frame and hoisted into the canopy by means of rope and pulley systems. Canopy nets require the use of a high-powered light to check for captures, and must be lowered to the ground before animals can be removed. Triple-high pole systems are commercially available; they allow three nets to be strung on one set of poles and are hoisted/lowered via a flagpole system. Some of these systems can be adapted to accommodate four nets strung one above the other (quad).

5.5.3.2 Storing and Handling Mist Nets

The use of mist nets could facilitate transfer of the fungal spores that cause WNS. The decontamination protocols in the WNS SOPs must be followed by researchers who are using mist nets.

Mist nets should be stored carefully and individually to prevent damage and tangles. The trammel loops on each side should be gathered in sequential order and then tied off together, such as slipping all lower loops over the top loop, which is then tied off. Some biologists roll the nets on the poles and wrap them in cloth to prevent damage. Colour-coded tape on the ends of the poles is used to indicate net length. Nets stored on poles are less portable than nets and poles stored separately.

Nets can also be stored in individual plastic grocery bags, which are readily available and can be disposed of once contaminated. The net is placed in the bag, and each set of trammel loops is slipped over one of the handles, which are then tied to enclose the bundled net. Labelling each bag with the length of the net is helpful. Sewing a colour-coded thread into the top trammel loop can also be used to distinguish net lengths, but thread colour may fade if bleach is used to decontaminate nets. Longer-lasting fabric mesh bags can also be used for individual net storage, and nets can be decontaminated without removing them from the bag.

Velcro, buttons, zippers, watches, and dangling jewelry snag fine mesh and should be removed or covered with tape before working with nets. Nets are frequently damaged by bats chewing on them; nets with large holes should be taken out of service until they can be repaired. Tie nets that are damaged beyond repair in a plastic bag before discarding them to prevent any chance of wildlife entanglement.

5.5.3.3 Mist Net Poles

Mist nets are set by fastening the net's trammel loops to poles. Poles made of 3-m lengths of aluminum tubing are light and strong but relatively expensive. Alternatively, thin-walled coated steel electrical conduit can be purchased at most building supply stores, and although it is heavier, it is inexpensive. The tubing should have a wall thickness of about 1.6 mm and should be at least 2.5 cm in diameter. Connectors (e.g., solid aluminum rods 20–30 cm long custom lathed to fit the inside diameters of poles perfectly) can be made to join lengths of pole to make longer sections and increase net height. Inexpensive connectors can also be made using lengths of threaded rod of appropriate size to fit inside the pole, with a large nut threaded onto the centre of the rod to separate the two poles. Alternatively, female conduit connectors can be attached to one end of each pole using a crimping tool (Kunz et al. 2009a).

Aluminum and fibreglass telescoping poles and modular poles are available commercially but may be expensive. These pole systems have the advantage of breaking down into small sections that are easy to transport (e.g., on aircraft).

5.5.3.4 Setting Standard Mist Nets

Set standard nets (i.e., not canopy nets) by threading one set of trammel loops in sequence onto a pole (either top loop first over the base of the pole or top loop last over the top of the pole). The pole is then anchored in place (see below), and the length of the net is played out of its storage bag as the crew member walks in the direction of the second pole. Take care to not let the net contact the ground or it will pick up debris that will have to be disentangled. Once the end of the net is reached, thread the second set of trammel loops, in sequence, onto the second net pole. Rotate the pole in the appropriate direction, while maintaining tension, to remove any twists. Anchor the second pole to the ground at a point where the net is held in correct tension without undue sag in the trammel lines.

Slide the top trammel loops to their desired position on the poles, and adjust the spacing between the remaining trammel loops on the pole so each shelf of the net has sufficient slack to form a pocket or "bag" into which a captured bat will fall (Figure 12). Having an appropriate degree of tension on the trammels and spread between the trammels is critical to optimal pocket formation. The deeper the pocket, the more the net overlaps and is visible to the bats, and the net may be effective at capturing bats coming from only one direction if the pocket is too large. If the pocket is too small, bats may not become sufficiently entangled and may escape. Increase the pocket depth in windy conditions, and then return it to a smaller pocket depth after the wind has subsided. Sometimes the tension on individual trammel lines needs to be adjusted to prevent sagging and ensure the net is evenly taut. Not all nets have trammels of equal lengths, and lengths can change over the lifetime of the net. Short lengths of nylon pantyhose are elastic, inexpensive, and easily untied, and make excellent tensioning devices. They are passed through the net where the trammel is attached, then tied around the pole at the desired tension.

Figure 12. Little Brown Myotis in mist net. Photo courtesy of A. Froschauer, U.S. Fish and Wildlife Service.

Attach guy lines to the poles and anchor them to objects such as stakes, trees, or rocks. Sections of rebar that are at least 40 cm in length (painted for visibility in the dark) can be hammered into the ground, and conduit poles can be slipped over them to anchor the bases of the poles. Longer rebar sections (80 cm) are needed for soft or muddy substrates. Piled rocks can also add stability to the bases of poles if needed.

If a net is to be closed but not disassembled, such as at the end of a netting session but before all bats have been processed, "spin" or "loop" the net onto itself so that animals cannot still be captured. It is possible for bats or birds to become entangled in closed mist nets that droop to form a net pocket.

The process of taking down a mist net is essentially the reverse of the steps used to set it. Double-check to ensure all bats, debris, and insects have been removed before closing the net. Close nets by sliding all of the trammel loops close together on the poles and draping any loose netting over the trammel strings. The net can then be decontaminated while on the poles or bundled back into a storage bag and placed into a container for later decontamination. If rolling nets onto net poles for storage, take great care that the loops stay as one tight bundle at the start and do not have bits of netting caught in between them.

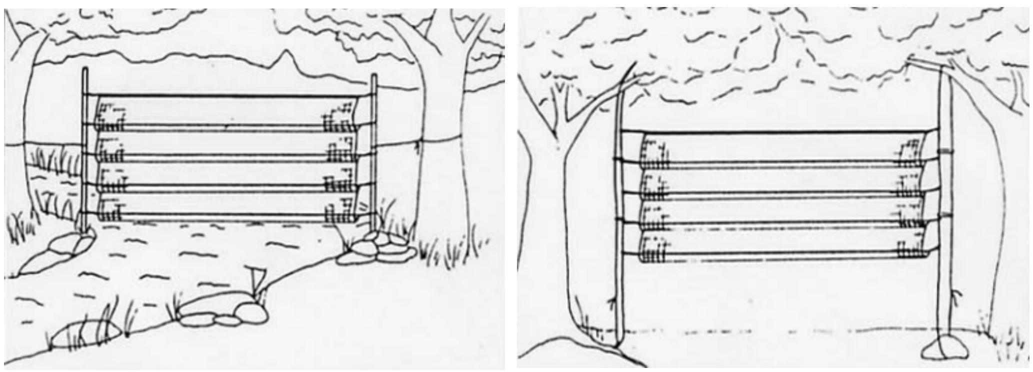


Figure 13. Example of mist net placement. Note that the net is placed in the vegetation such that a potential flight corridor is blocked by the net (from Kunz and Kurta 1988).

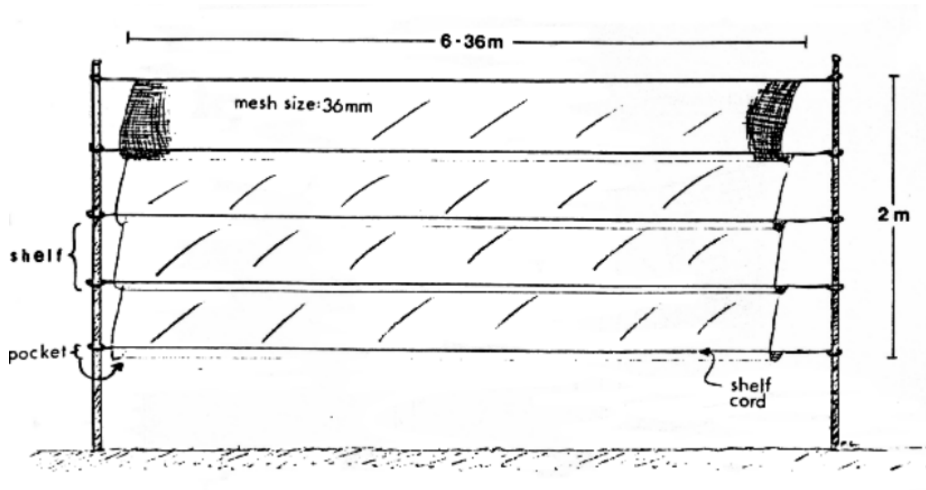


Figure 14. Mist net components and typical dimensions.

5.5.3.5 Setting Canopy Mist Nets

Canopy nets are commercially available and work well, especially in corridors where the tree canopy overhangs the corridor. These nets typically take considerable time to set up. A top pole and bottom pole are attached to the net. Two cords, each weighted with a lead fishing sinker, are thrown over tree limbs on each side of the corridor. The cords must be at least 2.5 times longer than the height of the limb to allow raising and lowering of the net and tethering of the cord. The sinkers are lowered, and the distal end of each cord is secured to a stake. The weights are removed and the cords are attached to the ends of the top pole of the net. Appropriately sized doweling can be slid into each end of the pole and secured to accommodate eye hooks for attaching the suspension cord. Another shorter set of cords should be secured to the lower pole to aid in lowering the net, especially if the suspension cord becomes caught on the branch.

A tarp placed on the ground below the net will keep the area clear of vegetation and debris, which can become entangled in the net when it is lowered. Dead branches in the canopy that interfere with the net can sometimes be broken off by striking them with a long stick or net pole (do this before the net is raised!). Offset nets placed below the canopy net can assist in creating a wall of netting.

5.5.3.6 Special Net Configurations

Mist nets can be configured to make a box shape, which is effective for netting over vertical shafts (Figure 15). Use a 9-m net to form an open-ended rectangle that is 2.6 m wide, and a 6-m net to form the roof and door. Clothes pegs can be used to temporarily secure the edges of the nets along the seams. The box could be made larger if necessary by using a 12-m net for the walls and two 6- m nets for the roof and door.

Figure 15. Box net setup around a vertical shaft. Photo courtesy of M. Sarell.

Using combinations of nets is generally more effective than using single nets. Stacking nets increases height, but stringing nets end-to-end in "V", "L", "W", "Z", or "T" configurations is also effective. For example, as a bat approaches a tree trunk to circle around it in search of insect prey (as Townsend's Big-eared Bat and Western Small-footed Bat (*Myotis ciliolabrum*) typically do [C. Lausen, pers. comm., 2018]), it is far more likely to be captured if there are two nets strung out from the trunk in a "V" or "L" formation where the trunk is at the intersection. Similarly, large, calm, shallow water bodies such as beaver (*Castor canadensis*) ponds may be best covered with nets in a zig-zag pattern (e.g., "W" or "Z"; Figure 16).

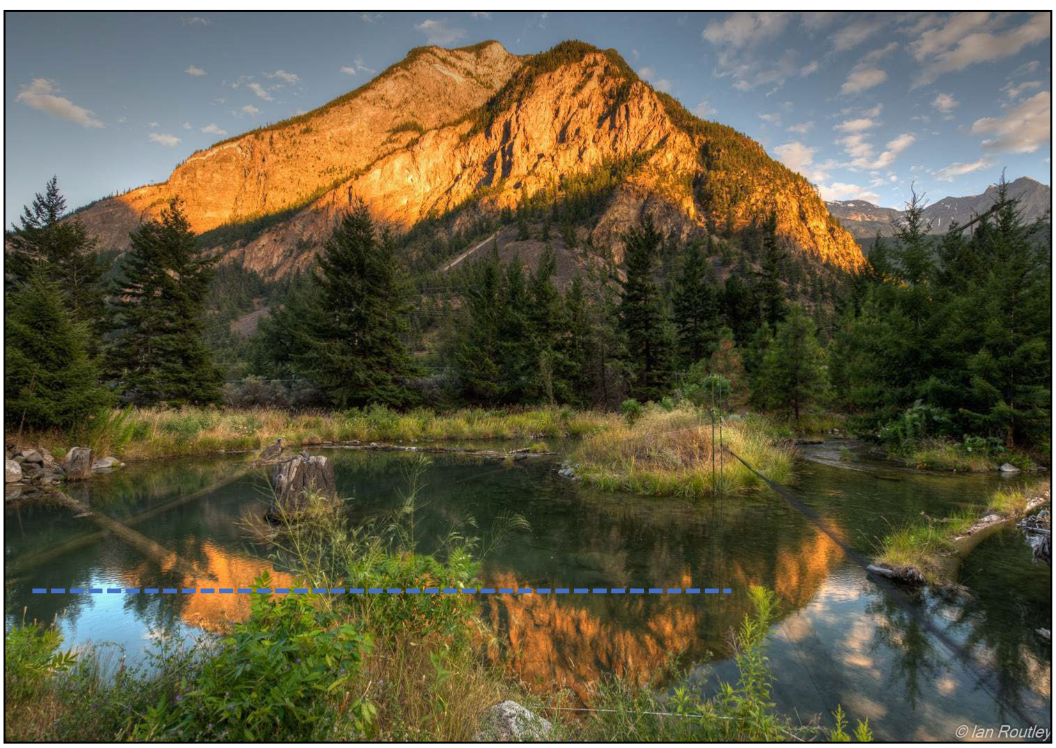


Figure 16. Zigzag net configuration across a beaver pond. Photo courtesy of I. Routley. Dashed lines highlight net locations.

5.5.4 Harp Traps

Harp traps, specifically designed for capturing bats, were first described by Constantine (1958) and were later modified by Tuttle (1974). Harp traps consist of one or more frames, usually made of aluminium or PVC tubing (Figure 20) (Kunz et al. 2009a). One or more banks of 3- to 3.5-kg monofilament fishing line are vertically strung across each frame. Lines are strung 2.5 cm apart. A holding bag is attached to the bottom of the frame (Figure 17). The trap works on the principle that a flying bat cannot easily detect or avoid the first row of lines, will become trapped between the lines, and will fall into the holding bag below. The bats are unable to crawl out over the slippery surface of the bag. Some bags have a plastic flap along the top, and captured bats crawl under the flap and remain there (D. Burles, pers. comm., 2018).

The degree of tension on the lines may have to be increased if bats are able to fly straight through without becoming trapped, or it may have to be reduced if they simply “bounce off,” but the optimum tension is different for different bat species (Kunz et al. 2009a). Commercially made harp traps are available in various dimensions and configurations, and can be carried, disassembled, and set up on site. Smaller harp traps can be constructed by hand (Palmeirim and Rodrigues 1993). Captured bats can be clearly seen if the holding bags are constructed of heavy duty clear polyethylene (B. Slough, pers. comm., 2018) (Figure 18), but they should not be used if rain is likely.

Figure 17. Harp traps set outside a barn. Photo courtesy of A. Froschauer, U.S. Fish and Wildlife Service.

Figure 18. Bats in a polyethylene bag of a harp trap. Photo courtesy of P. Kukka, Yukon Government.

Harp traps need less continuous monitoring than mist nets. Considerations for the placement of harp traps are similar to those for setting mist nets (Figure 19). Harp traps may be hung off the ground by ropes or positioned on legs outside entrances to buildings, caves, or mines. Trapping success tends to decrease with each successive trapping night in the same location (Kunz and Anthony 1977; Duffy et al. 2000).

The major advantages of harp traps are that they do not require constant supervision (thus, several can be set up per night), do not entangle bats, and can be used to catch species that tend to avoid mist nets (such as Western Small-footed Myotis and Long-eared Myotis) (Holroyd et al. 1994). A major disadvantage is that they bring multiple bats into close contact with each other, which could facilitate the transmission of the fungus that causes WNS. For this reason, harp traps are recommended only for situations where it is highly likely that all of the bats captured already roost together (e.g., close to a roost site). Like mist nets, harp traps must be decontaminated by following the most current version of the WNS decontamination protocol. Other disadvantages include the relatively small area sampled by the trap, and its greater cost to purchase (several thousand dollars).

Harp traps should be checked at least once per hour (USFWS 2016). Harp traps used at maternity roosts should be checked more frequently so that any pregnant or nursing females do not spend long periods in the trap. Harp traps can be deactivated by removing the holding bag or by turning the trap perpendicular to the flight path of the bats (Kunz et al. 2009a). Predators may be attracted to bats in harp trap holding bags.

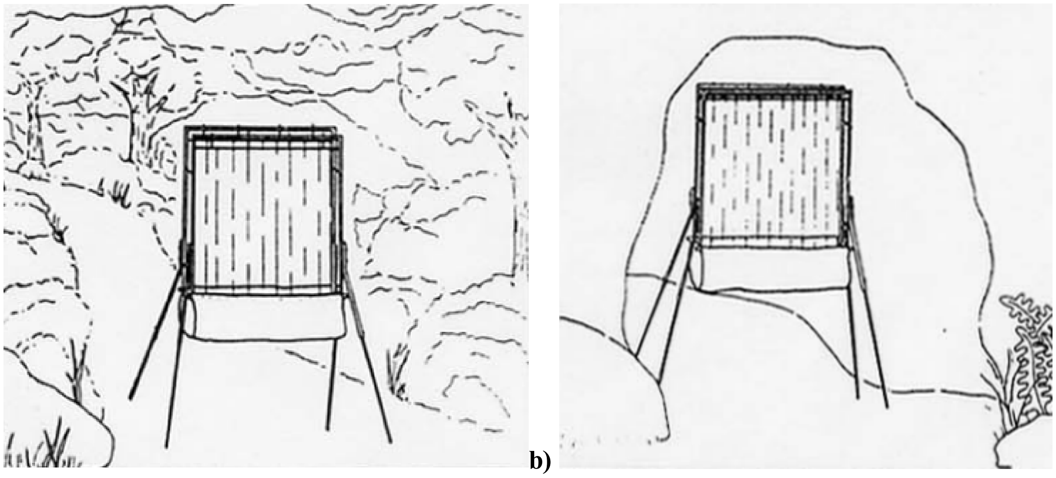


Figure 19. Examples of harp trap placement (a) along a forest trail, (b) at the entrance to a cave (from Kunz and Kurta 1988).

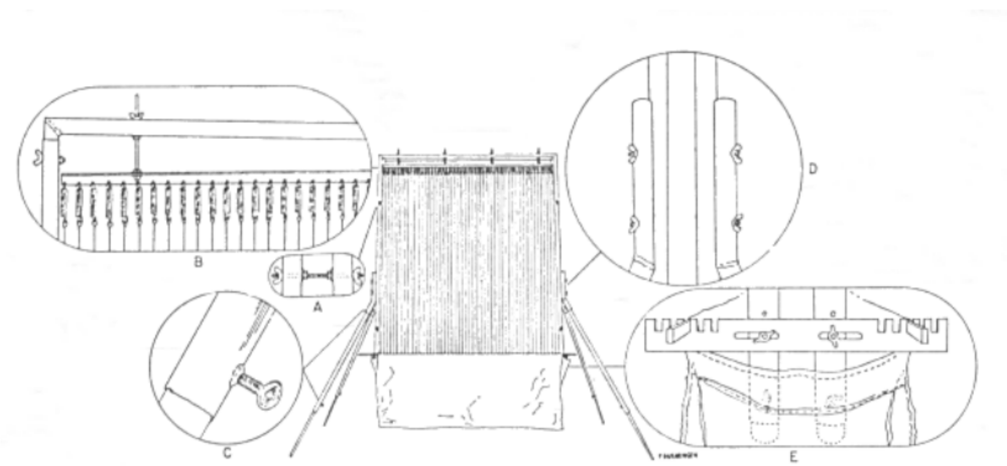


Figure 20. Harp trap design and detail (from Tuttle 1974; drawn by Tom Swearingen).

5.5.5 Capture Procedures

- **All capture procedures should be conducted using the most current version of the SOPs for WNS. Refer to the Canadian Wildlife Health Cooperative website (http://www.cwhc-rcsf.ca/bat_health_resources.php).**
- At least two crew members are needed for mist netting and harp trapping of bats, at least one of whom should be experienced with mist net setup and removal of bats from nets. All people who handle bats must have current rabies and tetanus immunization. More nets can be set up and a better nightly survey can be conducted with more crew members who are experienced with bat capture.
- The number of nets set at a particular time and location should not exceed the ability of the field crew to monitor them at reasonable intervals (every 5−10 minutes) and promptly remove captured bats (Sikes et al. 2016).
- Record environmental conditions (e.g., air temperature, cloud cover, wind, precipitation) at the beginning and end of the survey.

- Bats typically follow edges such as cutlines and cliffs. This is more likely when light levels are high. For example, streetlights outside building roosts may force bats to fly along hedgerows or in shadows of other buildings rather than in open lit skies. At the beginning of the night, bats generally emerge to find standing water for drinking. Then they will forage. Place nets along likely commuting zones between drinking, foraging, and roosting sites, or place nets directly at these sites, as appropriate.
- Because different bat species behave differently, it is imperative to vary the locations of the mist nets to appropriately target all species that are expected to occur in the area. A combination of tall nets and short nets under branches, along varying widths of trails/roads, etc. will maximize the chance of capturing more species. The more maneuverable a species is, the more likely it is to go around a net; therefore, precautions should be taken, such as closing off the ends of a net with vegetation so that it makes flying around the end of the nets difficult. Remember that if you can easily move around your net, so can a bat.
- Placing nets double or triple high (stacked) or placing a net directly under an object such as a bridge or thick tree branch, will reduce the chance of a bat flying above the net without being captured. If the nets do not fill the entire opening, place them so there is open space on only one side (sides, top, bottom). To reduce the chance of a bat flying below the net, extend the net to the ground (C. Lausen, pers. comm., 2018). Leave open the end of the net that is farthest from a linear edge (e.g., closer to the middle of a clearcut area, not the pole that is up against the treeline). Longer nets should be used in this situation so that the bat is less likely to reach the open end as it flies along the edge habitat.
- Net placement:
    - Choose the appropriate lengths of net to match the capture opportunities at the site.
    - Position nets to take advantage of topographic and vegetative features that could be used to "channel" bats into the nets
    - Unless an effort is made to sample at different heights within the canopy, the presence of some species in a study area may go undetected. Set nets at several different heights to increase the chances of catching all species (see Table 3). Double-high and triple-high sets can be used to target high-flying species.
    - Place nets near roosts; near openings to caves, mines, or buildings; over streams, ponds, and small bodies of calm water; over or under bridges; and along flyways such as riparian gaps, trails, cliffs, cutlines, and tertiary roads (Kunz and Kurta 1988). Avoid setting nets directly in front of day roost openings because of the potential to disturb maternity colonies.
    - Net poles can be attached to bridge railings, fence posts, or buildings to gain additional height. Elastic bungee cords can be used to attach poles to fences or railings. Screws and pipe strapping can be used to temporarily attach net poles to the sides of openings in buildings.
    - Use a handheld bat detector to verify the presence of bat activity, and ensure nets are set up at productive sites. This will also allow immediate detection of captured bats.
    - Multiple nets can be set adjacent to each other in various configurations (e.g., "I", "V", "T", or "L" shapes) so that a bat that dodges one net may fly into another.
    - When setting nets across streams or trails, capture success increases if the net is positioned beneath overhanging branches or canopy, which tend to channel bats

into the net (Figure 13). Often the spaces around nets can be closed by filling them with loose, dead branches or rope, or by temporarily tying live branches to block escape routes.

  - Pruning shears and a small saw can be used to remove stray branches that may contact the net. Ensure that property owners authorize any vegetation cutting. Damaging live vegetation may not be allowed within a park or ecological reserve.
  - Assign each net an identification number (capture device number). A sketch of the net setup with identification numbers is a helpful aid and can be taped in place at the bat processing location for quick reference.

- When netting over water, ensure that nets are sufficiently high enough that the added weight of a captured bat does not cause the net to droop and submerge the bat.
- It is often easier to capture bats along commuting routes (such as flyways) rather than where they feed because they may orient via spatial memory while commuting rather than by sensory perception (echolocation), and thus often fail to avoid a mist net (Mueller and Mueller 1979). In feeding areas, bats rely on their echolocation system, which increases their probability of detecting a mist net, and reduces netting success.
- Placing a net across a trail immediately after a sharp curve can be successful at capturing fast-moving bats (Finnemore and Richardson 2004).
- Use caution when placing nets across trails or roads that could be used by other people. Nets should not be set across active roads where traffic is expected, although setting the nets on the roadside parallel to the road may be productive. Vehicles may unexpectedly appear on almost any drivable road, even at night in remote study areas. A crew vehicle (constantly attended by a crew member) can be used to block tertiary roads so drivers of any other vehicles can be warned.
- Caution is also needed in areas where livestock could wander through nets or guy lines.
- Systems of ropes and pulleys can be used to pull canopy nets high into trees (see descriptions and diagrams provided in Kunz et al. 2009a).
- If netting on successive nights in the same general area, change the location and configuration of the nets each night to increase the capture rate.
- Do not open nets until at least 30 minutes after sunset to reduce the chance of catching late-flying birds. Terrestrial wildlife may also be at risk of wandering into low nets. Any captured non-target wildlife (e.g., flying squirrels [*Glaucomys sabrinus*]) (M. Sarell, pers. obs.) should be removed from the net as soon as possible. Flying squirrels can often free themselves once the net is pulled taut. The legs of owls should be held firmly by another crew member (wearing sturdy leather gloves) to keep the talons from injuring the person who is disentangling the bird.
- Periodically “tweak” nets to provide optimal bag in net pockets as conditions change. This could include flicking nets to remove accumulated water droplets if required. Remove any large insects that become entangled. Large, spiky insects can cause severe tangles if they are left to struggle.
- Lighting conditions at particular sites (e.g., dark valleys) may require earlier opening of nets (USFWS 2017).
- Nets may be strategically placed in moonshadow when the moon is bright. Consider closing some nets as the moon’s light changes and they are illuminated, while opening other nets as they become shadowed.

- Open nets from around 30 minutes after sunset to about 2400 or 0100 hours (or later at higher latitudes), depending on weather and levels of bat activity. Capture success will typically decline as the night progresses or weather conditions deteriorate. Some species, such as those in the long-eared bat species group, may be captured throughout the night (D. Burles, pers. comm., 2018).
- Check each net at least every 10 minutes. Net monitors should move quietly, refrain from smoking, and use the minimum of white light needed to adequately inspect the net. Harp traps do not require constant attention, but they should be checked frequently if pregnant or lactating females are likely to be caught.
- Bats must be removed from nets as soon as possible after capture to minimize stress, risk of injury or escape, and damage to the net. Bats removed quickly from the net typically become less tangled and do less damage to the net. Removal of a bat should, ideally, take less than 3 or 4 minutes (USFWS 2017).
- Remove bats from the same side as they entered, as determined by the position of the pocket relative to the shelf cord that separates each shelf (Kunz and Kurta 1988). There is no standard method for removing a bat from a mist net. Freeing the areas of the bat's body in the reverse order that they contacted the net, starting at the tail, often works the best. Sometimes a wing needs to be carefully extended to disentangle it.
- Some people find the use of a crochet hook helpful to remove a section of net from a bat's body, especially strands snagged in a bat's teeth or buried deeply in a bat's fur (Figure 21). The hook is also useful for removing a net strand caught behind a bird's tongue.

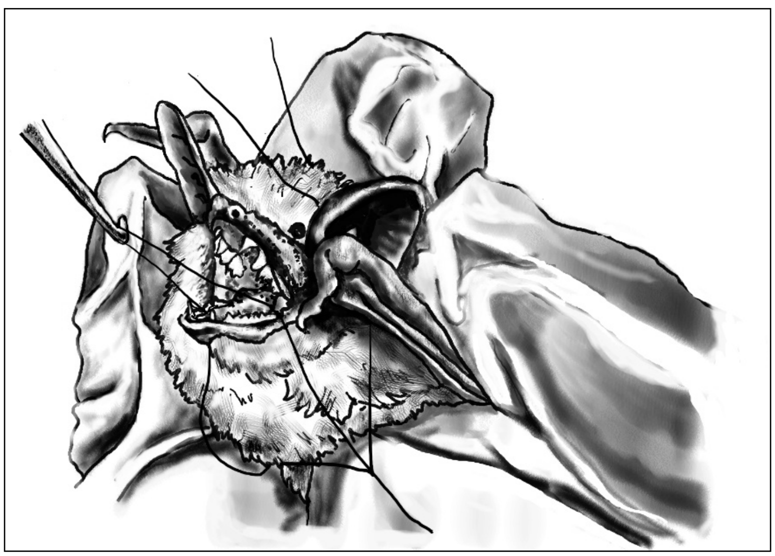


Figure 21: Crochet hook used to remove mist net strand from a bat's teeth. Drawing courtesy of Lorraine Andrusiak, 2018.

- Be prepared to cut one or more strands of the net to remove severely entangled animals that cannot otherwise be removed quickly.
- Check each bat for injuries as soon as they are free of the net. Females in late pregnancy should be processed and released immediately.

- If multiple bats are captured at once, close some or all empty nets until the captured animals are removed and workers are available to monitor the other nets again. This will prevent any additional captures of bats, which could become badly entangled or chew through the nets in the meantime. Do not forget to account for the time the nets were closed when calculating trapping effort.
- Assign each bat a unique identification that includes the date of capture (e.g., 2018Jun25-01, 2018Jun25-02…). If trapping is being conducted at more than one site on a given night, the captures by different field crews can be distinguished with letters (e.g., 2018Jun25A-01, 2018Jun25B-01). Use the unique identification to label photographs, acoustic recordings, and any samples taken from the bats.
- Ensure that the date code used is unambiguous and cannot be misinterpreted by others. Year and month should be written out completely (e.g., 2018 July 6, not 18-6-7) because all-numeric codes are easily misinterpreted.
- Collection of samples for DNA analysis (see Section 5.5.7 Biological Sample Collection) is recommended for cryptic species that cannot be readily identified in the field.
- Record species, gender, age class, reproductive condition, mass, and forearm length of each bat (see Section 5.10.6). Additional measurements may be helpful for identifying particular species, as recommended in the identification key that is used. Observations of body condition, wounds, or presence of ectoparasites should be recorded in the "comments" field.
- Release bats by letting them fly off the hand or place them on a tree trunk to fly off on their own accord. Torpid bats will need to be rewarmed with the aid of disposable heat packs before release. If chemical heat packs are used, be sure the bat never comes in direct contact with the pack.
- Obtaining acoustic recordings of bats as they are released can assist in confirming species identification (see Section 5.4.5: Reference Recordings).

5.5.6 Morphometric Measurements, Gender, Age, and Reproductive Assessment

Handling bats and collecting data from captured bats must be conducted in accordance with the most recent version of the WNS SOPs. Refer to the Canadian Wildlife Health Cooperative website (http://www.cwhc-rcsf.ca/bat_health_resources.php).

- Once a bat is removed from a net or trap, place it in a cloth holding bag (about 20 cm × 30 cm) with a drawstring closure. Bags with French seams (doubled and sewn on both sides) or that are turned inside out so the seams are on the outside are preferred so there are no loose threads to entangle the animals.
- Store bats in holding bags in a dark, quiet area. Bat bags can be placed in individual open, walled containers (e.g., yogurt containers, disposable drink cups) that can be disposed of or decontaminated. This will prevent the bags from rolling around and contacting each other. Some species of bats typically hang upside down when roosting; therefore, it is preferable to suspend the bat bag in a way that will allow the bat to roost in a somewhat natural position while in the bag.
- Tree-roosting bats (Eastern Red Bat, Hoary Bat) typically do not hide when roosting; thus, mesh bags suspended in a quiet place are more suitable for those species than are solid cloth bags.

- Mark each capture bag in some way, noting the time of capture and the number of the capture device from which the bat was removed; this will provide a reference when the bat is processed. Paper labels or tape can be applied directly onto the bags to mark them.
- Holding time of bats should be minimized; it should include a short period before processing to allow the bats to de-stress following capture, and should allow only enough time to collect the data required. It is generally recommended that bats be given at least 10 minutes to roost quietly in the holding bag before processing to avoid potential capture myopathy. Some species such as Hoary Bats are prone to capture myopathy (C. Lausen, pers. comm., 2018).
- Release females that are heavily pregnant (the fetus can easily be felt within a swollen abdomen), without processing, after a short resting period (10–15 minutes) in a holding bag. If data on pregnant females are required, process and release those females as soon as possible after the 10-minute resting period. This will minimize stress, which otherwise may cause the female to start giving birth (C. Lausen, pers. comm., 2018).
- Lactating females should be released within 1 hour of capture. Under normal sampling conditions, bats should not be held more than 2 hours (Finnimore and Richardson 2004). If the weight of bats is a required measurement, wait at least 1 hour for the bats to void their digestive tract, unless they have been captured immediately upon emergence. Bats can normally be processed in less than 15 minutes (M. Sarell, pers. obs.).
- Bat processing time can be minimized by having one person handle and measure the bats while another person records the data.
- If recapturing the same individual is a possibility, clipping a bit of fur between the shoulder blades of captured bats will make them temporarily identifiable. Wing punch biopsies (see below) will also make recaptured animals identifiable. Recaptures should be avoided because they can cause the bats increased stress.
- Disposable gloves must be worn to handle each bat in most situations, in accordance with the WNS SOPs (Figure 22), unless the bats that are being captured are all using the same roost.

Figure 22. In most cases, gloves are required to handle bats, in accordance with white-nose syndrome standard operating procedures. Photo courtesy of C. Albrecht.

- Handle bats in a manner that minimizes stress to the animals. Hold bats gently in your cupped hand, with the head held between your thumb and forefinger. Some researchers place the first two joints of a bent index finger along the back of the bat, and use the thumb and second finger to surround the wings (Hooper and Amelon 2014). Pinning the forearms above the bat's back can strain the flight muscles (Kunz et al. 2009a).
- The bat's body or base of its wings (humerus) should always be supported. Bats should never be held outstretched by their delicate wingtips because this could injure the shoulder muscles. The head can be restrained (e.g., for ear measurement) by applying gentle finger pressure on the top of the head or under the jaw.
- Measure the bat's body mass with a portable Pesola spring scale or digital electronic balance, and record it to the nearest 0.1 g. Bats can be weighed while in the cotton holding bags, and then the weight of the bag can be subtracted from the total weight. Body mass is not used for species identification for B.C. bats and is rarely analyzed for most projects. If very accurate measurement is needed (e.g., to determine the suitability of an individual for tag attachment), the bats should be retained for 1 hour before weighing to ensure that food has cleared the digestive tract. Note that the body mass of an active individual can vary considerably over a 24-hour period (Hutson and Racey 2004).
- Methods for taking standard morphometric measurements are described and illustrated in most identification keys. Forearm length (Figure 24) indicates overall size and is the standard morphometric character measured. Using calipers, measure the forearm length from the base of the thumb to the end of the ulna, to the nearest 0.5 mm. Take three measurements of the right forearm and record either the average or the most consistent measurement. Forearms of juveniles may be smaller than the published range for the species (Hutson and Racey 2004).
- Measure ear length with a ruler placed gently against the base of the notch at the base of the distal side of the tragus (which is aligned with the base of the pinna). Allowing the bat to bite onto a gloved finger can help align the head, and another finger can be used to move the fur out of the way. Do not measure on the medial side of the tragus because this underestimates the length. Accurate ear measurements can be difficult to obtain on live bats.
- Gender is determined from the obvious presence of male external genitalia (Racey 2009). Reproductive condition in males can be assessed by testes location and size. The testes become enlarged in individuals that are producing sperm (pre-mating).
- A more detailed assessment of male reproductive condition can be conducted, if desired, by noting the amount of stored sperm in the caudal epididymides. Sperm are stored in the caudal epididymides underneath the enlarged testes (Racey 2009). Empty epididymides appear as thin black bands along the tail membrane, and are a reliable way of identifying a young-of-the year male. Males in their first year may produce sperm in late summer (Cryan et al. 2012), but this seems to be rare (C. Lausen, pers. comm., 2018). As the epididymides enlarge with stored sperm, they stretch to become conspicuous and pale, and superficially resemble enlarged testes, so careful inspection must be made. When the epididymides are full, the testes cease sperm production and regress, often becoming barely detectable as small "grains of rice" in the lower abdomen. This drop in testosterone triggers mating to begin (Neuweiler 2000). Sperm is transferred from the male into females during copulation, which depletes the stored sperm levels in the caudal epididymides. A "black lining" becomes visible as the epididymides empty and darken again. Sometimes a rough visual estimate can be made of how much stored sperm is remaining in the epididymides, which provides an indication of how much mating has occurred, and how much potential remains for further mating. The use of these techniques

has indicated that bats mate in fall, and some species (e.g., Yuma Myotis) can continue to mate in mixed-sex colonies in early spring (West Kootenay region; C. Lausen, pers. comm., 2018). Once sperm has been stored in the caudal epididymides, they remain stretched and will no longer appear as very thin bands; this provides another method of identifying adult versus young-of-year males (see below).

- Noting the reproductive status of females is important for determining if young are being recruited into the population (and to what extent). This will become increasingly important in evaluating recovery strategies for endangered species, and assessing the impacts of climate change on these long-lived mammals (e.g., Adams and Hayes 2008; Adams 2010).
- Gentle palpation of the abdomen is used to determine whether the female is carrying a fetus, although early pregnancy cannot be differentiated from a full stomach. Lactating females have enlarged nipples surrounded by bare skin, which when gently massaged will express milk. Post-lactating females also have bare patches around the nipple, but milk cannot be expressed (Racey 2009). The nipples of multiparous females are relatively large and cornified (Kunz and Hood 2000). Nulliparous females have very small nipples, sometimes with small tufts of fur on them. Gently blowing on the bat's chest to separate the fur can assist in locating the nipples of long-furred species or nulliparous females.
- Juveniles (young-of-the-year) are distinguished from adults by the presence of cartilaginous epiphyseal plates in the finger bones (Anthony 1988), generally pinpoint sharp teeth, and in males, thin empty caudal epididymides that have never contained stored sperm (not stretched out; see above) (C. Lausen, pers. comm., 2018). Finger joints of juveniles appear tapered and less knobby than those of adults (Figure 25). Juveniles tend to have dull, dark fur of uniform colour (Nagorsen 2002). Several traits may be needed to reliably differentiate adults from juveniles.
- Degree of tooth wear is sometimes used as a relative indicator of age (Christian 1956; Anthony 1988), but it is not always reliable and should be used for broad age categories only (Brunet-Rossinni and Wilkinson 2009).
- Because bats are long-lived, classifying individuals to either "adult" or "juvenile" is not sufficient for long-term monitoring of the age structure of populations. If certain factors cause increased mortality of certain age classes, this could easily go undetected. When possible, record a relative tooth wear code for individuals. Because bats wear teeth at different rates depending on their food (species and habitat differences) and amount of use in a year (Brunet-Rossinni and Wilkinson 2009), no specific numerical scale works well for all situations. A general characterization of whether the upper canines have experienced little wear (> 2/3 tooth remaining), moderate wear (1/3–2/3 tooth remaining), or extreme wear (< 1/3 of tooth remaining) can provide a broad categorization of the age structure of a population (C. Lausen, pers. comm., 2018). Use of a magnifying lens is recommended for tooth examination.
- Identify bats by using a key to external features (e.g., Nagorsen 2002), and then double-check the identification by using a table of external characteristics (see Appendix B) (Bachen et al. 2017). Most adult bats can be identified in the field.
- It is difficult to distinguish certain species in the field. For example, in some areas of their range (in British Columbia), Little Brown Myotis and Yuma Myotis cannot be reliably distinguished based on their external characteristics (Herd and Fenton 1983); the use of additional acoustic and genetic methods is recommended (Weller et al. 2007; Luszcz and Barclay 2016).
- Record morphometric data or other observations that can help differentiate between similar species (especially when the species is difficult to distinguish).

- Collect ectoparasites, if desired, using fine forceps to carefully pull them off the bat. Place the ectoparasites in 95% ethanol in vials and label the vials with the date of collection, the investigator's name, the bat's capture reference number, and the area of the body from which it was collected (e.g., "base of ear"). Small paper labels written in pencil (not ink) can be inserted inside the vial if external labels are smeared or lost.
- Record wing damage index (see WNS SOPs for more information).
- Take clear voucher photographs of any species that is provincially listed as "Unknown" or "Accidental", as well as adult bats of any species that has not been previously detected in the study area, and adult bats that have not been positively identified in the field. Views of the head in profile, including the ear, the head from directly above showing the length of the snout, and the foot and calcar (Figure 23) are useful for confirming identification. Adjust the name of each image file on the digital camera to include the bat's identification number (preferred), or record the image numbers within the bat's capture data.

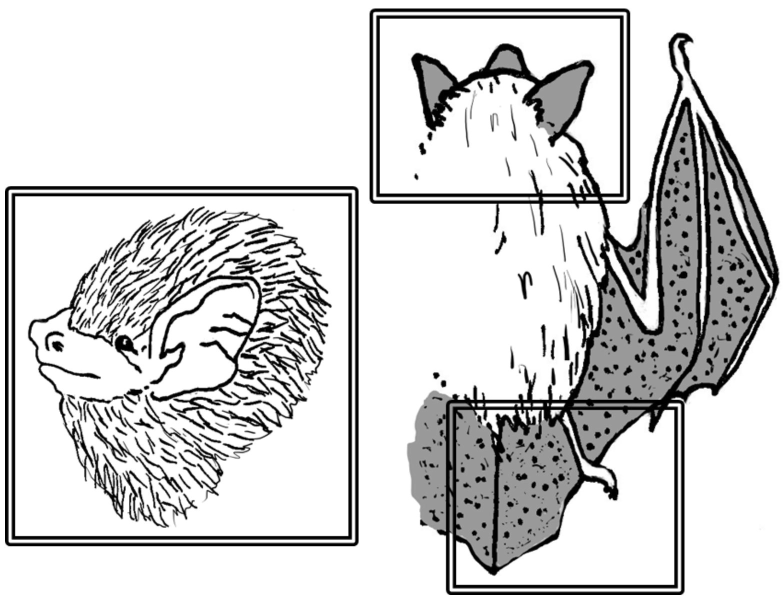


Figure 23: Voucher photographs. Drawing courtesy of Lorraine Andrusiak, 2018.

- **Be conservative when classifying bats to species.** The species code system used by the provincial Species Inventory Database allows biologists to identify each bat observation to the taxonomic level that can be determined. This will indicate that an observed bat was one of several species, even if a single species cannot be positively identified. DNA sampling can be used to confirm the species identification at a later date.

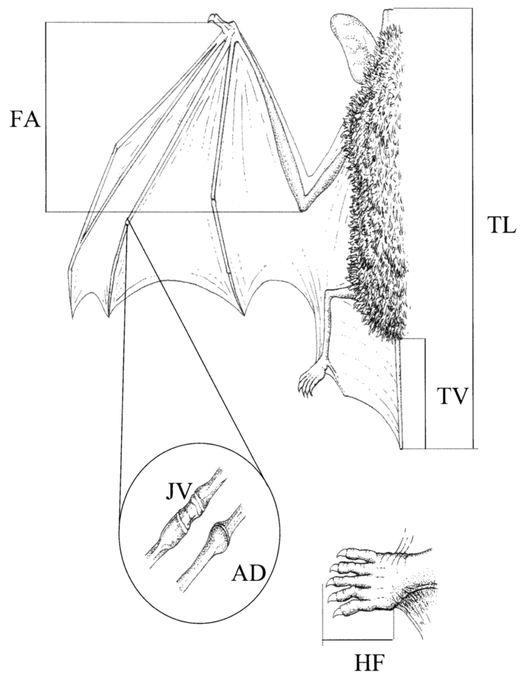


Figure 24. Forearm (FA) and other measurements (TL = total length, TV = tail-vent length, HF = hind foot, JV / AD = juvenile / adult joint (see Figure 25)). Drawing by B. Coslick from Menzel et al. 2003.

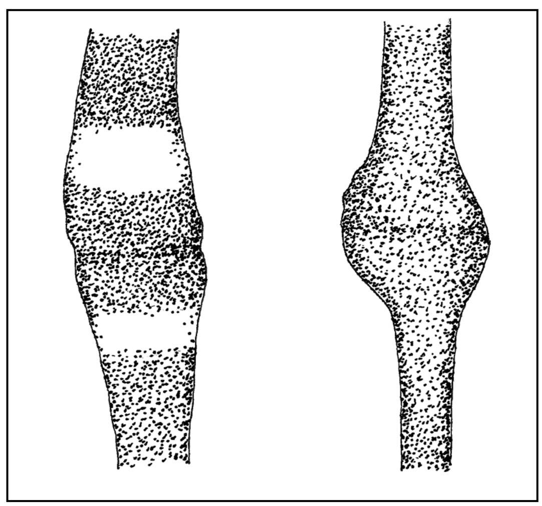


Figure 25. Finger joint of a juvenile bat ([left] tapered shape, and translucent areas in epiphyseal plates should be visible with the aid of a flashlight backlighting the wing) and an adult bat ([right] rounded, knobby, and opaque). Drawing courtesy of Lorraine Andrusiak, 2018.

5.5.7 Biological Sample Collection

Analysis of stable isotopes in bat fur has been used to study long-distance bat movements (e.g., Fraser 2011; Segers and Broders 2015). Use fine scissors to clip a small amount of hair

(1 cm × 1 cm) from between the shoulders of the bat. Place hair samples in labelled vials or small envelopes and store according to the requirements of the laboratory that will conduct the analysis. Wipe scissors thoroughly with an alcohol swab or flame-sterilize them and allow them to cool between sampling other bats to prevent cross-contamination (AMNH 2018).

Guano is used to study diet composition, conduct WNS surveillance, and identify species by DNA analysis. Guano pellets can usually be obtained from inside the cloth bag that is used to hold the captured bat. Place pellets from an individual bat in a small, labelled envelope, such as a coin envelope, and allow them to air dry. Ensure that pellets are not crushed during storage or transport because this makes DNA analysis more difficult (L. Harris, pers. comm., 2017). Do not store guano in plastic containers because this will cause moisture retention, which degrades DNA. For long-term storage (> 1 month), freeze the samples to prevent gradual DNA degradation. Do not repeatedly freeze/thaw samples because this will also degrade DNA. Once the sample is frozen, it is best to keep it frozen until it is processed (C. Lausen, pers. comm., 2018).

Wing punch biopsies (Lausen 2005) or wing swabs (Player et al. 2017) are taken to confirm species identification through DNA analysis. For biopsy sampling, gently hold the wing of the bat extended over a sterile cutting surface. Take samples using a 2–3 mm sterile biopsy punch applied to the flight membrane near the leg (Figure 26), while avoiding large blood vessels (USGS 2021; AMNH 2018). Two-millimetre punches are recommended for all *Myotis* species due to their small body size (C. Lausen, pers. comm., 2018). Location of blood vessels can be determined by backlighting the wing. Slightly rotating the punch will assist in cutting the sample. Remove the excised sample from the punch interior or the cutting surface with sterile, fine-tipped forceps, and place it in a sample vial. Forceps and biopsy punches must be flame-sterilized between use on each bat, allowed to cool and then immersed in ethanol (preferred) or wiped with an alcohol swab, and then allowed to dry (AMNH 2018).

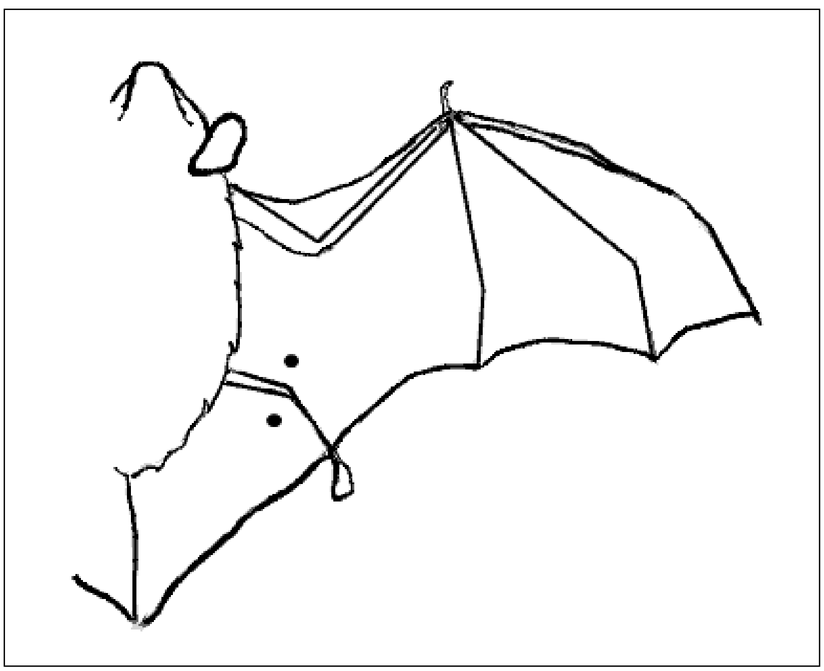


Figure 26: Locations for wing punch biopsy (USGS 2021). Drawing courtesy of Lorraine Andrusiak, 2018.

The holes left by the biopsy punch heal quickly, although wounds created near or during winter dormancy may heal slower than those created earlier in the year (Faure et al. 2009; Ceballos-Vasquez et al. 2015; Player et al. 2017). Various methods have been used to store wing biopsy samples (Corthals et al. 2015). The lab that will analyze the samples should confirm its requirements.

Wing swabbing is a minimally invasive method of collecting samples for DNA analysis to confirm species identification and conduct WNS surveillance (Player et al. 2017). Wing swabbing is the preferred method of collecting DNA samples; it can be used late in the season when bats are entering hibernacula, or during hibernation. Sterile cotton or polyester-tipped swabs are lightly rubbed across the ventral surface of the wing to collect epithelial cells; however, great care should be taken to not to apply so much pressure that the delicate wing membrane becomes abraded (Player et al. 2017). Swabs should be labelled and stored according to the requirements of the laboratory that will conduct the analysis. Change gloves between processing each bat. Buccal swabs can also be used to collect DNA, but this method is more invasive than wing swabbing, and it could injure the bat (Corthals et al. 2015; Player et al. 2017).

Collect dead bats whenever practical, and store them frozen, with a label that indicates the date and location of collection, and the collector's name. Dead bats can be used for DNA analysis or can be submitted to the province (www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-conservation/bats).

5.5.8 Marking Bats

Marking bats provides individual identification for long-term studies of movement, population demographics, and roosting behaviour, but short-term marking, such as light tagging and fur clipping, may be useful in certain situations. The most common methods of marking small insectivorous bat species are described below.

5.5.8.1 Forearm Banding

Bats may be permanently marked with numbered, aluminum alloy, forearm bands that are designed specifically for bats. Bands designed for birds should not be used (Ellison 2008). Bat bands are rounded and lipped, and do not have sharp edges or corners, which can injure delicate flight membranes.

Porzana Ltd. (Icklesham, UK) makes bands in two main sizes that are appropriate for bats in B.C.: 4.0 mm × 0.38 mm wide, and either 2.4 mm or 2.9 mm internal diameter. For larger bats, like Hoary Bats, the 3.5-mm internal diameter Porzana band (width 5.5 mm × 0.35 mm) is most appropriate. Bands can be labelled with numbers/letters.

Place no more than one band on each forearm. Bands are fitted around the distal end of the bat's forearm (Figure 27) and are gently pressed closed with the fingers. When correctly fitted, a small gap remains between the band ends so that the band can move some distance along the forearm without perforating or abrading the wing membrane or damaging the forearm (Kunz and Weise 2009) (Figure 27). Custom-made banding tools are currently available from BATS Research Center (John Gumbs, Pennsylvania); they can be used to ensure that bands are not overtightened. BATS Research Center also supplies a customized tool for removing bands for any reason, such as accidentally placing the band on too tightly; it is highly recommended that researchers have this tool when banding bats (C. Lausen, pers. comm., 2018). Contact BATS Research Center to obtain anodized coloured bands; grey metallic bands are available from Porzana.

Figure 27. Little Brown Myotis with forearm band. Photo courtesy of A. Froschauer, U.S. Fish and Wildlife Service.

Figure 28. Banded Little Brown Myotis at rock roost. Photo courtesy of B. Slough.

Identification of individuals via forearm banding has been used to obtain long-term data on colony sizes, reproduction, migration routes, and survival (Jung and Kukka 2016; D. Hobson, pers. comm., 2018) (Figure 28), but bat band recovery rates in general are very low outside of colony projects (Ellison 2008).

5.5.8.2 Freeze-branding

Freeze-branding is done by cooling small metal branding devices in dry ice, and then applying them to the dorsal skin of the bat (Sherwin et al. 2002). The fur where the brand was applied then grows in white, forming a permanent mark that makes the bats easily identifiable during recapture or while roosting (thus eliminating the need for recapture). The marks are not visible immediately after branding; Sherwin et al. (2002) reported that white fur appeared 22–60 days after marking. This technique may be useful for long-term studies at sites where roosting bats are readily visible, but it requires experience by the applicator to produce legible marks (Powell and Proulx 2003). Freeze-branding has also been used to estimate the rate of PIT-tag loss (Wimsatt et al. 2005).

5.5.8.3 PIT-tagging

Passive integrated transponder (PIT) tags (Figure 29) are tiny circuit chips enclosed in a glass capsule (Smyth and Nebel 2013). Tags used on bats are 10–12 mm long and approximately 2 mm wide, about the size of a grain of rice. The tags are dormant until they are activated by a low-frequency radio signal emitted by a scanning device, whereupon they respond by sending a unique, alphanumeric "barcode" back to the scanner. PIT-tags are injected subcutaneously, usually between the shoulder blades of the bat, and the wound is sealed with surgical glue (Wimsatt et al. 2005; Burns and Broders 2015). Invasive procedures that cause tissue damage should not be used on bats in late summer when they are preparing to enter hibernation because wounds heal more slowly at that time (Player et al. 2017). Pre-sterilized tags supplied in applicator needles are preferred, if available (H. Schwantje, pers. comm. 2018).

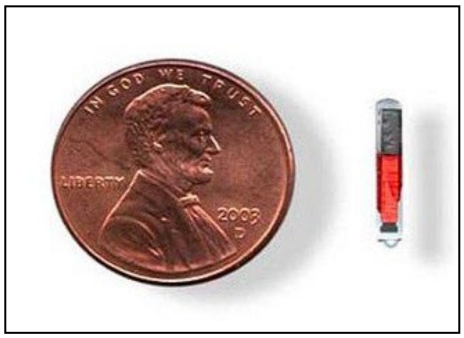


Figure 29. PIT-tag (Photo: public domain).

The advantages of PIT-tags are that they are normally permanent (as long as the wound is sealed with surgical glue after tag insertion), do not require recapture of the animal (limiting stress and recapture bias), can be read continuously and repeatedly by passive, automatic systems (e.g., a tag reader set up at the entrance of a roost or hibernaculum), and have few negative effects on the animal (Wimsatt et al. 2005; Ellison et al. 2007; Smyth and Nebel 2013; Britzke et al. 2014). The disadvantages are that they require a scanner to read them, they can be read only at short distances (typically a few centimetres), and they are expensive. Arrays of multiple readers can be used at sites with larger entrances (Britzke et al. 2014). PIT-tagging is time-consuming; therefore, its use is limited to long-term studies at permanent or semi-permanent roosts that are used by large numbers of bats.

5.5.8.4 Fur Clipping

Fur clipping can provide a short-term mark for identifying previously captured bats. Patches are typically clipped with small scissors, and the clipped area may be visible from a few weeks to nearly 1 year, depending on the species' period of moult in relation to the timing of clipping (Kunz and Weise 2009).

5.5.8.5 Light Tagging

Light tagging is used for visual observation of free-flying bats at night. This technique can assist in recording reference calls of previously captured individuals. It has also been used to determine flight heights and investigate foraging behaviour and foraging habitat use (Fellers and Pierson 2002). This technique is most useful in non-forested or sparsely forested study areas where tagged bats can be readily observed from a high vantage point (M. Sarell, pers. obs.). A small chemiluminescent light tag, such as a miniature light stick (2.9 mm × 24 mm), can be glued to a bat's fur (Buchler 1976; Barclay and Bell 1988; Hovorka et al. 1996). The light tag is a short-term visual mark that can be used to track the bat as its echolocation calls are being recorded or its behaviour is being observed. It is necessary to use light sticks that are made from non-toxic materials and are small enough to be used on B.C.'s bat species.

After suitable bats (considering target species, age, gender, and weight) are captured, light tags are activated by breaking the inner capsule in the miniature light sticks. Because information can gleaned from these tags for only a few hours at most, they should be attached using non-toxic glue sticks such as those marketed for use by children. This will ensure the glow stick falls off or can be groomed off within hours or days. Attach activated light tags to the bat's back (for low-flying bats; e.g., Little Brown Myotis) or abdomen (for higher flying species; e.g., Big Brown Bat). Light tags should not be attached to heavily pregnant females or to lactating females because they may interfere with nursing.

Once the tag is affixed, release the bat in an area of low bat activity and record its echolocation calls as it flies away. Forest clearings are good release sites because the bat will tend to circle several times before flying out of range (D. Thomas, pers. comm., cited in RIC 1998a).

For behavioural observations, station numerous observers (as many as possible) at vantage points in the study area where the light tagged bats may fly. Record descriptions of bat observations on digital voice recorders.

This technique is labour-intensive, and bats can be observed for only a few hours, at maximum, after release (Britzke et al. 2014), and frequently just for minutes (D. Burles, pers. comm., 2018). The effects of capture, handling, and tag attachment may alter the tagged bat's behaviour after its release, so caution should be used when considering using light tags to conduct behavioural studies. Consider whether sufficient time and trained personnel are available to conduct observations of light tagged bats if capture activities are still ongoing.

5.5.9 Radio-telemetry

Radio-telemetry is used for locating and identifying roost sites. By gluing radio-transmitters to the backs of bats (Figure 30), it is possible to track the bats to a roost site. Tagging smaller species (e.g., Californian Myotis or Western Small-footed Myotis [*M. ciliolabrum*]) or small individuals may be inappropriate because of their body mass relative to that of a radio tag (see below). Adult male bats of appropriate size can be radio-tagged without great concern. Only adult females that are in early pregnancy or are non-parous, lactating, or post-lactating should be tagged. Females in late pregnancy and juveniles (during the summer months) of either sex should generally not be tagged (Amelon et al. 2009).

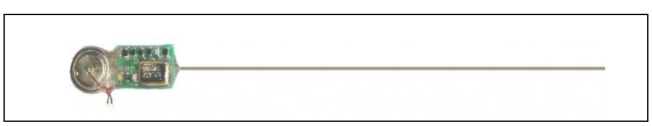


Figure 30. Bat radio-transmitter (Photo: Holohil Systems Ltd.).

Very high frequency (VHF) radio-tags are most commonly used on bats and are available as small, lightweight units from a variety of manufacturers. VHF tags are glued onto the back of bats (see below). Some tags can be equipped with a temperature sensor to study use of torpor where body temperature is of interest.

GPS tags and tags with dataloggers that can record animal activity, light level, and tag temperature are available in sizes/masses that can be carried by larger bat species, and may be particularly useful in investigating long-distance bat movements (Weller et al. 2016). These large tags are sutured to the back of the bat; their attachment requires use of a general anaesthetic (Castle et al. 2015). Anaesthesia and suturing of transmitters must be conducted by or directly supervised by a qualified veterinarian (Dr. H. Schwantje, pers. comm., 2018). GPS and datalogger tags may require recapture of the bat to retrieve recorded data (Castle et al. 2015), so researchers who are considering using these tags must also review how data can be retrieved for particular tag models and judge the likelihood of recapturing bats.

For volant animals, the recommended maximum mass that should be attached is 5% of the animal's body mass (Aldridge and Brigham 1988). The mass of the glue used to attach the transmitter should also be considered when calculating the appropriate transmitter weight. The calculation of body mass does not include a stomach full of insects. Additional mass will have significant effects on an animal's flight performance (Aldridge and Brigham 1988; O'Mara et al. 2014). Although there is no doubt that additional mass could change a bat's behaviour, especially when foraging, it can be argued that carrying a transmitter is not that much different from carrying a fetus (which typically weighs more than the smallest transmitters), which adult females do each year. It is unclear what effects changing the centre of gravity may have on a bat's flying ability, especially on males that are unaccustomed to such mass gains (see also Kalcounis and Brigham 1995 for effects of mass on bats).

There is evidence that females of some species can carry transmitters < 5% of their body mass without long-term impacts on survival, reproduction, and body condition (Neubaum et al. 2005), but in general, there is limited information on the impacts of attaching transmitters on bats due to a lack of follow-up studies on attachment methods (O'Mara et al. 2014). Some researchers have used transmitters that weigh 5–10% of a bat's body mass (see review in O'Mara et al. 2014). Researchers who propose to use larger tags must provide justification in their permit application based on the species' morphology and flight characteristics, the results of previous studies on transmitter effects, or the unique circumstances that make a heavier load less detrimental (e.g., attachment during winter hibernation when daily flight is not occurring).

Radio-telemetry can be used to study movements and locate the roosts of most species, especially in summer, when roosts tend to be relatively shallow compared to some winter roosts. However, this assumes that the movements and roosting habitat of tagged bats are the same as those of untagged individuals. Radio-telemetry is an expensive and time-consuming technique (Wilkinson and Bradbury 1988). Sample sizes are typically very limited due to the time and financial constraints imposed by this method and to the limited detection ranges.

Long-distance movements of bats have been tracked using an array of automated radio-telemetry receivers (Taylor et al. 2011, 2017). This system could offer promise for studying bats that travel long distances to hibernacula.

Use of radio-telemetry may require a federal spectrum licence. Some suppliers offer transmitters and receivers that are exempt from the licensing requirement in Canada. Consult regional wildlife managers about other wildlife telemetry projects that are being conducted in their region before ordering equipment to ensure that the transmitter frequencies do not overlap with those already in use.

The smallest transmitters that are currently available weigh about 0.2 g and have a battery life of 9–22 days (Figure 31). Larger transmitters (0.7 g) may last 3–4 weeks and have slightly greater detection distances. Battery life can also be extended by reducing the signal rate and, in some cases, using a programmed schedule to tun the transmitter on/off.

Figure 31. Myotis with radio-transmitter. Photo courtesy of Alaska Department of Fish and Game.

Bat transmitters have a detection distance up to 2–4 km, but this varies greatly depending on topography. Signals may be blocked by rock, so some bats that are roosting in crevices, mines, or caves may be undetectable.

Surgical latex adhesives that are recommended for attaching transmitters include Perma-Type Surgical Cement, Torbot, or Osto-bond (Carter 2018). The adhesive power of glue deteriorates over time, so fresh bottles should be purchased for every field season (Carter 2018). The longevity of the glue can be increased by keeping it in the fridge. Skin-bond should no longer be used for attaching transmitters because its chemical recipe has been altered, which has made it less effective as an adhesive for this purpose.

The amount of time a transmitter remains attached can vary widely and depends on the roosting behaviour of the bat (e.g., tree roosting versus rock crevice roosting), the time of year, and the procedure used to glue the transmitter. Glued transmitters remain attached for an average of about 9 days, considerably less than the battery life of many transmitters (O’Mara et al. 2014). Depending on the transmitter type and manufacturer, transmitters may need to be used within a few months from the time of production. The life of some transmitters can be extended for several years by storing them in a refrigerator, and in some cases, unused or recovered transmitters can be re-batteried or refurbished (e.g., Holohil).

5.5.9.1.1 Procedures for Transmitter Attachment

- Once a bat is captured, weigh it and evaluate whether to radio-tag it based on the 5% rule and its gender and reproductive state.
- Activate the radio-tag (this may require removing a magnet or soldering a wire connection) and use a receiver to verify that it is working. Check and record the frequency; it may be slightly different from the manufacturer’s specification, and may vary over time and with temperature, so be sure to check the frequency again before you release the bat.
- Hold the bat on a soft surface (e.g., bat bag) or carefully in air with its wings forward, exposing the scapula. Carefully clip an area of hair approximately the size of the radio-tag between the shoulder blades. Remove only half of the hair length for Townsend’s

Big-eared Bat and Spotted Bat. Be sure not to clip the bat's skin. If you accidentally cut the bat, do not attach a radio-tag, and release the bat immediately.

- Once the hair is removed, apply a small amount of surgical adhesive to the clipped area and to the surface of the tag that will be in contact with the bat (Brigham, n.d.). Allow the glue to become tacky (i.e., when it begins to bubble—approximately 5 minutes; refer to instructions on the glue container).
- Place the tag on the bat. It should be placed between the shoulder blades, at the bat's centre of gravity, with the antenna oriented toward the tail, and should be held in place for approximately 30–60 seconds. Do not release the bat until the glue is dry (~15–20 minutes), and during the drying process, do not let the bat move around. This can be easily accomplished by wrapping the bat in a knee-high nylon stocking and applying just enough tension around the bat to allow it to breathe normally but not to move and potentially dislodge the transmitter (C. Lausen, pers. comm., 2018).
- Use the receiver to track the bat as it is released to ensure that it can fly properly and has not been grounded in the vicinity.
- Track the bat to its roost during next day. Personnel who are conducting radio-tracking should be aware of property boundaries and avoid trespassing onto private property. Night tracking may be required to, at minimum, identify the general vicinity of the roost, which will allow for more intensive day searching. This may be especially important when locating bats that are roosting in rock, where the signals may be lost during the day.
- Radio-tracking can be conducted on foot or by aircraft or vehicle. Diesel engines may produce less electric interference with telemetry equipment than gasoline engines (S. Grindal, pers. obs., cited in RIC 1998a). Always mount the antenna on the outside of the tracking vehicle to reduce interference. The use of multiple-element antennae requires that there be no obstacles (especially metallic ones) between the individual elements of the antennae (C. Lausen, pers. comm., 2018). For example, when mounting an antenna on a high-brace airplane, do not attach the antenna so that the aircraft brace is between the elements (pictured correctly in Figure 32). The shortest element is always the front of the antenna.

Figure 32. Telemetry antenna correctly attached to aircraft wing strut. Photo courtesy of C. Lausen.

- The direction of the signal may be difficult to determine when the receiver is very close to the roost. Removing the antenna and aiming the coaxial receptor of the receiver toward the roost can help narrow down the location of the bat with sufficient directionality. Holding out just the end of the coaxial cable may also provide sufficient directionality to locate the site that is occupied by the bat, but it is best to coil the cable into a small bundle that can act as a long antenna at close range. Another trick to locating transmitters at close range, when even the lowest gain is too high to provide directionality, is to adjust the receiver's frequency up or down slightly. Directionality is regained when going off-frequency.

- Note that the first roost selected by the bat after being released may not be representative due to the stress from capture and handling. Therefore, the data from the first roost should generally not be used.
- If a bat cannot be located the next day after transmitter attachment, an aircraft may be needed to find its day roosting area. Signals are generally more likely to be heard from the air than from the ground, although this varies with terrain.
- Use triangulation to document a bat's location if its roost is on private property or in inaccessible terrain.
- Record the characteristics of the roost once it is located, and conduct an exit survey that evening.
- Radio-transmitters may be shed in the roost; this may not be easily detected if bats are located only during the day. If possible, check each transmitter at least once nightly about 1 hour after sunset to confirm that the bat has left the roost and the transmitter is still attached to it.
- Tracking may be conducted at night to document foraging locations, but several observers with receivers will likely be needed to accurately triangulate locations of fast-moving bats.

5.5.10 Capture and Telemetry Data Reporting and Analysis

Data reported and their interpretation will vary according to the purposes of the survey. Consult the Wildlife Species Inventory data template for Bat Capture and Telemetry (www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates). Basic data analysis should include the following:

- List the species captured for each study area.
- Describe weather conditions during the surveys and discuss how the conditions might have affected the results. Note changes in weather if any occur during the night.
- For capture surveys, for each species, sex, and reproductive class (if known), calculate the following:
    - number of bats caught per net-night or per m^2/hr (a net-night is equivalent to one 6-m length of net set up for one night), and/or
    - number of bats caught per night or hour of harp trapping.
- Include a discussion of the assumptions that are implicit in any assessment of relative abundance from capture surveys (e.g., closed populations, constant and equal catchability over multiple capture sessions, indices such as catch-per-unit-effort are proportional to the actual population) and the likelihood of those assumptions being confounded (Kunz et al. 2009b; Ingersoll et al. 2013).

Data reporting for telemetry projects will vary with the purposes of the project but could include the following:

- number of roosts, size of roost area, and inter-roost distances of individuals, by species, reproductive status, and sex (using GIS mapping and spatial analysis software)
- roost types used by individuals
- number of nights each roost was used, and frequency of roost switching
- changes in group size or composition (if known)
- total amount of time each bat was tracked
- summary of weather conditions during tracking of each bat
- roost characteristics (crevice, tree, building); tree species, live/dead tree, tree diameter, decay stage, bark remaining (use wildlife tree codes in British Columbia Ministry of Forests and Range and British Columbia Ministry of Environment 2010); canopy closure; elevation; aspect
- for rock crevices: height off the ground, orientation, dimensions of crevice opening, and rock type
- a map showing sample locations and locations of any roosts or hibernacula located

5.6 Radar Surveys

Radar surveys provide data on bat flight paths, including direction, altitude, speed, and timing (Hayes et al. 2009). The advantages of radar are its ability to detect bats at long ranges and its lack of directionality (Hayes et al. 2009). The disadvantages of radar are its high cost, limited portability, and high power requirements, and the skill set required by the operator(s). Standard radar operating systems have been criticized for their inability to discriminate between bats and other animals (e.g., large insects, small birds) (Hayes et al. 2009). Radar systems that can effectively detect bats produce short wave length emissions, have suitable antennae, and use advanced filtering software to discriminate bats from other self-powered objects. The effective range of radar is 2 km, although terrain often reduces the effective sampling area. Species identification is generally not possible unless acoustic recording systems are synchronized with the radar (Dagenais 2016).

At present, radar surveys for bats in B.C. have limited application and are usually conducted in conjunction with radar surveys for birds during impact assessment studies of wind farms. Advancements in technology and greater availability of trained personnel may result in radar surveys being used more widely.

5.6.1 Personnel

- Field crews for radar surveys should consist of at least two people, at least one of whom should have experience in operating the radar unit and interpreting radar data.

5.6.2 Field Procedures

Radar surveys are usually targeted at detecting birds; detection of bats is a secondary objective because they can rarely be distinguished from small birds. Only general procedures are given here:

- Record data from 30 minutes before sunset to 30 minutes after sunrise (Holroyd and Craig 2016c).
- Record weather data (air temperature, cloud cover, precipitation, wind speed) at the beginning and end of each sampling session and hourly throughout.
- Do not sample during periods of rain.

- For each “bat-like” target or group of targets, record behaviour, such as flight direction, altitude, flight speed, flight pattern (which may help to distinguish bats from birds), changes in flight direction, and number of individuals in the group.
- Record radar data on digital media so they can be reviewed and quality checked later (Holroyd and Craig 2016c).
- There are not currently any provincial templates to record and submit radar data. Survey information can be reported using the General Survey template (https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates).

List of Acronyms, Abbreviations, and Initialisms

BMP	Best Management Practices
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
dB	decibels
DNA	deoxyribonucleic acid
FS	full spectrum
GPS	Global Positioning System
HPF	high pass filter
kHz	kilohertz
ms	millisecond
PIT	passive integrated transponder
RISC	Resources Information Standards Committee
SARA	*Species at Risk Act*
SNR	signal to noise ratio
SOP	standard operating procedures
TBC	time between calls
WNS	white-nose syndrome
ZC	zero-crossing

Glossary

ABUNDANCE: an estimate of the number of individuals in a population. Absolute abundance is expressed as the number present per area (density), but this cannot be reliably assessed for bats. Relative abundance is expressed as the number caught or detected per unit time (frequency). Relative abundance can be compared between localities or over time, but reliable comparisons of relative abundance cannot be made between different species of bat.

ACOUSTIC ATTENUATION: the loss of energy (amplitude) in a sound wave as it propagates through a medium such as air.

ACOUSTIC GROUP: a group of two or more bat species that have overlapping acoustic call characteristics and are difficult or impossible to distinguish acoustically.

ALIASING: an artifact of digital signal processing that occurs when the sampling system is oversaturated (overwhelmed by incoming sounds); frequencies above half the sampling rate are "reflected," giving the appearance of a mirror image (below the maximum frequency as dictated by the sampling rate). Aliases may be produced by bats that are very close to the microphone (i.e., too loud) or by inappropriate sampling rates.

ANALOOK W: Titley Scientific Inc. bat species call identification software.

APPROACH PHASE: a series of shortened, higher-frequency calls emitted when a bat has detected a potential prey item (or other object); this phase is used to discern greater detail (size, shape, distance, and movement) about the object of interest than can be gathered using search phase calls.

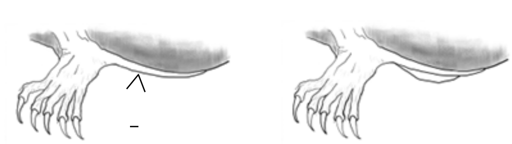
BAT DETECTOR: a device capable of transforming (and often recording) ultrasonic signals into sounds audible to humans.

BATKITE: a method of temporarily tethering a bat to obtain a reference call recording; it allows the potential recording of calls produced by bats that are not reacting to the ground as clutter. Because the bat is less confined in its flight pattern, reference calls obtained in this manner may more closely resemble free flight calls (Lausen et al. 2009).

BAT PASS: a sequence (see Call Sequence below) of two or more calls (pulses), separated by at least one second, that is registered when a bat flies within range of an observer or the detection equipment (Fenton 1970). It is the traditional unit of activity (Gannon et al. 2004). New standards introduced with the NABat Monitoring program redefine a pass as a sequence of pulses separated by more than 2 seconds; bats that can have time between calls ≥ 1 seconds are not broken into individual passes (Loeb et al. 2015).

BIODIVERSITY: biological diversity: the variety of life forms, the ecological roles they perform, and the genetic diversity they contain (Wilcox 1984 cited in Murphy 1988).

CALCAR: a cartilaginous extension of the ankle that supports the edge of the uropatagium or tail membrane (below, left). The presence or absence of a keel on the calcar (below, right) is an identifying feature for some species.



CALL LIBRARY: a collection of echolocation recordings from identified (known) species, usually grouped by region, that is used to compare with recorded calls of unknown species identity.

CALL SEQUENCE: a succession, or pattern, of echolocation calls, or pulses (see Bat Pass).

CFCRead: Titley Scientific Ltd. software required for downloading data from Titley acoustic detectors.

CLIPPING: the truncating of a recorded high-frequency call which may be due to inappropriate detector settings or a bat flying extremely close to the microphone.

CLUTTER: an object/surface (e.g., grass, trees, other bats, rocks, buildings) as perceived by a bat; the degree of spatial complexity in the environment (O'Keefe et al. 2014).

CLUTTER CONTINUUM: the progression of variation in call shapes/frequencies of bats related to the degree of habitat complexity (e.g., density or abundance of obstacles such as trees, rocks, other bats, insect prey in the environment). Because bats tend to respond similarly when approaching a surface/object (tendency for an increase in frequency, bandwidth, and call repetition rate, with a decrease in call duration), call characteristics of some acoustically similar species converge, complicating species identification (C. Lausen, pers. comm. 2018).

CONSTANT FREQUENCY: the production of a single frequency; in some North American bats, this is a long, low frequency "pure" tone echolocation call that is used in open habitats.

DECIBELS: the measurement of intensity, or loudness, of a sound.

DENIER: the number of grams in 9000 m of fibre. A unit for measuring the fineness of mist nets. The lower the number, the finer the net.

DETECTION ZONE: the general area of airspace within which an echolocating bat passing a microphone will be heard/recorded.

DETECTOR NIGHT: the sampling period for acoustic inventory extending from sunset (or shortly before) to sunrise (or shortly thereafter) on the following calendar day.

DIVIDE-BY-n (COUNTDOWN) DETECTOR: a bat detector that divides the frequency of an incoming ultrasonic signal by a factor of "n," thus bringing the signal into the human range of hearing. This is commonly called "frequency division."

DIVISION RATIO: in zero-crossing sampling, the pre-set number (*n*) of "crossings" as a sound wave passes the zero point.

ECHOLOCATION: also called biosonar, the use of self-produced sound (often ultrasonic) and the detection/interpretation of returning echoes to navigate, detect prey, and communicate (Griffin 1958).

EPIDIDYMIDES: plural of epididymis.

EPIDIDYMIS: a duct that originates on the posterior surface of each testis and connects the testis to the deferent duct. It stores sperm produced by the testis, and its size and colour can be used to infer a male bat's reproductive condition.

EPIPHYSEAL PLATES: cartilaginous areas where growth takes place in bones. Their configuration in finger joints can be used to differentiate juvenile from adult bats.

FEEDING BUZZ: also known as the "terminal phase;" a series of short-duration echolocation calls emitted just prior to prey capture to provide precise fine-scale information on target distance.

FILTERS: user-defined filters can be created in some bat analysis software, including Analook and Anabat Insight (Titley Scientific). Filters essentially scan files for call fragments that meet certain criteria, which helps the user streamline data analysis through a sorting or filtering process. Multiple filters can be used together as a scan or decision tree to auto-identify large data sets.

FLY-WAY: any corridor used by bats commuting between roosting and foraging areas. Fly-ways are excellent sites for capturing bats in mist nets and harp traps. Fly-ways often are delimited by physical structures, such as vegetation or buildings.

FREQUENCY: a characteristic of a sound, measured in kilohertz (kHz), defined as the number of sound waves passing by a given point per second.

FREQUENCY MODULATED: a broadband echolocation call that sweeps through a range of frequencies that are useful for navigating in cluttered habitats.

FULL SPECTRUM: a method of recording ultrasound that maintains all sound components, including amplitude, of the original signal.

HARMONIC: a characteristic of sound waves where tone(s) accompany the originally produced frequency (also known as the "fundamental tone" or "first harmonic"). Harmonics occur in positive integer multiples of the fundamental tone.

HARP TRAP: a specialized trap designed exclusively for capturing bats, consisting of an array of closely spaced vertical lines.

HETERODYNE: a method of transforming ultrasonic signals; incoming sound is mixed with another signal to produce frequencies that are audible to humans.

HIBERNACULA: the plural of hibernaculum.

HIBERNACULUM: any overwintering site used by hibernating bats.

JUVENILE: a bat that has not yet experienced its first winter.

KALEIDOSCOPE: Wildlife Acoustics Inc. automated bat species call identification software.

KILOHERTZ: the unit of frequency of a sound. 1 kHz = 1000 cycles per second.

LACTATION: the period of milk production by female mammals nursing young.

LIGHT TAGGING: temporarily attaching a miniature light stick to the belly or dorsal fur of a bat to track a known individual while obtaining a reference call. Light tags may also be used to identify foraging ranges, clarify habitat use, or make behavioural observations.

MIST NET: a fine mesh net, supported by poles, designed specifically for capturing bats.

NET-NIGHT: a measure of mist netting effort. One net-night is equivalent to setting up one 6 m length of mist net for one evening.

NULLIPAROUS: has never given birth.

NYQUIST THEOREM: the sampling theorem that dictates a digital sampling rate must be at least twice the maximum frequency of the incoming signal in order to accurately capture all of the information in the incoming signal.

OSCILLOGRAM: the graphical representation of a recorded sound based on sound wave pressure, where time is recorded on the x-axis and amplitude is recorded on the y-axis.

OVERWINTERING STRATEGY: the behaviour exhibited by species or individuals at times outside the breeding season. This can include either migration or hibernation.

PAROUS: has given birth at least once.

PARTURITION: the process of giving birth.

PINNA: external ear.

PINNAE: plural of pinna.

PIT TAGGING: inserting a passive integrated transponder (~ 1 cm in length by 2 mm in diameter) under the skin of an animal to mark it with a unique electronic code for mark recapture or long-term demography studies.

PRESENCE/NOT DETECTED: a survey intensity that verifies that a species is present in an area, or states that it was not detected.

PROJECT AREA: an area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resources and/or species inventory. Sampling generally takes place within smaller study areas within this project area.

RADIO TELEMETRY: use of a specialized radio receiver to directionally locate a radio transmitter with a specific frequency that has been attached to an animal. Three directional locations from different starting points (triangulation) can identify the general location of the transmitter. Radio telemetry can be used to clarify habitat use, especially to identify roost sites, and track an animal's movement within a home range.

RANDOM SAMPLE: a sample that has been selected by a random process, generally by reference to a table of random numbers.

REFERENCE CALL: a recording of a call from an identified (known) species.

ROOST: any site used by bats for rest, sleep, torpor, food digestion, shelter, etc. A distinction can be made between **DAY** and **NIGHT** roosts. Day roosts tend to be used throughout the daylight hours, whereas night roosts are used temporarily at night between foraging bouts. Examples of roosts are attics, rock crevices, and tree cavities.

ROOST HABITAT: an ecosystem type in which roost structures may be present (e.g., urban areas, old forest, talus slopes).

ROOST STRUCTURE: a natural or anthropogenic feature in which a roost is present (e.g., a house, snag, cut bank, or cliff).

ROOSTING STRATEGY: the behaviour exhibited by roosting bats. Bats may either be solitary or colonial.

SAMPLING RATE: the number of times per second that an anlaog sound is measured and digitized, expressed in kilohertz (kHz). For example, a sampling rate of 196 kHz means that an analog signal is digitized 196,000 times per second. Also, the number of equally-spaced samples taken for each 1 s of signal (Fraser et al 2020). This number must be at least twice that of the highest frequency of interest to record that frequency.

SEARCH PHASE: a sequence of echolocation calls used to provide relatively coarse-scale information on distance and potential prey when navigating. Typically, longer duration and less broadband than terminal calls.

SONOBAT: bat call analysis (and species classification) software designed by J. Szewczak, founder of SonoBat.

SONOGRAM: the visual depiction of ultrasound frequencies (y-axis) emitted as a function of time (x-axis).

SPLIT HARMONIC: the transfer of energy in a call from one harmonic into another higher harmonic.

STRATIFICATION: the separation of a sample population into non-overlapping groups based on a habitat or population characteristic that can be divided into multiple levels. Groups are homogeneous within, but distinct from, other strata.

STUDY AREA: a discrete area within a project boundary in which sampling is conducted. Study areas should be delineated to logically group samples together, generally based on habitat or population stratification and/or logistical concerns.

SURVEY: the application of one RISC method to sample one taxonomic group for one season.

SWARMING: a behaviour involving multiple bats congregating at a single site (often a hibernaculum) at night in late summer, where they circle repeatedly, chase each other, and sometimes mate. The function of swarming is not well understood, but it may serve as a social or mating event, or to indicate the location of suitable hibernacula.

SYSTEMATIC SAMPLE: samples that are selected at a predetermined interval or frequency (e.g., every 10 m along a transect). Contrasted with random sample.

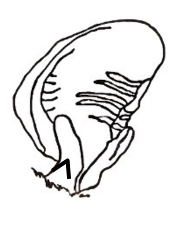
TERMINAL PHASE: also known as the "feeding buzz"; a series of short-duration, low-intensity calls emitted just prior to prey capture to provide fine-scale information about target distance, movement, size, and/or shape.

TESTES: male organs of spermatogenesis.

TIME EXPANSION: a method of transforming an incoming signal by expanding it over time while preserving the original sound component details. Recording is not continuous (no recording during signal expansion).

TORPOR: an energy saving behaviour during which a bat lowers its metabolic rate and body temperature and enters an inactive state.

TRAGUS: the fleshy appendage at the base of a bat's external ear. Its characteristic shape and size is diagnostic for some species.



TUNABLE NARROW BAND DETECTOR: a type of bat detector that uses an internally generated pure tone to make selected ultrasonic signals audible. Can receive only a narrow frequency band (3 to 5 kHz) at any one time. Commonly referred to as heterodyne bat detectors. These detectors cannot record sound for spectral analysis.

ULTRASONIC: any sound above 20 kHz, which is generally inaudible to human hearing.

UROPATAGIUM: the tail membrane of bats, which extends on either side of the tail to the hind limbs.

VERSPERTILIONIDAE: the taxonomic family to which all bats that commonly occur in British Columbia belong. The so-called “mouse-eared” or “plain-nosed” bats.

VOLANT: capable of flying.

ZERO-CROSS: a method of recording ultrasound that preserves frequency and time characteristics of the original signal but not amplitude. It counts the number of times a signal crosses the “zero-energy line” of an oscillogram, at a set ratio called a division ratio.

ZIPLINE: a method of temporarily tethering a bat to obtain a reference call recording. This method constrains the tethered bat to flying in a relatively straight line and within a few metres of the ground, which results in generally high clutter call shapes.

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Appendix A. Species Codes for Bats in British Columbia

Species Code	Scientific Name	Common Name
ANPA	*Antrozous pallidus*	Pallid Bat
COTO	*Corynorhinus townsendii*	Townsend's Big-eared Bat
EPFU	*Eptesicus fuscus*	Big Brown Bat
EUMA	*Euderma maculatum*	Spotted Bat
LACI	*Lasiurus cinereus*	Hoary Bat
LABO	*Lasiurus borealis*	Eastern Red Bat
LANO	*Lasionycteris noctivagans*	Silver-haired Bat
MYCA	*Myotis californicus*	Californian Myotis
MYCI	*Myotis ciliolabrum*	Western Small-footed Myotis
MYEV	*Myotis evotis*	Long-eared Myotis
MYLU	*Myotis lucifugus*	Little Brown Myotis
MYSE	*Myotis septentrionalis*	Northern Myotis
MYTH	*Myotis thysanodes*	Fringed Myotis
MYVO	*Myotis volans*	Long-legged Myotis
MYYU	*Myotis yumanensis*	Yuma Myotis
NYMA	*Nyctinomops macrotis*	Big Free-tailed Bat
PAHE	*Parastrellus hesperus*	Canyon Bat
TABR	*Tadarida brasiliensis*	Mexican Free-tailed Bat

Appendix B. Physical/Behavioural Characteristics of British Columbia Bat Species (data sourced primarily from Nagorsen and Brigham 1993; van Zyll de Jong 1985)

Species Code[a]	Forearm (mm)	Ear (mm)	Tragus (mm)	Hind Foot (mm)	Mass (g)	Calcar	Similar Species	Distinctive Features
EUMA	47.9–53.1	34–41	13–14	9–10	16.2–21.4	no keel	none	Black dorsal fur with large white spots on rump and shoulders; extremely large pink ears
COTO	39.0–45.2	27–40	10–15	7–10	6.0–13.5	no keel	none	Giant ears; two prominent vertical, glandular swellings on nose; long, pointed tragus
ANPA	48.0–57.4	26–33	12–17	9–17	12.0–24.3	no keel	none	Pale colour, with short fine fur; tragus is long and narrow with a toothed outer edge; snout has glandular swellings; usually passive; large teeth
EPFU	43.0–52.0	11–21	5–11	8–15	8.8–21.9	keel	MYTH	Light mane; readily bites; emerges early; large, broad head; short blunt tragus; black flight membranes and ears; swollen areas visible on each side of nose
PAHE	27.0–33.0	11	??	6	3.0–6.0	no keel	MYCI, MYCA	Tri-coloured fur, light grey to yellowish; dark leathery facial mask; tragus is club-shaped and slightly curved; ears more rounded than MYCI; large foot > 1/2 tibia
LABO	39.3–43.0	12		9	10.0–15.0	keel	none	Dense fur ranges from pale orange to rusty red; tail membrane densely furred above; ears short and partly furred
LANO	39.1–43.9	9–15	4–8	6–11	5.8–12.4	no keel	none	Dark fur with silver/white-tips; blunt face; short blunt tragus; upper surface of tail membrane furred only at base
AECI/LACI	50.3–57.4	13–16	9–10	10–15	20.1–37.9	keel narrow	none	Large bat with dense grizzled hair tips; upper surface of tail membrane furred; sometimes growls in defense
MYCA	29.4–35.0	8–15	4–8	5–9	3.3–5.4	keel	MYCI, PAHE	Medium brown or even orange; haired-snout except tip; dark mask and wings; foot longer than MYCI; tail barely extends beyond membrane; Fmin ~50 kHz

Species Code[a]	Forearm (mm)	Ear (mm)	Tragus (mm)	Hind Foot (mm)	Mass (g)	Calcar	Similar Species	Distinctive Features
MYCI	28.8–33.4	8–15	4–9	6–8	2.8–5.5	keel	MYCA, PAHE	Light brown; contrasting dark facial mask; snout mostly bare; long, narrow, straight tragus; very small foot; tail extends several vertebrae beyond membrane; Fmin ~40 kHz
MYLU	33.0–40.3	9–17	4–10	6–13	6.2–10.2	no keel	MYYU, MYEV	Fur glossy and thick; readily bites; blunt tragus, about half the ear length; lighter fur on underside; shallower forehead than MYYU; use detector to confirm Fmin is ~40 kHz
MYYU	30.0–38.0	8–16	5–10	6–13	4.0–8.5	no keel	MYLU	Fur drab; little contrast between dorsal ventral pelage; relatively passive; tragus is blunt and about half the length of the ear; wing membranes and ears are dark brown; forehead is steeper than MYLU; use detector to confirm Fmin 45–50 kHz
MYVO	34.0–43.0	9–15	5–7	7–10	5.5–10.0	keel	none	Fur on underside of wing between elbow and knee; rounded ears; membranes very black; dark fur; foot/tibia ratio << 0.5
MYEV/ MYKE	36.0–42.0	17–22	8–12	7–11	4.2–8.6	None or partial keel	MYSE, MYLU	Long snout and ears; dark mask; fringe of hairs visible with a hand lens on outer edge of tail membrane; contrasting upper and lower pelage; dark brown or black pinnae, tragus has small lobe at its base; tabs on edge of tail membrane are prominent and symmetrical
MYSE	34.0–38.0	14–19	8–12	7–11	5.0–10.0	None or indistinct keel in some areas	MYEV	Dark shoulder spots; tragus is long, narrow, and pointed; edge of tail membrane is bare or has only a few scattered hairs; tabs on edge of tail membrane are symmetrical but small (M. Sarell, pers. obs.)

Species Code[a]	Forearm (mm)	Ear (mm)	Tragus (mm)	Hind Foot (mm)	Mass (g)	Calcar	Similar Species	Distinctive Features
MYTH	40.0–44.5	15–20	8–11	8–11	5.4–8.4	no keel	EPFU MYEV	Distinctive fringe of small stiff hairs on outer edge of tail membrane; “tabs” on edge of tail membrane are prominent and asymmetrical, curving toward tail (M. Sarell pers. obs.).
TABR	37.0–41.0	8–15		6–9	7.0–12.0	NA	none	Tail extends well past membrane; ears not joined at base
NYMA	58.0–64.0	28		12	22.0–30.0	NA	none	Very large bat with long forearms; vertical wrinkles on the lips along the muzzle; ears joined at base; bicoloured fur with basal portions white, and tips reddish to dark brown; no tail membrane (i.e., a free tail)

[a] Species codes are defined in Appendix A.

Appendix C. Suggested Equipment List

Roost Searches

- Maps of study area
- First aid kit
- Personal protective equipment
- Building plan, if appropriate
- Headlamp for each person
- Flashlight
- Red photographic filter (25 or 29) for light sources
- Pen light for examining crevices
- Fibre optic scope for examining crevices (optional)
- Camera
- Handheld GPS unit
- Data sheets and pencils
- Flagging tape
- Binoculars
- Bat detector
- Extra batteries for all equipment
- Sample containers for guano

General Acoustic Sampling

- detector(s) with weatherproof housing for remote/long-term/winter remote deployments
- power source (internal or external)
- security housing if theft or vandalism are a concern
- calibrated (by manufacturer) and/or otherwise tested microphone to ensure appropriate sensitivity, with weatherproofing for remote/long-term/winter deployment
- cables of sufficient length to raise the microphone to an appropriate height
- formatted memory cards
- extendable poles and cables for raising the microphone
- grounding wire to attach to the microphone pole (if used) for deployments in dry/windy areas where electric charge buildup may affect equipment performance
- camera or smartphone/tablet to document setup and habitat
    - GPS units or smartphone/tablet to enter geographic locations into the detector (if applicable)
    - data sheet/notebook
    - screwdrivers and electrical tape may also be useful

Reference Call Recording:

- spotlight with a beam extending at least 12–18 m (1–3 million candlepower)

- bat detector (ideally full spectrum) with the capability to make voice notes
- fishing line (10–15 lb)
- two poles
- elastic thread
- miniature glow sticks (2.5-cm [1-inch] length or smaller)
- non-toxic glue stick
- rubber bands
- swivels
- scissors
- decontamination supplies

Capture

- All applicable permits
- Decontamination and hygiene supplies specified by WNS SOPs, and copy of WNS SOPs
- First aid kit
- Bear spray
- Insect repellent (ideally without DEET)
- Handheld GPS unit
- Waders/rubber boots
- Bat holding bags
- Chemical heat packs or hand warmers for rewarming bats, and covers for them (e.g., old socks)
- Leather gloves for handling large bats
- Long, heavy leather gloves for extracting any captured owls or other non-target wildlife capable of injuring people
- Plastic bags and sheets in multiple sizes
- Sealable containers for used nets and bat bags, and for waste
- Portable work surface(s) that can be covered, disposed of, or decontaminated
- Map of study area
- Hard copy data sheets (including waterproof sheets), pencils, Sharpie markers
- Notebook paper or duct tape for temporary bat bag labels
- Air thermometer
- Wind meter (optional)
- Laptop or tablet computer
- Handheld bat detector (ideally with earphones)
- Two-way radios (one for each crew member)
- Headlamps, at least one for each crew member
- Tabletop or hanging lanterns
- Handheld flashlights
- Bat holding bags and sterilizable or disposable isolation containers
- Scissors
- Crochet hook
- Fine forceps

- Cigarette lighter for sterilizing forceps
- Magnifier
- Biopsy punches, cardboard sheets (cutting boards), wing swabs, sample vials, and labels
- Coin envelopes and desiccant
- Bat identification keys (may be carried as electronic copies on laptop or tablet)
- Digital or spring scale
- Digital or manual measuring calipers
- Flexible ruler with markings that go right to the end
- Banding tools and bands
- Camera
- Compass
- Mist nets of various sizes
- Large tarps to lay under canopy nets
- Net poles and pole connectors
- Pruning saw and shears
- Lengths of rebar and hammer for anchoring conduit poles
- Multiple lengths of rope and stakes for guy lines
- Net repair kit
- Rechargeable screw gun/screwdriver, screws of various sizes, and pipe strapping to fasten net poles inside buildings
- Small syringe and water for rehydrating bats, if required
- Extra batteries for all electronic equipment

Radio-telemetry

- Radio-transmitters appropriately sized for the target species
- Radio-telemetry receiver
- Antenna (multiple elements) and coaxial cable
- Surgical skin adhesive
- Scissors (high quality. e.g., dissecting type; curved scissors minimize the chance of accidentally cutting the bat)
- Portable soldering iron (e.g., butane pen type) and solder if needed to activate transmitters
- Roost Tree Data Form (contact Small Mammal & Herpetofauna Specialist) for describing roosting habitats upon relocation of tagged bats

Exit Surveys

- Handheld counter
- Headlamp with deep red filter
- Night vision equipment
- Handheld flashlight
- Data sheets and pencils, or digital voice recorder

- Air thermometer
- Watch
- Handheld bat detector (ideally with headphones and recording function)
- Folding chair

Internal Counts

- Safety plan
- Rescue and evacuation plans if needed for the site
- All applicable permits
- Personal protective equipment (e.g., coveralls, gloves, dust mask, safety glasses, H2S detector, hardhat) if required for the site
- Decontamination and hygiene supplies specified by WNS SOPs, and copy of WNS SOPs
- Headlamp with red light
- Quick-reading digital thermometer
- Data sheets and pencils
- Ladder if required for access
- Fibre optic scope (optional)
- Camera (infrared preferred)

Radar Surveys

Note that equipment required will depend on the particular model and features of the radar unit employed.

- Study area map
- Radar unit, monitor, and power source
- Handheld radios for communication
- Headlamps (one for each person)
- Handheld GPS unit
- Digital voice recorder
- Digital video recorder
- Laptop computer
- Hard copy data sheets and pencils
- Extra batteries for all lights and electronic devices

Appendix D. Selected Suppliers of Equipment Used for Bat Inventory

Equipment Type	Commercial Suppliers
Mist nets and net poles	Avinet & Avian Research Supplies 276 Canco Rd. Portland, ME 04103 https://www.avinet.com/en/mist-nets/usa
	Bat Conservation & Management 1263 Claremont Dr. Carlisle, PA 17015 https://batmanagement.com/
	Ecotone Stryjska 24, 81-506 Gdynia, Poland http://www.mistnets.com/ultra_mistnets.html
	Ron Redman (Arkansas) – triple-high pole sets batman72015@yahoo.com
	Titley Scientific https://www.titley-scientific.com/us/ BatNets.com
Harp traps	Bat Conservation & Management 1263 Claremont Dr. Carlisle, PA 17015 https://batmanagement.com/
Thermal cameras	Bat Conservation & Management 1263 Claremont Dr. Carlisle, PA 17015 https://batmanagement.com/
Biopsy punches	Stevens Medical Supplies 8188 Swenson Way Delta, BC V4G 1J6 https://stevens.ca/
	Surgo Surgical Supply http://www.surgo.com/z_homepage.htm
Bat detectors	Land-based Learning https://landbasedlearning.ca/shop/ Wildlife Acoustics https://www.wildlifeacoustics.com/ Titley Scientific https://www.titley-scientific.com/us/
Bat bands and banding equipment	Porzana Ltd. Elms Farm, Pett Lane Icklesham, East Sussex TN36 4AH, UK http://www.porzana.co.uk/bat_rings.html

Equipment Type	**Commercial Suppliers**
	BATS Research Center 107 Meadow View Court Shohola, PA 18458-3444 Office & Fax 570-409-0395 batresearch@yahoo.com contact: JOHN GUMBS
Radio-telemetry tags, receivers, antennae	ATS Track 470 First Ave. NW Isanti, MN 55040 https://atstrack.com/tracking-systems/entomologists-and-bat-package.aspx
	Holohil Systems Ltd. 112 John Cavanaugh Dr. Carp, Ont. K0A1L0 https://www.holohil.com/
	Lotek Wireless Inc. 115 Pony Dr. Newmarket, Ont. L3Y 7B5 http://www.lotek.com/avian.htm
PIT tags and readers	Avid Identification Systems, Inc. 185 Hamner Ave. Norco, CA 92860 https://avidid.com/solutions/wildlife
	Biomark 705 S. 8th St. Boise, ID 83702 https://www.biomark.com/contact/
	Identification Solutions www.uidevices.com
	Oregon RFID 4246 SE Ogden St. Portland, OR 97206-8452 https://www.oregonrfid.com/
	Trovan Ltd. http://www.trovan.com/en Eidap Inc. Tel: +1 780 467 2707 Fax: +1 780 467 5160 Email: info@eidap.com Pacific Veterinary Sales Tel: +1-800-663-6644 Fax: +-877-850-1510 Email: trevor@pacificpet.net