Journal of Mammalogy, 88(2):526–533, 2007

COMPARISON OF SAMPLING METHODS FOR INVENTORY OF BAT COMMUNITIES

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From 1999 to 2005, we sampled the bat fauna of Catalonia (northeastern Spain, Mediterranean region) using 3 methods (bat detectors, mist nets, and roost surveys) and determined the total number of bat species present ($S = 22$). Twelve bat species and 5 acoustic groups ($\geq$5 different species) were identified using bat detectors, 17 species were found during roost inspections, and 13 species were trapped using mist nets. However, mist nets yielded the highest species richness per number of individuals sampled, as demonstrated by rarefaction. Some species were always either over- or undersampled according to the sampling method used. We also evaluated 3 guilds of bats defined by summer roost preferences, documenting a significant correlation between guild and detection method; cavity-roosting bats were underrepresented when only bat detectors and mist-net surveys were used, whereas rock crevices or man-made structure and tree guilds were underrepresented when only roosts were surveyed. Different techniques should be used to assess the richness of bat communities and we recommend combining all the methods described above in future bat surveys.

Key words: bat communities, bat detectors, Mediterranean region, mist nets, roosts, sampling methods, species richness, surveys

The order Chiroptera is the 2nd most diverse order of mammals (Wilson and Reeder 2005) and exhibits great numerical, taxonomical, functional, and ecological diversity (Simmons and Conway 2003; Stevens and Willig 2002). However, assessing the distribution of bat species and the composition of bat communities is a challenge (Jaberg and Guisan 2001) because their nocturnal behavior, large home ranges, and the problems associated with species identification in flight (Walsh and Harris 1996) make accurate surveys difficult.

Studies of bat distribution and habitat preferences use different sampling techniques to describe the great complexity of bat communities. From the analysis of specimens housed in museum collections (López-González 2004) to the use of advanced technology (i.e., bat detectors—Vaughan et al. 1997), numerous different methods of sampling bats are currently in use, although today most researchers employ a combination of techniques (Duffy et al. 2000; Jaberg and Guisan 2001).

Bat detectors enable bats to be studied in greater detail and are now employed by most researchers in censuses of bat faunas (Barataud 1998; Ciechanowski 2002; Pauza and Pauziene 1998) and in the analysis of habitat use (Avila-Flores and Fenton 2005; Vaughan et al. 1997; Wickramasinghe et al. 2004). Despite their shortcomings (Hayes 2000), bat detectors frequently are used in annual monitoring programs (Walsh et al. 2001). However, scientists have become concerned with the validity of data derived from this method. Over the last decade a growing number of studies have examined the advantages and disadvantages of techniques using bat detectors (Ahlén and Baagoe 1999; Barclay 1999; Hayes 2000) and various authors have analyzed sampling methods for bats in a search for better bat survey strategies (Duffy et al. 2000; Murray et al. 1999; O'Farrell and Gannon 1999). Despite the fact that acoustic sampling methods seem to yield greater species richness than captures (Murray et al. 1999; O'Farrell and Gannon 1999), almost all authors agree that echolocation monitoring should be but one component of bat surveys and that a combination of techniques is required for more comprehensive inventories (Barclay 1999; O'Farrell and Gannon 1999).

Mist nets have several drawbacks: they are time-consuming to set up, need to be placed in flyways or water sources with good canopy coverage over the net, cause stress in animals, and, moreover, obtain biased samples of bat species assemblages (Murray et al. 1999). Harp traps are less stressful; however, the species sampled varies with body size, flight patterns, and type of echolocation (Duffy et al. 2000). On the other hand, bat detectors cause no stress to bats, although the data they

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produce also are biased, because high-flying bats and those that emit low-intensity calls are underrepresented (Barclay 1999; Duffy et al. 2000).

Other techniques should be considered in bat survey studies. Finding roosts in man-made structures or in caves and mines represents a useful survey method; several bat species can be inventoried in roosts or when they leave roosts at sunset (Mitchell-Jones and McLeish 1999; Tuttle et al. 2000). Another technique that should be considered is bat-box surveys. These artificial roost sites should not be viewed merely as alternative roosts sites (Brittingham and Williams 2000; Flaquer et al. 2006; Lourenço and Palmeirim 2004) and are useful for providing data on bat communities, especially in areas with a lack of old trees bearing natural roosting sites (Flaquer et al. 2007). Bat boxes may be particularly effective for surveying bats in woodland habitats; for example, at least 73% of British bats are known to have roosted in boxes (Mitchell-Jones and McLeish 1999; Stebbings and Walsh 1991).

Because of their peculiar climatic and ecological features, Mediterranean countries differ remarkably from the areas of Europe where most data on habitat use by bats have been gathered. Yet, little is known about habitat preference in bats in the Mediterranean Region (Russo and Jones 2003). From 1999 to 2005, we studied the bat fauna in and around 10 natural areas distributed along the Catalan Mediterranean coastline in northeastern Spain. Captures of bats with mist nets and roost surveillance were combined with the use of ultrasonic detectors. We discuss the advantages and disadvantages of each method and compare the efficiency of each technique for assessing species richness of bats. Additionally, we provide recommendations for future monitoring and survey strategies in this region.

Materials and Methods

Study area.—The Catalan coast is located in the northeastern Iberian Peninsula (40°42′N, 0°50′E) and comprises 580 km of coastline and littoral and prelittoral mountain ranges covering 31,000 km^2 and ranging from sea level to 1,700 m in elevation. The predominant climate is Mediterranean (annual mean temperatures around 15°C and annual precipitation between 500 and 700 mm/year). Climate varies with topography, although summers generally are dry and hot (precipitation $<$ 200 mm/year and mean temperatures around 20°C), whereas spring and autumn are wet. Vegetative communities are dominated by *Quercetum ilicis galloprovinciale* and *Quercus mediterraneo montanum*, although scattered beech (*Fagus sylvatica*) forest could be found in the coldest areas.

Identification of bats.—Bats were identified in the field based on morphological and dental criteria in live bats (Arthur and Lemaire 1999; De Paz and Benzal 1990; Helversen 1989; Menu and Popelard 1987; Palmeirim 1990; Schober and Grimmberger 1996). Additionally, we used ultrasonic bat detectors (models D230 and D240x; Pettersson Elektronics AB, Uppsala, Sweden) with frequency division, heterodyne, and time expansion ($\times$10) systems, as well as a portable digital tape (SONY TCD-D8; Sony Corporation, Tokyo, Japan) and a laptop computer to record echolocation and social calls (Ahlén 1990; Barataud 1996; Russ 1999). Sounds were analyzed by Bat Sound (Pettersson Elektronics AB). We used a sample frequency of 44,100 samples/s, 16 bits/sample, and automatic fast Fourier transform (a mathematical formula for calculating frequency data from time data) with a Hanning window (Russ 1999). Recordings were screened for the presence of the characteristic social calls emitted during the mating period (Russ 1999; Russo and Jones 1999) and calls were identified by means of a library of known echolocation call sequences for each species. Identification of the soprano pipistrelle (*Pipistrellus pygmaeus*) and Schreibers's bat (*Miniopterus schreibersii*) were based on presence of social calls, observations of wing-shape in good conditions, or both (Ahlén 1990). For the purposes of acoustic identification, we treated the following pairs of species as single "taxa": lesser/greater mouse-eared bats (*Myotis blythii*/*M. myotis*), Natterer's/Geoffroy's bats (*Myotis nattereri*/*M. emarginatus*), Daubenton's/long-fingered bats (*Myotis daubentonii*/*M. capaccinii*), noctule/greater noctule (*Nyctalus noctula*/*N. lasiopterus*), and brown/gray long-eared bats (*Plecotus auritus*/*P. austriacus*—Ahlén 1990; Ahlén and Baagoe 1999; Barataud 1996).

Bat survey techniques.—Between 1999 and 2005, we randomly used 3 different approaches for sampling bat species richness of bats (bat detectors, mist nets, and inspection of roosts), from April to November, in 10 natural areas located along the Catalan coast.

In all, we surveyed 418 independent bat detector stations at heights from sea level to 1,629 m above sea level ($\bar{X}$ = 359 m ± 417 *SD*). We used D240x and D230 bat detectors and activity was quantified by counting the number of passes per 10 min at each point (Wickramasinghe et al. 2003). The D230 detector was tuned to use frequency division, which provides for both broadband (records all frequencies) and continuous (records all bat passes) recording. We recorded the output from frequency division on channel 1 of the portable digital recorder and we used the time-expanded output from detector D240x to record bat calls from each pass on channel 2 of the portable recorder (Vaughan et al. 1997). According to Ahlén and Baagoe (1999), time-expansion sounds retain call structure and have high sound quality and so can be analyzed to identify species. Additionally, we used the heterodyne system from the detector D240x scanned up and down to cover all frequencies (Ahlén and Baagoe 1999).

We used standard techniques to mist net bats (O'Farrell and Gannon 1999). Net heights varied from 2.5 to 3 m and lengths varied from 3 to 18 m and were placed along or around waterways, ponds, and flyways. The amount of time employed and the number of nets used depended on the physical characteristics of each location (O'Farrell and Gannon 1999). In all, we established 68 independent stations with mist nets representing 3,561 m^2 of mist-net collecting surface operating for a total of 175.4 h. These stations were situated at elevations between 41 and 1,481 m above sea level ($\bar{X}$ = 643 ± 373 m). We operated mist nets for 173.8 ± 82.7 min (range 60–590 min) and had a mean length of 17.1 ± 8.1 m (range 3–35 m).

TABLE 1.—Frequencies of occurrence of the 22 bat species and number of species detected by 3 bat-sampling methods in a coastal Mediterranean area.

Species	Mist nets	Roost surveillance	Bat detectors
Rhinolophus ferrumequinum		7.76	0.1
R. hipposideros		3.46	0.05
R. euryale		7.29	0.12
Myotis myotis		2.46	0.61[a]
M. blythii	2.36	0.02	
M. nattereri		0.45	
M. emarginatus	0.79	11.43	
M. daubentonii	3.94	0.38	2.95[b]
M. capaccinii		0.01	
Pipistrellus pipistrellus	20.47	0.24	29.22
P. pygmaeus	14.17	13.56	40.79
P. nathusii		0.01	
P. kuhlii	3.15	0.19	4.68
Hypsugo savii	20.47		4.8
Nyctalus leisleri	7.09		1.15
N. noctula/N. lasiopterus			0.15
Eptesicus serotinus	6.3	0.69	4.36
Barbastella barbastellus	3.15		1.39
Plecotus austriacus	13.39	0.66	1.92[c]
P. auritus	3.15		
Miniopterus schreibersii	1.57	51.37	0.01
Tadarida teniotis			7.72
Number of species	13	17	17

[a] Species pairs with *M. blythii*.
[b] Species pairs with *M. capaccinii*.
[c] Species pairs with *P. auritus*.

We used standard techniques to find roosts (mines, caves, and man-made structures—Mitchell-Jones and McLeish 1999; Tuttle et al. 2000), and we applied guidelines established by Mitchell-Jones and McLeish (1999) to identify and count bats in roosts. The 271 roosts found and visited were situated at elevations from sea level to 1,300 m above sea level ($\bar{X}$ = 346 ± 312 m) and were visited 2.0 ± 3.1 times (range 1–28; total visits 541). Roosts sampled more than once were visited in different seasons or years (O'Farrell and Gannon 1999).

Statistical analysis.—We used 3 statistical approaches to identify and quantify possible sampling biases between the 3 different methodologies employed in the study. First, we used a log-linear analysis to search for differences between the 3 sampling methods in the species composition and abundance of bat communities (Torre et al. 2004). This technique allowed us to determine what species were under- or oversampled by each sampling method. The standardized residuals after the log-linear analysis were used to represent the degree of deviance from the null model (no under- or oversampling of a species by a sampling method), and the statistical significance was verified by examining the components of maximum likelihood comparing these values with the critical level of significance ($\chi^2 = 3.84$, $d.f. = 1$, $P < 0.05$). Second, we used the nonparametric Kruskal–Wallis test (Zar 1996) for comparing methods, because species richness and abundance did not have a normal distribution within the sampling methods and had a heterogeneity of variances. Because no post hoc tests are available for nonparametric tests, we conducted pairwise comparisons and used Bonferroni corrections to correct for significance level (Rice 1989); thus, our acceptable critical region was $P = 0.05/3 = 0.0166$.

Finally, given that the total number of individuals observed varied among methods, we used rarefaction to provide a meaningful interpretation of the different species richness found in each of the 3 sampling methods. Rarefaction takes into account species richness and abundance and allows comparisons between assemblages of equivalent numbers of individuals. We used Ecosim 7.0 software (N. J. Gotelli and G. L. Entsminger 2001, Ecosim: null models software for ecology, http://www.garyentsminger.com/ecosim/index.htm) to generate individual-based rarefaction curves of species richness and associated variance for each of the 3 sampling methods (Lambert et al. 2005; Torre et al. 2004). The computer-sampling algorithm of the program randomly draws a sample of specified size from the total sample and computes a mean and a variance for species richness after 1,000 iterations. The individual-based data sets were obtained after pooling replicated samples into single ones for each sampling method (Gotelli and Colwell 2001).

The statistical comparison of species richness by rarefaction curves and of the number of individuals depends on the correct assessment of the number of individuals captured, counted, detected, or a combination of these. Roost surveys and mist-netting both allow determination of the number of individuals counted or trapped for every species sampled, despite that the number of individuals sampled represent a fraction of the population. Bat detectors, on the other hand, count bat passes but cannot identify individuals. The number of passes detected likely is correlated to the number of individuals (Wickramasinghe et al. 2003), although there is no way of enumerating exactly the number of individuals present on the basis of passes counted because bat detector samples may count the same individual more than once. This will have a negative effect on estimates of species richness carried out by rarefaction (i.e., species richness will be underestimated).

All methods and procedures used in the present study followed the guidelines for the capture, handling, and care of mammals as approved by the American Society of Mammalogists (Animal Care and Use Committee 1998).

RESULTS

In all, the 3 sampling methods detected 22 species of bats in the study area and revealed qualitative and quantitative differences between bat communities according to the sampling method. Twelve bat species and 5 acoustic groups (≥5 different species) were identified using bat detectors, 17 species were found during roost inspections, and 13 species were trapped using mist nets (Table 1). Some species were identified by only 1 method (roost surveys: Nathusius's pipistrelle [*Pipistrellus nathusii*], *M. nattereri*, and *M. capaccinii*; mist nets: *Plecotus auritus*; bat detectors: European free-tailed bat [*Tadarida teniotis*]), although some of these species form part of acoustic pairs.

A log-linear analysis was performed with frequencies of occurrence for all the identified species (22) and for each sampling method, yielding highly significant differences (inter-

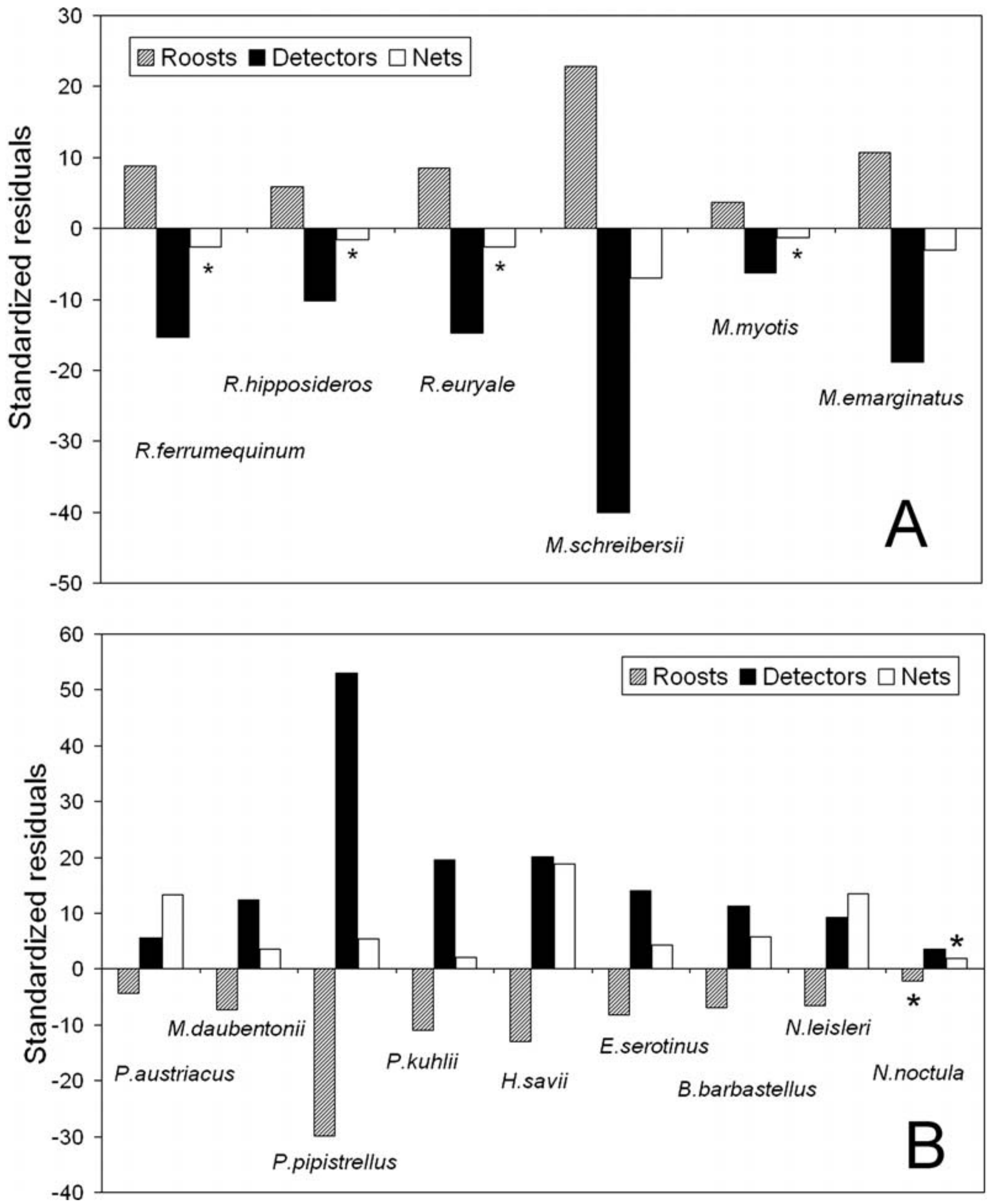

FIG. 1.—Standardized residuals after a log-linear analysis showing A) bat species oversampled by roost surveys and undersampled by bat detectors and mistnetting, and B) species undersampled by roost surveys and oversampled by bat detectors and mistnetting (interaction of species × method: $G = 12{,}842$, $d.f. = 42$, $P < 0.0001$). All species showed significant differences in frequencies of occurrence between methods. Positive residuals: oversampling of a species; negative residuals: undersampling of a species. Residuals marked with asterisk were not significantly different from zero. Some species are acoustic pairs in the case of bat detectors (see Table 1).

action of species × method: $G = 12{,}842$, $d.f. = 42$, $P < 0.0001$). All the species sampled except *M. capaccinii* and *P. nathusii* showed significant differences between the 3 sampling methods in their frequencies of occurrence. Members of the family Rhinolophidae and *M. myotis*, *M. nattereri*, *M. emarginatus*, and *M. schreibersii* were oversampled by roost inspections, but undersampled by bat detectors (Fig. 1A). On the other hand, *P. auritus*, *P. austriacus*, *M. daubentonii*, common pipistrelle (*P. pipistrellus*), Kuhl's pipistrelle (*P. kuhlii*), Savi's pipistrelle (*Hypsugo savii*), serotine (*Eptesicus serotinus*), western barbastelle (*Barbastella barbastellus*), and Leisler's noctule (*Nyctalus leisleri*) were oversampled by the use of bat detectors and mist nets, but undersampled by roost inspections (Fig. 1B). *P. pygmaeus* was oversampled by bat detectors and undersampled by roost inspections and nets, *T. teniotis* was oversampled by bat detectors and undersampled by roost inspections, and *M. blythii* was oversampled by net sampling. Some species, such as *P. pygmaeus* and *P. pipistrellus*, were detected mainly by bat detectors (40.8% and 13.6%, respectively), whereas others were most often detected by roost inspections, such as *M. schreibersii* and *R. ferrumequinum* (51.4% and 7.8%, respectively), or by mist

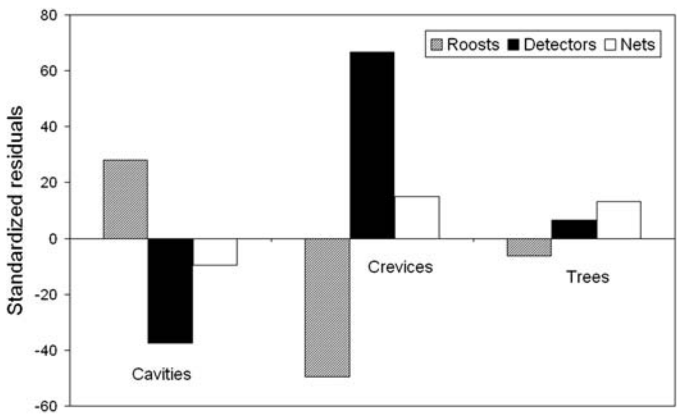

FIG. 2.—Standardized residuals after a log-linear analysis performed with the 3 guilds based on summer roost preferences and the 3 sampling methods (interaction of guild × method: $G = 9{,}679$, $d.f. = 4$, $P < 0.0001$). Positive residuals: oversampling of a guild; negative residuals: undersampling of a guild. All the residuals were significantly different from zero.

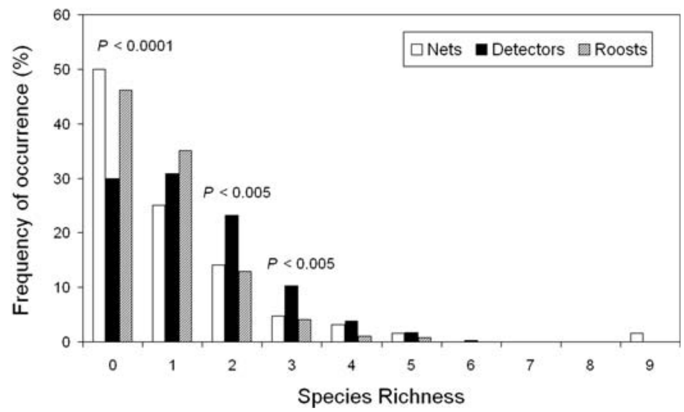

FIG. 3.—Frequencies of occurrence of stations with 0–9 species detected by all sampling methods. Statistical differences between methods for all categories were assessed by means of a log-linear analysis with sampling methods (3 categories) and number of species detected (9 species; interaction of species richness × method: $G = 47.45$, $d.f. = 18$, $P < 0.0001$). Significant differences between categories are shown by P-level.

netting, such as *H. savii* and *P. austriacus* (20.5% and 13.4%, respectively; Table 1).

A 2nd log-linear analysis was performed by grouping bat species into 3 guilds on the basis of their summer roost preferences: cavities (*Rhinolophus* sp., *M. myotis*, *M. blythii*, *M. nattereri*, *M. capaccinii*, *M. emarginatus*, *P. austriacus*, *P. auritus*, and *M. schreibersii*), trees (*Nyctalus*, *P. nathusii*, and *B. barbastellus*), and rock or man-made structure crevices (*P. pipistrellus*, *P. pygmaeus*, *M. daubentonii*, *P. kuhlii*, *H. savii*, *E. serotinus*, and *T. teniotis*). Once again, differences in frequencies of occurrence between sampling methods for the 3 guilds were highly significant (interaction of guild × method: $G = 9{,}679$, $d.f. = 4$, $P < 0.0001$) and were found for the 3 paired comparisons. As can be seen in Fig. 2, roost inspections oversampled cavity-dwelling species, but undersampled both the crevice- and tree-roosting guilds. Bat detectors oversampled the crevice-roosting guild and, to a lesser extent, the tree-roosting guild, whereas they undersampled the cavity-roosting guild. Finally, mist nets oversampled the crevice- and tree-roosting guilds, but undersampled the cavity-roosting guild. We observed a high degree of agreement in species occurrence frequencies for bat detectors and mistnetting and, in most cases, both methods over- or undersampled estimates for the same species.

A log-linear analysis performed using the frequencies of occurrence from stations with 0–9 species detected by all sampling methods yielded highly significant differences (interaction of species richness × method: $G = 47.45$, $d.f. = 18$, $P < 0.0001$). Mist nets and roost surveys showed a higher proportion of sampling stations with negative records (50% and 46% with no species recorded, respectively), whereas bat detectors showed a higher proportion of sampling stations with 2 and 3 species (23% and 10% of the total stations, respectively; Fig. 3). Frequencies of occurrence of 1, 4, 5, 6, and 9 species per station did not differ between sampling methods (Fig. 3).

The number of individuals sampled differed greatly between methods, with a total of 13,477 individuals counted in roost inspections, 6,031 bat passes (contacts) counted with bat detectors, and only 128 bats captured in mist nets. The mean number of species detected per station by bat detectors was 1.33 ± 1.22 (*SD*), with a range of 0–6 species. The mean number of contacts per station was 14 ± 25 (*SD*), with a range of 0–186. The mean number of species detected by roost surveys was 0.81 ± 0.96 (*SD*), with a range of 0–5 species. The mean number of bats per roost was 49.7 ± 320 (*SD*), with a range of 0–5,000. The mean number of species detected by mistnetting was 1.01 ± 1.54 (*SD*), with a range of 0–9 species. The mean number of bats captured per station was 2.0 ± 4.3 (*SD*), with a range of 0–30.

The species richness detected was significantly higher for bat detectors than for mist-net stations ($H = 8.24$, $d.f. = 1$, $P = 0.004$) or for roosts ($H = 33.55$, $d.f. = 1$, $P < 0.0001$), although no significant difference was detected between mist nets and roosts ($H = 0.01$, $d.f. = 1$, $P = 0.89$). The number of individuals or contacts per station was higher for bat detectors than for mist nets ($H = 43.96$, $d.f. = 1$, $P < 0.0001$) or for roosts ($H = 36.85$, $d.f. = 1$, $P < 0.0001$), although no significant difference was detected between mist nets and roosts ($H = 3.25$, $d.f. = 1$, $P = 0.07$). However, because species richness increases with the number of individuals recorded, we generated individual-based rarefaction curves to compare species richness between sampling methods for the same number of individuals. Mist nets had the highest richness per number of individuals sampled, followed by bat detectors and then roost surveys (Fig. 4).

DISCUSSION

The combination of sampling methods used in our Mediterranean study area during the 6 years of sampling detected 22 species of bats. This number agrees with the total number of bat species known to be present in the area (Flaquer et al. 2004; Palomo and Gisbert 2002; Serra-Cobo 1987) and represents

85% of species belonging to the very rich Iberian bat fauna (Palomo and Gisbert 2002). Overall, 77% of the species were detected by acoustic monitoring, 77% at roost sites, and 59% with mist nets. Our results confirm that combined survey techniques are required for thorough bat inventories (Barclay 1999; O'Farrell and Gannon 1999), as has been found for terrestrial small mammals in the same area (Torre et al. 2004).

Although the sampling effort was intense, the rarest species in the study area (*P. nathusii*, *M. nattereri*, *M. capaccinii*, *P. auritus*, and *N. noctula*/*N. lasiopterus*) were detected by only 1 method, a fact that indicates that rare species may be easily overlooked if only 1 inventory technique is used. On the other hand, common species such as *P. pygmaeus* were identified by all the methods used. As noted by O'Farrell and Gannon (1999) and Murray et al. (1999), the number of species detected by bat detectors was significantly higher than that detected by mist nets, whereas roost inspections yielded the same species richness as bat detectors. Nevertheless, mist nets and roost surveys had a higher proportion of sampling stations with negative records and in almost half of the stations our sampling efforts were fruitless; in these localities, detectors were a more efficient method.

Of all methods, mist nets detected the highest species richness per number of individuals sampled, probably because of biases related to the location of sampling stations near ponds or rivers, especially suitable habitats for bats in the Mediterranean region (Russo and Jones 2003). Species-rich sites were found in dry regions wherever nets were located near the isolated ponds or rivers and at 1 station we detected 9 different species on a single night, the highest number of species detected by any sampling method at a single station in this study.

According to our results, the most viable method for assessing species richness of cavity-roosting bats (especially *Rhinolophus*) is to find their roosts, a limitation that should be taken into account in studies where only mist nets and bat detectors are used. On the other hand, roost-finding techniques underrepresent crevice- and tree-roosting bats. We ruled out the use of climbing as a means of examining tree roosts (Ruczyński and Bogdanowicz 2005) because this method is highly time-consuming and requires specially trained researchers. Furthermore, the Catalan forests lack old trees bearing natural roosting sites as a consequence of forest management practices that emphasized timber extraction until the middle of the 20th century (Flaquer et al. 2007, and references therein). In light of the results from wetlands in the study area (Flaquer et al. 2005, 2006), it is likely that the lack of old trees in the study area with suitable roost sites will increase the importance of bat boxes (Flaquer et al. 2006; Ruczyński and Ruczyńska 2000).

Field surveys based on captures in mist nets and harp traps provide the opportunity to collect biological and morphological data that cannot be obtained with bat detectors (Duffy et al. 2000; O'Farrell and Gannon 1999). Furthermore, some species are easier to capture in mist nets than with other capture methods. We believe that annual bat-capture programs based on intensive small-scale trapping in mist nets and harp traps (Mitchell-Jones and McLeish 1999) would be a useful tool for sampling bat communities.

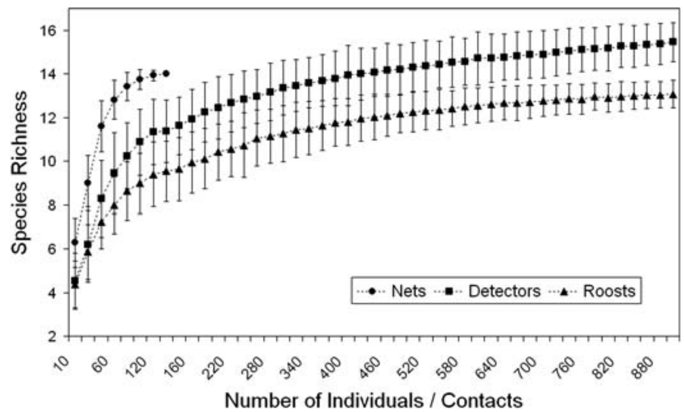

Fig. 4.—Rarefied species accumulation curves showing number of species (mean ± *SD*) versus number of individuals or contacts detected by each sampling method.

Although some European research has focused on analyzing changes in bat populations (Ransome and Hutson 1999; Walsh et al. 2001), little is known about bats in the Mediterranean region (Russo and Jones 2003). We documented that a combination of capture and bat detector techniques is effective (Duffy et al. 2000; O'Farrell and Gannon 1999), although cavity-roosting bats and some rare species often are underrepresented. Without roost-survey techniques we would have missed 3 of the 22 species encountered. Therefore, roost surveys are essential for assessing bat species richness in Mediterranean areas; finally, although not studied here and as an untested recommendation, we believe that the lack of old trees could make the use of bat boxes useful in bat surveys in this region. We recommend combining all the methods described above in future surveys and monitoring programs for Mediterranean bats.

Resumen

Entre los años 1999 y 2005, la fauna de quirópteros de Cataluña (NE España, región Mediterránea) fue inventariada usando 3 métodos de muestreo (detectores de ultrasonidos, redes de niebla y visitas a refugios) obteniendo información sobre las 22 especies de quirópteros presentes en la zona. Doce especies y 5 grupos acústicos (≥5 especies diferentes) fueron identificadas usando detectores de ultrasonidos, 17 especies fueron detectadas durante la inspección de refugios, y 13 especies fueron capturadas usando redes de niebla. No obstante, la rarefacción demostró que las redes de niebla tuvieron la mayor riqueza relativa al número de individuos capturados. Comparamos las frecuencias de aparición de las especies identificadas con los 3 métodos de muestreo y observamos que ciertas especies eran sobre muestreadas o infra muestreadas dependiendo del método de muestreo usado. También se agruparon las especies en 3 gremios definidos por la preferencias en el tipo de refugio utilizado durante el verano. Una correlación altamente significativa entre el gremio y el método de detección fue encontrada y los quirópteros de cavidades quedaron infra representados cuando solamente los detectores de ultrasonidos y

las redes de niebla fueron utilizadas. Por otro lado, los quirópteros que utilizan grietas en rocas o en infraestructuras humanas, y los que utilizan refugios en árbol, quedaron infra representados cuando solamente se inspeccionaron refugios. Creemos que para determinar la riqueza de las comunidades de quirópteros es necesario utilizar diversas técnicas y recomendamos la combinación de todos los métodos descritos arriba en futuros estudios sobre las comunidades de quirópteros.

Acknowledgments

Bats were caught with permits from the Catalan government's Ministry of the Environment and Housing (Ministeri del Medi Ambient i Habitatge) and in some cases were banded following the criteria established by the Spanish government's Ministry of the Environment (Ministerio de Medio Ambiente). The work was supported by the Generalitat de Catalunya, Diputació de Barcelona, and Consorci del Parc natural de Collserola. We also thank the Natural Park staff of the Àrea Protegida del Montgrí i les Illes Medes, Parc Natural dels Aiguamolls de l'Empordà, Parc Natural del Cap de Creus, Parc Natural del Delta de l'Ebre, Paratge Natural d'Interès Nacional de l'Albera and Parc Natural dels Ports, Parc Natural de Collserola, Parc del Foix, Parc Natural del Montnegre i el Corredor, Parc Natural de les Guilleries–Savassona, and Parc Natural del Montseny. Fieldwork would not have been possible without the support of R. Ruíz-Jarillo, X. Puig, A. Burgas, A. Ribas, F. Solà, R. Garcia, and D. Burgas. We also thank 2 anonymous reviewers for their useful comments on former versions of the manuscript.

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Submitted 4 May 2006. Accepted 4 September 2006.

Associate Editor was Douglas A. Kelt.