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DESIGNING MONITORING PROGRAMS USING FREQUENCY-DIVISION BAT DETECTORS: ACTIVE VERSUS PASSIVE SAMPLING

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Different types of bat detectors provide advantages and disadvantages for studying particular aspects of bat ecology. The Anabat II bat detector system is a widely used frequency-division detector that has the flexibility to be used for both active (researcher present) and remote (researcher absent) monitoring. Active monitoring is commonly used when recording known calls for the development of a call library, mobile sampling of transects, or when sampling near mist-netting sites. Passive monitoring permits establishment of multiple, simultaneously monitoring stations, thereby improving large-scale habitat surveys. Active monitoring results in increased call quality as researchers can follow bats with the detector, while passive sampling permits multiple simultaneous sampling stations. The type of monitoring used depends on resources (equipment and people), the length of the study, and the study objectives. Frequency-division detectors, such as the Anabat, are well suited for use in a variety of sampling designs.

Keywords: active monitoring, Anabat, echolocation, frequency division, passive monitoring, ultrasonic bat detector
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Introduction

Ultrasonic detectors have increased our ability to study bat ecology. In development of study designs, many potentially important factors need to be identified and addressed. These factors include the advantages and disadvantages of different types of bat detectors, type of sampling, objectives of the study, and resources available. Through consideration of these factors, the ability to address study objectives will be maximized.

Three broad classes of bat detectors can be used to study bat echolocation calls; heterodyne, frequency-division, and time-expansion systems. Frequency-division detectors divide the incoming frequency by a preset value to obtain a human audible representation of the call. The Anabat II bat-detector system (Titley Electronics; *www.titley.com.au*) is a frequency-division bat detector widely used in North America and Australia. Numerous authors have used the Anabat system to evaluate habitat use (Hayes 1997; Humes et al. 1999; Kalcounis et al. 1999; Krusic et al. 1996; Law et al. 1999; Mills et al. 1996; Seidman and Zabel 2001; Zimmerman and Glanz 2000) and for acoustic identification (Betts 1998; Britzke et al. 2002; Krusic and Neefus 1996; O'Farrell et al. 1999).

The Anabat system includes a broadband microphone (detects a wide frequency range simultaneously), a zero-crossings interface module (ZCAIM), and recording and analysis software. The recording software Anabat 6 has two modes: record and monitor. In record mode, calls are only saved when prompted by the user, while the monitor mode automatically records detected echolocation calls based on user-defined criteria. The Analook program permits analysis of previously recorded echolocation calls.

Recording Media

The type of recording media used largely determines the results obtained. The Anabat system permits use of 3 different recording media. Calls can be recorded to a tape recorder. While permitting easy transport, this setup has the disadvantage of increasing analysis time as the tape must later be replayed through the computer. Tapes also have limited storage capacity and lead to reduced call quality (O'Farrell et al. 1999; E.R. Britzke, unpub. data).

Anabat also permits direct storage to a laptop computer. This setup reduces analysis time and enhances call quality, thereby enhancing the ability to acoustically identify species (O'Farrell et al. 1999). However, use of a laptop computer requires additional equipment (batteries, inverters, protective boxes, etc.). Because Anabat files are small (1-15 kb each), a 200 MB hard drive contains sufficient storage for extensive sampling over multiple years (Corben and Fellers 2001).

Recently, the CF Storage ZCAIM has been developed that merges the benefit of the two recording media for use in passive monitoring. This component saves calls to a compact flash card. Digital storage of the call means that quality is as high as with a laptop, but less equipment is necessary.

The recording situation determines the best recording media to be used. For example, if the researcher is present at the recording station, benefits from the ability for real-time analysis possible with the laptop computer are probably preferred.

Comparisons with Time-expansion Detectors

The Anabat system eliminates information about harmonic structure by only using the harmonic with the most energy. Additionally, the Anabat system does not retain information about call amplitude. In comparison with time-expansion detectors, frequency-division detectors measured higher minimum frequencies and lower maximum frequencies (Fenton et al. 2001). However, differences between the two systems amount to 1-2 kHz, which is smaller than many other sources of variation (Murray et al. 2001).

Several studies have compared the number of calls recorded in direct comparisons of the 2 detector systems. The Anabat system detected fewer echolocation calls than did a time-expansion detector (Fenton 2000; Fenton et al. 2001), but these studies focused on the detection limits of the two bat detectors. When sampling in the field, time-expansion detectors experience a "dead time" as calls are being downloaded to tape (although see Jones et al., this volume), thereby effectively sampling for only 7.5% of the time (Fenton 2000). Even with the difference in sensitivity between the two systems, frequency-division systems will detect more than twice the number of files (Corben and Fellers 2001). In a large-scale field comparison in forests of the southern United States, the differences in number of files recorded between the 2 systems varied with sampling location. The Anabat system detected more bat activity at ground level, but the reverse was true above the canopy (M. Menzel, unpub. data). To maximize applicability of results, as many recording situations as possible should be incorporated into comparisons of detector types.

Calibration

Microphones used in different types of ultrasonic detectors differ in their sensitivities to high-frequency sounds. Differences in microphone sensitivity also occur within the same type of bat detector (Larson and Hayes 2000). Therefore, before commencing any study using multiple bat detectors, equipment must be calibrated (Hayes 2000). This requires an ultrasonic sound source (e.g., insect repeller – Larson and Hayes 2000). Calibration should also be done periodically throughout the study. Additionally, detectors should be randomly assigned to recording stations to minimize the impacts of differing microphone sensitivities on the results.

TYPES OF MONITORING DESIGNS

Bat detectors allow 2 types of recording: active and passive monitoring. Active monitoring involves the researcher being present to adjust the orientation of the microphone relative to the bat and to manually save detected echolocation calls. Active monitoring permits contact to be maintained with the bat, resulting in improved call quality (Fig. 1). Passive monitoring involves the automatic recording of echolocation calls without an observer present, based on predefined criteria. The directionality of the microphone in a fixed (passive) position can exert a strong influence on sound quality and on the quantity of calls recorded. Thus, a trade-off exists between call quality and the benefits of simultaneous sampling.

Studies using passive recording generally include multiple systems spaced across the landscape, thereby requiring protection of equipment from the environment. Protective boxes have been developed for both tape recorder (Hayes and Hounihan 1994) and laptop-operated (O'Farrell 1998) systems. While these setups serve to protect the equipment from weather, factors such as humidity have a potentially major influence on the detection of echolocation calls.

EXAMPLES OF USE

The objectives of the study determine the most effective sampling design. Below are examples of sampling design most useful for examining species identification, locating high-activity areas, acoustic sampling in conjunction with capture techniques, and evaluating habitat use.

Species Identification

Before acoustic identification can be attempted, a known-call library must be established. Known calls are commonly collected from active recording of hand-released bats. However, immediately after release, bats generally produce atypical calls (i.e., distress calls – Britzke et al. 2002; O'Farrell et al. 1999). Additionally, call sequences can be examined after the release of some individuals to determine if researchers need to adjust their distribution around the release point to increase recording quality. Passive monitoring, while still permitting species identification, inflates the number of calls that cannot be identified (E.R. Britzke, unpub. data).

Locating Areas of High Activity

Another use of acoustic monitoring is to find sites with high activity during initial surveys of large areas. Commonly, research is focused on the distribution of a target species within a large area (i.e., national forest, national park, etc.). Within a large area, the number of potential sites is generally greater than the number that can be sampled during the study. Using active monitoring, sites with high levels of activity can be

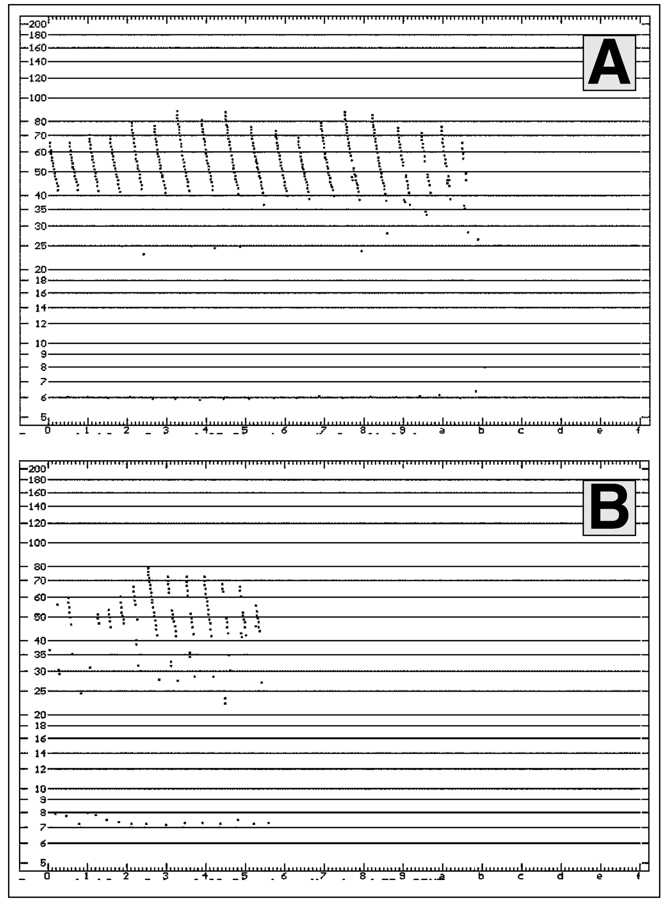

Figure 1: Time-frequency displays generated by Analook of northern long-eared myotis (*Myotis septentrionalis*) search-phase calls recorded using active (**A**) and passive recording (**B**). Time between calls has been compressed to allow multiple calls to be displayed simultaneously. Time (msec) is on the x axis, and frequency (kHz) in on the y axis.

located or the presence of a target species can be determined. Numerous areas can be surveyed for short periods of time to generate a representative picture of species present at a site, and later analysis can establish a sampling priority for these sites. Thus, effort can be focused on areas with increased likelihood of locating target species. For example, in the southern United States, active monitoring was used to survey 40 kilometers of roadways in a single night for the federally endangered Indiana myotis (*Myotis sodalis*). One site was identified and subsequent mist netting led to location of the second (and largest-known) Indiana myotis maternity colony in Tennessee (Harvey 2002).

Additional Sampling

Ultrasonic detectors are commonly used in conjunction with traditional capture techniques. Active monitoring can also be used to sample when the researcher is not monitoring mist nets. In areas where the majority of the species use high intensity echolocation calls, simultaneous sampling with the Anabat system detected the presence of more species than mist nets (Murray et al. 1999; O'Farrell and Gannon 1999). However, in both of these studies, the most complete picture of the bat community was uncovered when ultrasonic detectors are used in conjunction with mist nets. Using a variety of methods maximizes the probability of detecting all species in an area.

Habitat Use

As bat populations decline throughout the world, understanding habitat use is becoming increasingly important. While data from bat detectors cannot be used to determine the number of individuals present in the area, there are several methods for defining the amount of bat use in an area. The most common measure of bat activity is the number of files or passes (Fenton 1970; Hayes 1997; Krusic et al. 1996). Britzke et al. (1999) developed a measure that incorporates the length of the echolocation call into levels of bat activity. Miller (2001) described an activity index that quantifies activity by the number of time periods that a species is present. Bat activity should be used as a relative term for assessing bat use. In some areas, 30 passes may represent high activity, while in others 100 may represent a low activity level. No matter the technique used, the researcher must explicitly define the means by which bat activity is measured and discuss the implications of this definition on the results.

Two sampling methods have been employed to infer habitat use by bats. Different habitat types can be sampled actively as an observer moves along a transect (Mills et al. 1996; Zimmerman and Glanz 2000). To account for temporal variation in bat activity, each transect is sampled during different periods of the night. However, the majority of the studies designed to examine habitat use have employed passive monitoring (Humes et al. 1999; Kalcounis et al. 1999; Krusic et al. 1996; Seidman and Zabel 2001). In these studies, a detector is randomly placed in each habitat type being sampled, and activity is compared among habitat types to infer habitat use. Due to considerable among-night variation in activity, sampling should be done simultaneously to increase comparability (Hayes 1997).

While numerous studies have examined habitat use, there is no published literature about spatial variation within a habitat (Hayes 2000). If spatial variability is not constant among habitat types, the results of studies examining habitat use are of limited value. Variability would be expected to increase with structural complexity of habitats as complex habitats have isolated areas that are suitable for bat activity, while less complex habitats (i.e., open fields) have one large area suitable for bat activity. Future studies need to examine the relationship between structural complexity and spatial variation in bat activity. This information can be used to improve the design of studies exploring bat habitat use.

The type of sampling design depends on many factors. Frequency-division bat-detector systems are useful in both active- and passive-monitoring schemes. Additionally, call libraries have been developed for large areas using the Anabat system, thereby permitting acoustic identification. Overall, the flexibility of the Anabat system in sampling permits this system to be used in a large number of studies of bat activity and habitat use.

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DESIGNING BAT ACTIVITY SURVEYS USING TIME EXPANSION AND DIRECT SAMPLING OF ULTRASOUND

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We reviewed acoustic studies that use time-expansion methods to determine habitat use by bats in Europe. Species identification can be quantified by using discriminant function analysis or neural networks. These methods maximize the information recorded from echolocation calls and allow confident classification of calls to species. Because the recording equipment is expensive, surveys typically involve one recording device and mobile sampling along transects. We walk transects for a fixed time period, starting at a fixed time after sunset. Bats are detected by listening on frequency-division mode, and calls are time-expanded upon detection. Our methods involve sampling replicates of each habitat and visiting habitats in random order over the summer. We estimate foraging success by calculating the ratio of feeding buzzes to passes. We illustrate our methods by describing habitat surveys in Britain and southern Italy. The broad bat community in Italy presents considerable challenges for acoustic identification, but nevertheless we achieved a high rate of correct classification of calls to species. More recently, we have used paired sampling of organic versus conventional farms, together with direct sampling of ultrasound, to determine whether intensive farm management has a detrimental effect on bat activity. Direct sampling overcomes the wasted download time inherent in time expansion, and allows acquisition of extended high-quality recordings.

Key words: acoustic identification, bat activity, bat detectors, habitat use, ultrasound
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