Variation in bat detections due to detector orientation in a forest

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Abstract Bat detectors are widely used to compare bat activity among habitats. We placed 8 Anabat II detectors at 2 heights, 3 directions, and 2 angles with respect to horizontal to evaluate the effect of detector orientation on the number of bat detections received. The orientation receiving the maximum number of detections had 70% more detections than the mean of the 7 other orientations on the same night. We found that detectors on 1.4-m stands received 30% more detections than detectors placed directly on the ground. Detectors oriented toward the direction with the fewest trees received 24–44% more bat detections than those oriented in 2 other directions. We hypothesize that many of the noises we could not positively identify as bats were actually poorly recorded bat calls. Listening to audiotapes may be more efficient than visual inspection of time-frequency displays for comparison of bat activity among habitats when species identification is not important. Studies that standardize methods among sites and maximize the number of bat detections received at a site via detector placement will be most effective.

Key words Anabat, bat activity, bat detector, echolocation, habitat use, monitoring

Field study of bats has advanced markedly due to the commercial availability of bat detectors (Ahlen and Baagoe 1999, Fenton 2000, Hayes 2000). However, with the promise of greater insights into bat biology, bat detectors have been used in the field without a thorough understanding of their limitations or standardized protocols (Hayes 2000). Recent research has begun to evaluate the equipment and methods necessary to obtain reliable information from bat detectors (Fenton 2000, Hayes 2000, Larson and Hayes 2000).

Due to its relatively low cost and reputation for ease of use, the Anabat II bat detection system (Titley Electronics, Ballina, New South Wales, Australia) is widely used to monitor bat echolocations. Anabat II detectors have been used to compare relative amounts of bat activity among habitats (Everette et al. 2001), forest types (Krusic et al. 1996, Law et al. 1998, Jung et al. 1999, Kalcounis et al. 1999), timber prescriptions (Erickson and West 1996, Humes et al. 1999), heights in the canopy (Hecker and Brigham 1999, Kalcounis et al. 1999, Hayes and Gruver 2000), and stream sizes (Seidman and Zabel 2001). Recently the ability of Anabat II to discriminate among different species of bats has been challenged (Barclay 1999, Fenton 2000). Despite these concerns, Anabat II remains a valuable tool for comparing relative amounts of bat activity among habitats (Fenton 2000).

Previous comparisons among habitats usually have been accomplished by deploying detectors remotely within the habitat to be sampled (Krusic et al. 1996, Humes et al. 1999, Jung et al. 1999, Seidman and Zabel 2001). The operator coupled the bat detector to a delay unit and cassette tape recorder, positioned the unit in the field, and returned the following day to retrieve the data collected. The implicit assumption in each of these studies was

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that the area sampled by the detector was representative of the habitat (Hayes 2000). However, our field experience using hand-held Anabat II detectors indicated that slight differences in the spatial orientation of the detector resulted in large differences in the number and duration of bat detections received. Laboratory studies also have documented that receptivity of bat detectors was directional in both the vertical and horizontal planes (Waters and Walsh 1994, Larson and Hayes 2000). Other studies have called attention to spatial variation in bat activity, particularly as it applies to different heights in the canopy, but those differences were attributed to ecological rather than methodological differences (Hecker and Brigham 1999, Kalcounis et al. 1999, Hayes and Gruver 2000). We assumed that smaller differences in orientation would affect the number of detections received by remotely deployed detectors, but we wanted to quantify the magnitude of this variation.

Larson and Hayes (2000) recommended orienting bat detectors toward probable flight paths because laboratory tests showed the Anabat II's field of detection was longer than it was wide. In the field, this translates to orienting detectors away from structural clutter created by vegetation (Oliveira 1998). Law et al. (1998) found no difference in the number of detections between detectors oriented parallel with and those oriented perpendicular to roads; however, detection quality was better for detectors oriented parallel to roads. We wanted to determine whether the orientation of detectors would substantially influence the number of bat detections received within forests.

Most studies that compared bat activity among habitats placed detectors either on the ground (Law et al. 1998, Seidman and Zabel 2001) or $\leq$2m from the ground (Krusic et al. 1996, Grindal and Brigham 1999, Humes et al. 1999, Everette et al. 2001). For ground-level studies, we hypothesized that detectors elevated above the understory would receive more bat detections than those placed directly on the ground.

Field studies using Anabat II that reported the angle detectors were oriented with respect to horizontal most often used 30° (Erickson and West 1996, Hayes 1997, Humes et al. 1999, Seidman and Zabel 2001), based on the recommendation of Hayes and Hounihan (1994). However, 45° is commonly used (Law et al. 1998, Kalcounis et al. 1999, Everette et al. 2001). Studies that strictly followed the recommendations of Hayes and Hounihan (1994) or Oliveira (1998) used frames to standardize angles among detectors (Hayes and Adam 1996, Hayes 1997, Humes et al. 1999, Everette et al. 2001). However, most studies did not specify how this angle was standardized among detectors. We wanted to determine whether slight differences in detector angle would influence the number of bat detections received at a site.

When remotely recording bats in forested habitat, many calls are short fragments, not easily distinguished from background noises (Britzke et al. 1999). Many researchers have used Thomas' (1988) definition that a bat detection consists of $\geq$2 ultrasonic pulses (Krusic et al. 1996, Grindal and Brigham 1999, Jung et al. 1999, Seidman and Zabel 2001). This implies that the time-frequency display of each ultrasonic noise was evaluated. However, in some studies bat detections were identified by simply listening to audiotapes (Krusic et al. 1996, Grindal and Brigham 1999, Seidman and Zabel 2001). In studies that remotely recorded echolocations onto audiotapes and then viewed time-frequency displays, only 50–70% of calls were of sufficient quality to be categorized even into species groups (Hayes and Adam 1996, Oliveira 1998, Hayes and Gruver 2000). Accordingly, we expected that many of the bat detections we recorded would be of poor quality and difficult to distinguish from background noise.

We had 2 competing hypotheses regarding sounds that could not be easily identified as bats. We reasoned that the only significant source of ultrasonic sounds in a forest would come from bats. Therefore, we hypothesized that many of the noises we could not positively identify as bats were actually poorly recorded bat calls. If this were true, we expected that when we received a large number of bat detections, we would also receive a large number of sounds we could not positively identify as bats. However, sounds such as twigs breaking under the feet of vertebrates, stridulating insects, and drops of precipitation striking a surface also have ultrasonic components that trigger bat detectors, particularly at close range. These sounds are more prevalent near the ground, so our alternative hypothesis was that detectors on the ground would receive more non-bat ultrasonic sounds than detectors elevated above the ground.

Our main objective was to quantify variation in the number of detections due to orientation of bat detectors placed at the same site within a forest. This included evaluating the relationship between orientation and extraneous noises recorded. Our ultimate goal was to determine an orientation for bat detectors in future studies that would maximize the number of bat detections received. Secondarily, we evaluated the accuracy and efficiency of identifying bat detections directly from audiotapes versus visual evaluation of time-frequency displays.

Study area

Our study area was a 10-ha old-growth redwood (*Sequoia sempervirens*) stand in Van Duzen County Park, Humboldt County, California. The stand was adjacent to the Van Duzen River on a flat river terrace. Vegetation in the stand consisted almost entirely of redwood trees and swordfern (*Polystichum munitum*). Redwoods formed a tall (≥80m) closed canopy and were predominantly large trees with few low branches (≤20m). Midstory, or shrub layer, was effectively absent at this site. However, swordfern created structural clutter similar to a low shrub, with some fronds reaching 1.1 m in height. Therefore, the only structural clutter that would affect reception of echolocations by bat detectors consisted of the boles of redwood trees and ferns. The amount of clutter in the stand was likely less than in other forest types (Humes et al. 1999, Jung et al. 1999).

The following bat species occur in redwood forests of northwestern California: *Corynorhinus townsendii, Eptesicus fuscus, Lasionycteris noctivagans, Lasiurus cinereus, Myotis californicus, M. evotis, M. volans, M. lucifugus, M. thysanodes, M. yumanensis,* and *Tadarida brasiliensis* (Zielinski and Gellman 1998; M. J. Mazurek, United States Forest Service, unpublished data; D. M. Purdy, Humboldt State University, personal communication).

Methods

Prior to sampling, we calibrated bat detectors relative to one another using a SONIN 60 PRO electronic distance-measuring tool (SONIN, Scarsdale, N.Y.) to emit an ultrasonic pulse at 40 kHz (Larson and Hayes 2000). We decided *a priori* that detectors should be set to a sensitivity of approximately 7.0. We set the sensitivity of the first detector to 7.0 and moved away from the signal to the farthest point where the signal was detected clearly. We placed each of the other bat detectors at this point and adjusted their sensitivities to match the audio output of the first detector. One detector was set to a sensitivity of 6.7, another was set to 7.2, and the remaining 6 were set to 7.0. All detectors were purchased at the same time, so we did not expect large differences in sensitivities (Larson and Hayes 2000).

Each bat detection system consisted of an Anabat II bat detector with an Anabat Delay Switch coupled to a voice-activated tape recorder (Radio Shack Optimus CTR-115; Tandy, Fort Worth, Tex.). Delay units contained an electronic clock that placed an audio time stamp on the tape after each ultrasonic noise. We synchronized the clocks on the 8 delay units prior to deployment in the field. Hereafter, we refer to the entire bat detection system as a bat detector. We built wooden frames to standardize the angle of the detector with respect to horizontal. We also built stands from SCH 80 PVC pipe, which elevated the frames 1.4 m off the ground. We selected this height so that detectors would be above most shrub-layer vegetation in redwood and nearby Douglas-fir (*Pseudotsuga menziesii*) forests.

We subjectively selected 7 sites within the stand to control for effects that may have been specific to a single site. We selected sites with relatively little structural clutter created by trees or downed woody debris (Erickson and West 1996, Grindal and Brigham 1999). We placed 8 bat detectors at each site (Figure 1). First, we subjectively determined

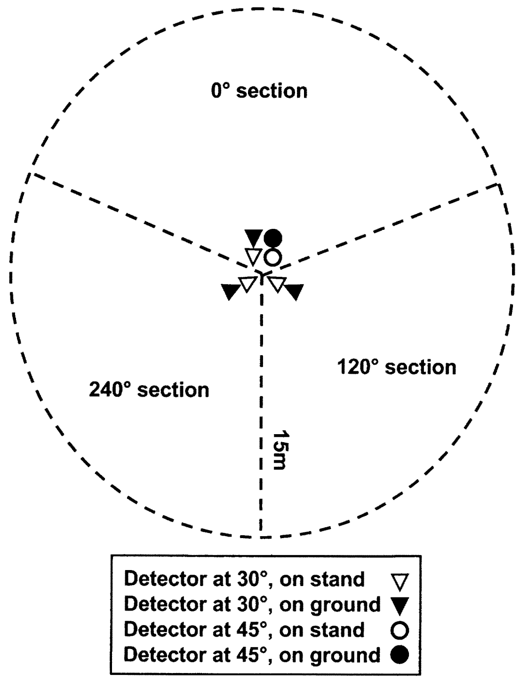

Figure 1. Schematic of bat detector placement at 7 sites within an old-growth redwood (*Sequoia sempervirens*) stand in Van Duzen County Park, Humboldt County, California, 1999–2000. The direction with the least structural clutter was considered 0° at each site, and 120° and 240° were established with respect to 0°. Sampling of the structural clutter created by vegetation was conducted within the 120° sections bisected by the direction in which detectors were oriented.

the direction with the least clutter at each site and called this direction 0°. Next, we established 2 other directions at 120° intervals. We placed 2 bat detectors facing each of the 3 directions (0°, 120°, 240°), 1 on the ground and 1 on a stand. All 6 of these detectors were oriented at an angle of 30° with respect to horizontal. We placed detector stands as close together as possible and the detector on the ground 0.3 m in front of the stand. To assess the effects of placing detectors at different angles with respect to horizontal, we oriented 2 additional detectors toward 0°. Both of these detectors were set at an angle of 45° with respect to horizontal, 1 on the ground and 1 on a stand. The entire array of 8 detectors and their stands was contained within a 3 × 2-m area.

Sites were sampled from 1–5 times each for a total of 16 sample nights. We sampled 12 nights between 6–30 September 1999, 2 on 23–24 May 2000, and 2 on 31 October–1 November 2000. In addition to calibration of detectors, we randomly assigned individual detectors to 1 of the 8 orientations each night to control for variation among individual detectors.

We sampled vegetation structure in a circular plot, with a 15-m radius, centered on the array of detectors. The circle was divided into 3 120° sections that were bisected by the direction detectors were facing (Figure 1). We measured the diameter at breast height (dbh) of all trees >5 cm dbh and calculated basal area for each of the sections. We used the mean of 2 visual estimates of percent fern cover and measured the distance from the detector to the first fern frond as indices of the understory clutter confronting detectors in each section.

Tape transcription

Using audio output alone and based on previous experience, we subjectively categorized each noise on the tapes as a bat detection or an extraneous noise. Noises separated by a calibration tone from the Anabat delay were counted as separate noises. All tapes were analyzed by 1 observer (TW) to prevent observer variability (Weller et al. 1998).

For the first 12 nights of the study, tapes were also played through the Anabat zero-crossing analysis interface module (Titley Electronics) so that a time-frequency display of each noise could be viewed on a computer screen. We made a preliminary visual assessment of whether noises were bat detections as the tape was playing. Noises were considered obvious bat detections when time-frequency displays showed a series of high-frequency (>20 kHz) pulses with a consistent interpulse time (Figure 2A). For noises that were not obvious bat detections, we saved the file and evaluated it more carefully using Analook software (Version 4.8n, Titley Electronics). Bat detections consist of a series of bat calls. Any file that showed ≥1 complete bat call was counted as a bat detection. A complete bat call had an uninterrupted sweep from high to low frequency on the time-frequency display (Figure 2B). Most files did not contain uninterrupted sweeps but instead displayed a series of high-frequency fragments. Categorization of such files was more subjective because bat detections could not be identified based solely on the presence of individual bat calls. Therefore, we used a combination of high-frequency fragments with relatively consistent interpulse times (Figure 2C) to identify bat detections. If a noise could not be identified as a bat detection via examination of its time-frequency display, it was recorded as an extraneous noise.

When evaluation of the time-frequency display disagreed with identification of bat detections based on audio output alone, we used the former in our analyses of differences among orientations. However, because of high concurrence between the 2 methods (see Results) and because the audio method was much quicker, the tapes for the final 4 nights were analyzed using audio output alone.

We were able to ascertain whether something identified as extraneous noise at one orientation was identified as a bat detection at another orientation because we deployed 8 detectors at each site with synchronized clocks. For each extraneous noise identified at a particular orientation, we reviewed data from the remaining orientations to determine whether they had received a bat detection at the same time. If so, we assumed that the extraneous noise was actually a poor recording of a bat detection.

Data analysis

We used mixed-effects models to examine differences among sections for vegetation variables and among orientations for detections and extraneous noises. We compared variance structures of models using likelihood ratio chi-square values. In each case, we selected models that did not assume equal variances among treatments. For analysis of vegetation variables, we assigned 120° sections as fixed effects and site was a random effect. We used Tukey-Kramer adjustments to compare among

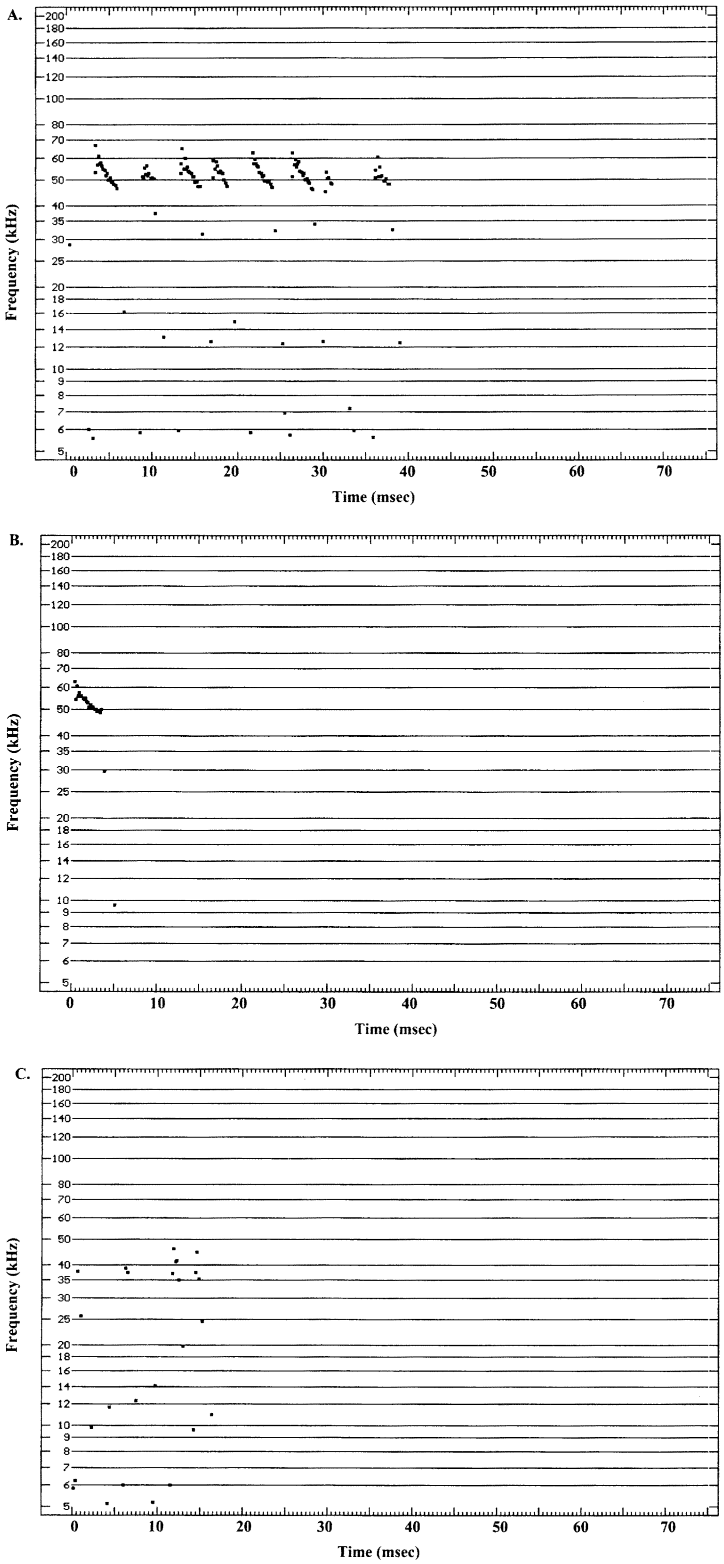

Figure 2. Examples of noises identified as bat detections using Analook software. The time between noises has been compressed: A: bat detection consisting of several obvious bat calls; B: bat detection consisting of one well-defined bat call; C: bat detection based on the presence of high-frequency call fragments and relatively constant interval between fragments.

sections. We analyzed variation in detections and extraneous noises by assigning each of the 8 orientations as fixed effects in the model and using planned comparisons to investigate differences among heights, directions, and angles with respect to horizontal. Random effects were the detector assigned to each orientation and sample night. Means and standard errors presented in the results were calculated by the least square means option of PROC MIXED in SAS Release 8.1 (SAS Institute, Cary, N.C.).

Results

We found significant differences among sections in the number of trees and percent fern cover (Table 1). Numerically, 0° sections had the lowest mean number of trees and the fewest trees at 5 of 7 sites. They also had the lowest mean basal area and the lowest basal area at 4 of 7 sites. Percent fern cover was greatest in 0° sections at all 7 sites, and the mean of 0° sections was greater than the cover at 120° ($t_{9.9} = 8.66$, $P < 0.0001$) and 240° ($t_{10.7} = 3.66$, $P = 0.012$).

There was great variation in the number of bat detections among detectors at 8 different orientations at the same site (Figure 3). On 4 nights, a detector at one of the orientations (120° on stand, 240° on stand, and twice at 240° on ground) did not receive any bat detections. The mean number of bat passes detected at the remainder of the orientations on those 4 nights ranged from 1.6-5.5. On the remaining 12 nights, the orientation that received the maximum number of detections had 1.7 (range = 1.4-2.4) times more detections than the mean of the 7 other orientations and 7.7 (range = 1.8-43) times more than the orientation with the fewest detections.

Number of detections varied among orientations ($F_{8,\ 18} = 9.04$, $P < 0.0001$, Figure 4). Factors contributing to differences in numbers of detections were height, direction, and angle with

Table 1. Structural clutter created by vegetation measured in 120° sections in 15-m radius plots. Each section was bisected by the angle that bat detectors were oriented. Sampling occurred at 7 sites in an old-growth redwood stand in Van Duzen County Park, Humboldt County, California, 1999–2000.

	0°		120°		240°			
Variable	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	F	P
Number of trees	3.0	0.2	4.6	0.8	6.3	1.2	5.21	0.034
Basal area (m^2/ha)	155.2	72.6	244.8	85.6	353.7	88.7	2.29	0.168
Fern cover (%)	73.2	6.1	11.3	3.7	33.6	8.9	37.71	<0.0001
Distance to first fern (m)	1.6	0.4	2.8	0.8	1.3	0.4	2.56	0.157

respect to horizontal. Detectors on stands received more detections ($\bar{x}$= 17.2, SE=3.1) than those on the ground ($\bar{x}$=13.2, SE=3.0, $t_{56.5}$=3.32, P=0.002). There were also differences among the directions that detectors were oriented ($F_{4,\ 24.4}$=3.13, P= 0.033). Those oriented toward 0° received significantly more detections ($\bar{x}$=16.7, SE=3.2) than those oriented toward 240° ($\bar{x}$=11.6, SE=3.0, $t_{32.7}$=3.51, P =0.001) and numerically more than those at 120° ($\bar{x}$ =13.5, SE=3.4, $t_{36.9}$=1.49, P=0.146). Detectors on the ground and at 45° with respect to horizontal received more detections ($\bar{x}$= 17.3, SE = 3.1) than those at 30° ($\bar{x}$=13.6, SE= 3.2, $t_{20.5}$=2.25, P=0.036). However, there was no difference in number of detections ($t_{19.3}$=0.35, P= 0.730) between detectors at 45° ($\bar{x}$=20.7, SE=3.4) and detectors at 30° ($\bar{x}$= 19.7, SE=3.6) when detectors were on stands.

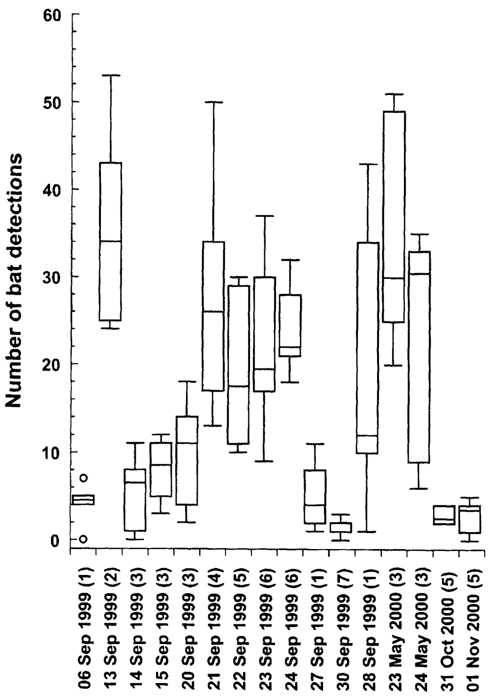

Figure 3. Box and whisker plot of the nightly variation in number of bat detections received by 8 bat detectors oriented in different directions at the same site. Seven sites, in parentheses after dates, were sampled within a stand in Van Duzen County Park, Humboldt County, California, 1999–2000. The box indicates the median, 25%, and 75% quartiles. Whiskers are the maximum and minimum values for the night. Outliers, represented as circles, were >1.5 times the interquartile range.

On 94% of the occasions, we identified the same noises as bat detections using audio output as we did using visual inspection of time-frequency displays. Whether audio or visual methods more accurately identified bat detections was unclear. We recorded 685 extraneous noises at 574 different times during 15 nights. We eliminated one sample night from this analysis due to early-morning drizzle, which caused ground-level detectors to record about 5 times as many extraneous noises as the corresponding detector on a stand. An extraneous noise at a particular orientation was identified as a bat detection at ≥1 of the other orientations on 56% of these occasions. Extraneous noises were correlated with the number of bat detections received by the detector on that night (r=0.49, n=112, P< 0.0001). Detectors on the ground did not receive more extraneous noises ($\bar{x}$=6.3, SE=1.1) than the corresponding detector on a stand ($\bar{x}$=5.9, SE=1.2, t_{65}=0.43, P=0.667).

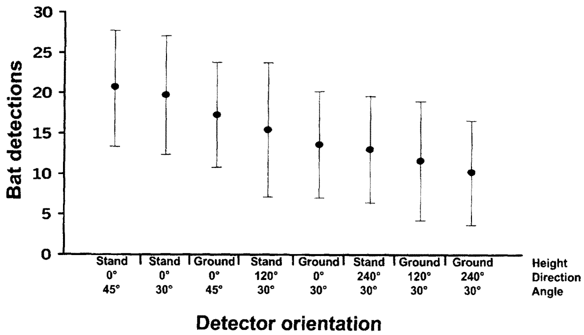

Figure 4. Mean number, in order of most to fewest with 95% confidence limits, of bat detections at each of 8 bat detector orientations recorded at 7 sites within an old-growth redwood stand in Van Duzen County Park, Humboldt County, California, 1999–2000. Detector orientation varied according to height (on a 1.4-m stand or on the ground); direction (where the direction with the least structural clutter was considered 0° at each site and 120° and 240° were established with respect to 0°); and angle (with respect to horizontal).

Discussion

The goal of studies comparing habitats by remotely sampling bats is to acquire a reliable index to their activity at a site. Bat detectors sample only a limited airspace, but the assumption is that this sample can be used to make inferences about the surrounding habitat (Hayes 2000). Variance due to differences in methods must be minimized to maintain validity of the index. Our results emphasize the importance of standardizing orientations of bat detectors among treatments. Indeed, the differences in number of detections we found among detector orientations at one site were comparable to differences among treatments in other studies (Erickson and West 1996, Brown et al. 1997, Humes et al. 1999).

The consequences of orienting bat detectors in directions that do not maximize the number of bat detections received can be serious. For instance, on the 4 nights where one of the orientations did not receive a bat detection, we would not have been able to detect presence of bats at a site where they were present. Therefore, it is critical to select an orientation so that each detector maximizes the number of bat detections it receives.

Our results suggest several practical measures that can help maximize number of bat detections received when remotely sampling bats at ground level. Elevating detectors provided the greatest improvement in numbers of bat detections received. We attribute this to detectors having a larger detection area and being closer to heights where bats were echolocating. Also, detectors were above understory vegetation that created obstructions between the bat and the detector microphone. Therefore, studies of "ground-level" bat activity in forests should elevate detectors off the ground so they are above the understory. Moreover, elevating detectors above the understory can minimize consideration of angle with respect to horizontal.

We also found that the direction detectors were oriented at a site was an important consideration. We detected more bats when detectors were oriented toward the area with the fewest number of trees. This supports previous recommendations to orient detectors toward the least cluttered area (Oliveira 1998, Larson and Hayes 2000, but see Law et al. 1998). Systematically changing the direction in which detectors were oriented has been used to prevent directional bias but required an operator to be present (Everette et al. 2001).

The orientation angle with respect to horizontal was an important consideration only when detectors were on the ground. Based on laboratory studies, a difference of 15° between ultrasonic sounds and bat detector microphones considerably reduced the distance at which sound was detected (Larson and Hayes 2000). We attribute the higher number of detections at 45° to larger volumes of airspace, potentially used by bats, sampled in comparison to detectors oriented at 30°. Additionally, detectors on the ground oriented at 30° faced more obstructions from ferns than those oriented at 45°. Our subjective determination of the direction presenting the least clutter for bat flight (0°) was most influenced by the number of trees. This bias is probably warranted for determining flight areas of bats within an old-growth redwood forest. However, 0° also had the most fern coverage, so the effect of angle with respect to horizontal for detectors on the ground may have been exaggerated.

Many studies have reported the angle of bat detectors with respect to horizontal, but few have specified the means by which this angle was maintained. Our results, in conjunction with those of Larson and Hayes (2000), indicated that standardization of this angle was important to acquire comparable results among treatments. Using a log or rock to prop the detector is probably an inadequate method to standardize angles among treatments. Our study illustrates the importance of using frames to standardize the angle at which detectors are oriented (Hayes and Hounihan 1994, Oliveira 1998, Humes et al. 1999).

Several studies have oriented bat detectors upward (90°) to sample bats in forests (Burford and Lacki 1995, Brown et al. 1997, Grindal and Brigham 1999). This obviates the need to orient detectors in any direction in the horizontal plane. It is likely that orienting detectors upward would adequately sample bats, provided detectors were also elevated above the understory. We considered orienting detectors upward for comparison to other angles from horizontal. However, orienting detectors upward was not practical for this study because of the potential for microphone damage due to condensation from fog. For this reason, we would not recommend orienting detectors upward where fog or rain may collect on the microphone.

Although we conducted our experiment in a single forest stand, our results are likely applicable to other stands and forest types. Structural clutter affects both the area where bats fly and the receptivity of echolocations by bat detectors and is therefore an important consideration. The differences among detector orientations that we documented may vary according to the amount of structural clutter in other habitats, but elevating detectors above understory and orienting them toward open areas where bats are likely to fly would generally be beneficial. Also, while Anabat II detectors lack sensitivity compared with other systems (Fenton 2000), our results should be applicable to other bat detection systems.

Standardizing and elevating detectors does not come without costs. Time and funds must be budgeted for stand construction. The detector system we used had a mass of 6.2 kg, including detection equipment, 12 V battery, and carrying case. The stands we built were rigid enough to support the detector system, endured >4 months of use in the field, and survived occasional attacks by black bears (*Ursus americanus*). The tradeoff was that the stand had a mass of 5.2 kg. Thus, the logistics of deploying detectors and stands in the field were not trivial.

Orientations that received more bat detections also received more noises that could not be identified as bats, and detectors on stands received more detections than those on the ground. However, the number of extraneous noises received by detectors on the ground was indistinguishable from the number received by those on stands; this indicated that most extraneous noises probably were not caused by ultrasonic components of ground-level noises such as precipitation or breaking twigs. In combination, these findings support our hypothesis that many noises classified as extraneous were actually poorly recorded bat echolocations.

Listening to tapes to identify bat detections required a comparable amount of subjectivity to visually evaluating time-frequency displays. It was easy to identify noises that were obvious bat detections using either audio or visual techniques. Conversely, bat detections consisting of a few poorly defined calls were difficult to identify using either technique. This indicated that call quality is important for assessing presence of bats as well as identifying species (Law et al. 1998, O'Farrell et al. 1999). We cannot objectively assess the accuracy of either method because we did not know which noises were actually bats. However, neither method was perceptively more accurate than the other. Time may be saved in future studies by identifying bat detections from audiotapes because the human brain is capable of quickly processing subtle differences in sound (Ahlen and Baagoe 1999). As long as the noises are classified consistently and scientific rigor is maintained, the validity of the index will be retained.

In conclusion, we emphasize the need for standardization in bat detector studies. We specifically recommend elevating detectors above understory vegetation and orienting detectors toward the direction with the fewest obstructions. When an index to bat activity without regard to species identification is the goal, detections can be efficiently quantified by trained personnel listening to audiotapes.

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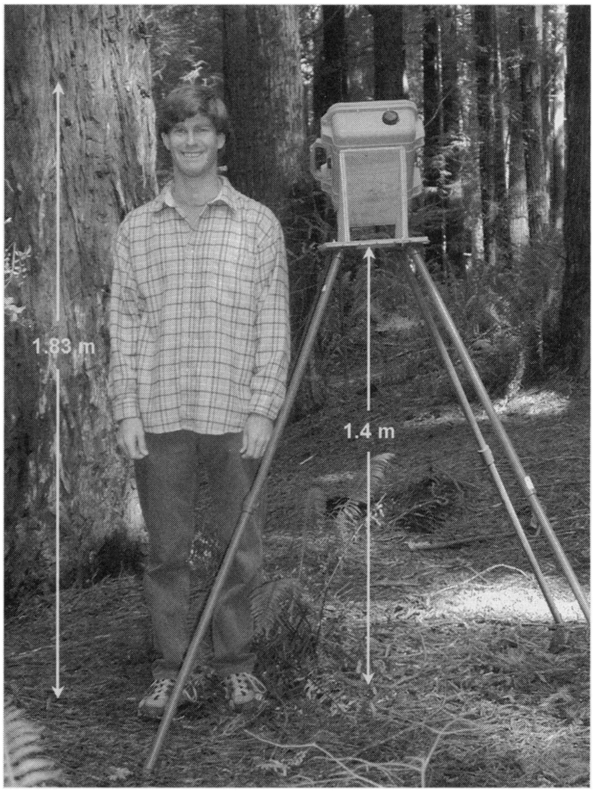

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