forests differ in some respects across the landscape, there are fundamental similarities in physical structure.

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Distribution of insectivorous bat species across four Costa Rican forest types

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Abstract: The global diversity of bats reflects their capacity for adaptive radiation and resource specialization. Half of all mammal species in Costa Rica are bats. This high diversity of bats may be due to high alpha diversity, temporal partitioning of resources or high species turnover between regions. We used an ultrasound detector and SonoBat call analysis software to sample for insectivorous bat species in forests within four regions of Costa Rica. With 8 hours of sampling, we detected 23 unique sonotypes (putative species) that likely represent about 50% of the insectivorous bats in Costa Rica and 25% of all bat species in Costa Rica. We also compared species composition at two times during the night at each site. Remarkably few species overlapped between sites (4 of 33) or times of night (3 of 21 at the two most diverse sites). Our success with SonoBat suggests that ultrasound analysis will be useful for further studies of neotropical bats.

Key Words: Chiroptera, forest type, Pettersson bat detector, resource partitioning, SonoBat

Introduction

Chiroptera is the most speciose order of mammals in the neotropics, with over 100 of these species living in Costa Rica. In comparison, the state of California contains less than 20 different species of bats. The distribution and abundance of bat species across the Costa Rican landscape has been shaped by their adaptive radiation into a variety of different resource niches. The high bat diversity in Costa Rica could be a product of high alpha diversity throughout the country, or it could include strong elements of beta and gamma diversity (increased species as new habitats and regions are added to the sample). Different regions of Costa Rica vary widely in elevation, prevailing winds, seasonality, plant distributions, and disturbance. This habitat diversity may permit the existence of many species that are restricted to particular habitats and/or bioregions.

Bat distribution and abundance have been traditionally difficult to study due to the limitations of mist-netting. Advances in the technologies of ultrasound detection of bat echolocation calls and computerized sonogram analysis now provide new tools for the sampling of bat communities. In this study, we recorded bat calls and used SonoBat software to explore the distribution of insectivorous bat species among four broad habitats (or bioregions) in Costa Rica: tropical dry forest, Pacific lowland tropical forest, Atlantic lowland tropical forest, and Pacific premontane forest. We collected calls at two times during the night to analyze the extent to which temporal resource partitioning contributes to bat diversity.

Methods

Using a Petterson D240X ultrasound detector, we collected search-phase bat calls at four sites in Costa Rica: Palo Verde (8 - 9 January), Corcovado (30 - 31 January), Las Cruces (7 - 8 February), and La Selva (10 - 11 February) (for sampling details, see "Temporal patterns in foraging activity of insectivorous bats on the Osa Peninsula, Costa Rica", Krivak-Tetley et al., in this volume). On each night, we sampled during two one-hour intervals, one early (between 18:00 and 19:50) and one late (between 21:00 and 23:00). At Palo Verde, we collected calls along the airstrip, approximately 300 m west of the research station. At Corcovado, we sampled on the airstrip immediately in front of the station.

TABLE 1. Number of calls of each bat sonotype (putative species) recorded during early and late sampling times at each site at each of four locations in Costa Rica.

Sonotype	Palo Verde		Corcovado		Las Cruces		La Selva		Original sonotype codes[a]
	Early	Late	Early	Late	Early	Late	Early	Late	
1	88	19	24	0	7	5	22	29	pvA, pvD, pvM, lcB, coE, lsB, pvB, pvC
2	0	16	0	5					pvE, coI
3	0	1	0	3					pvF, coJ
4	6	0							PvG
5	0	2							PvH
6	0	1							pvI, coG
7	1	0							PvJ
8	1	0							PvK
9	2	0							PvL
10	0	1							PvN
11			0	8					CoA
12			4	5					CoB
13			7	0			10	2	coD, lsG
14			1	0					CoF
15			2	1					CoH
16			1	0					CoK
17			2	0					CoL
18			0	1					CoO
19					12	9			lcA
20					0	1			lcC
21							4	4	lsA, lsE
22							3	18	LsD
23							0	8	LsF
Total:	98	40	41	23	19	15	39	61	

[a]site codes = pv, co, lc, ls

At Las Cruces, we sampled outside the Casa Wilson. At La Selva, we collected calls from around the new laboratory building near the start of the trail leading to the arboretum.

Using SonoBat software (version 1.46, DNDesign, Jacksonville, FL), we analyzed each recorded series of bat calls and categorized them into sonotypes (putative species).

TABLE 2. Number of unique bat sonotypes and total recorded calls at each of four sites in Costa Rica. Also indicated are the numbers of bat sonotypes unique to, and overlapping between, early and late sampling times at each site.

Site	Unique sonotypes	Total calls recorded	early	early and late	late
Palo Verde	10	138	4	1	5
Corcovado	11	64	5	2	4
Las Cruces	3	34	0	2	1
La Selva	5	100	0	4	1

We sorted calls on the basis of characteristic frequency, high and low frequencies, call duration and interval, and call slope. We estimated the number of species present as the number of distinct sonotypes. We determined the overlap in species composition between sites by cross-referencing sonotypes collected from each site.

Results

In 16 total hours of sampling (4 hrs/site), we collected 336 series of bat calls, distributed among 23 distinct sonotypes (Table 1; examples of representative sonotypes in Appendix; examples of all sonotypes archived on course computer as "Bat.Type*.CompProj. 2002.wav", where * = sonotype ID number). We found more species at Palo Verde and Corcovado (10 and 11) than at Las Cruces and La Selva (3 and 5). There was remarkably little between-site overlap in species (Table 1). The one species present at all four sites also tended to be the most abundant at each site. Two species were present at both Corcovado and Palo Verde and one overlapped between Corcovado and La Selva. Each of the remaining 19 species was recorded at only one sampling site.

At Palo Verde and Corcovado, we found a large difference between the species composition immediately after dusk and those later in the night (Table 2). At Las Cruces and La Selva, where we found fewer total species, most species were active during both times of night.

Discussion

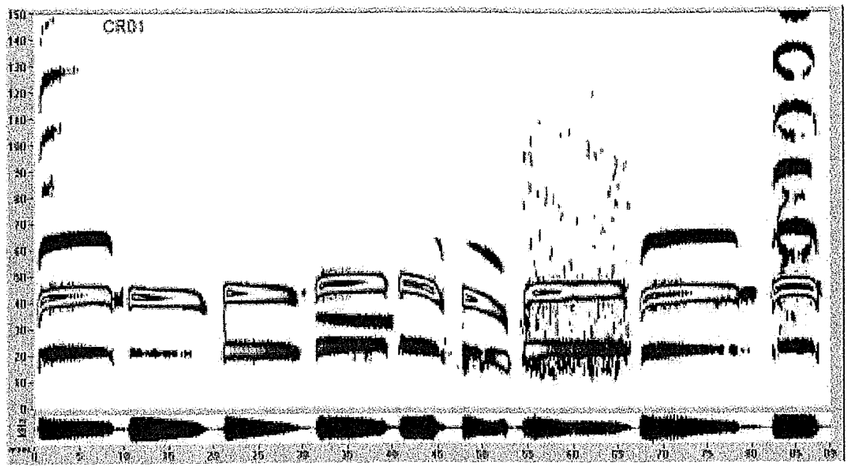
The ultrasound detection and analysis equipment used in this study proved valuable in quantifying differences in bat activity and sonotype richness across geographical and temporal gradients. Of the 106 Chiroptera species in Costa Rica, 43 are categorized as insectivorous (which are the most likely guild for detection by ultrasound sampling). We were able to distinguish 23 different sonotypes, so we may have recorded over 50% of the insectivorous species in Costa Rica. Only four of these sonotypes occurred at more than one site, and only one occurred at all four sites. This lack of overlap suggests that many bat species are specific to broad habitats or bioregions. We also found temporal variation in the bat community. At the two sites with the highest sonotype richness (Palo Verde and Corcovado), only 3 of 21 sonotypes overlapped between the early and late sampling periods. The remarkable diversity of bats in Costa Rica seems to be largely a product of high species turnover between regions and high temporal resource partitioning within sites. In California, where one of us has experience, comparable sampling efforts with the same equipment could also detect 4 or 5 insectivorous bat species in the same place at the same time (as we did at the most diverse sites in Costa Rica). However, in California, moving between sites or sampling at different times would detect fewer new species.

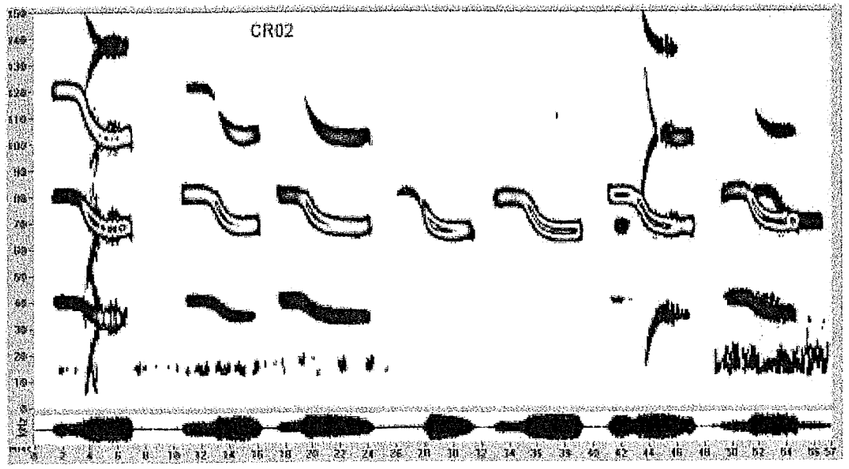
By using an ultrasound detector combined with SonoBat software, we were able to

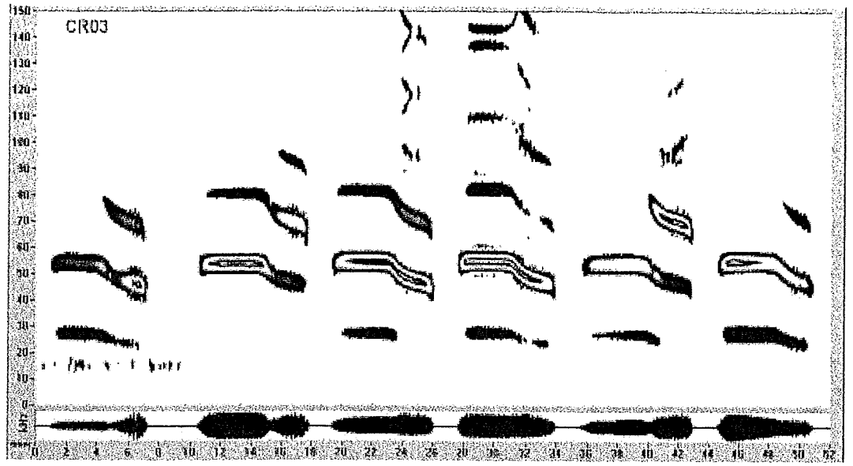
detect nearly 25% of the bat diversity in Costa Rica with only 8 hours of data collection. This would have been unlikely with mist netting techniques. However, ultrasound detection also has limitations as a sampling tool. Because sampling is based on echolocation, it is primarily useful for studying insectivorous rather than frugivorous or nectarivorous species. It is also difficult to estimate abundance as individuals cannot be readily distinguished.

Future studies could investigate the variation in sonotype richness between habitats within sites (e.g., edge, forest, riparian, etc.). Also, further research could quantify the temporal variation in bat activity and community composition, particularly at dawn and dusk. Combining this technology with a conventional mist-netting census could produce a more accurate description of the bat community while also enabling researchers to match sonotypes with bat species.

APPENDIX. Compiled views of bat calls created in SonoBat, showing representative sonograms for the following designated sonotypes: CR01, CR02, CR03, CR04, CR06, CR08, CR09, CR10, CR11, CR12, CR13, CR16, CR18, CR19, CR21 and CR22. Each call shown in these views was pulled from a different recorded bat call series. Compiled views are labeled with sonotype code, and divided with black lines when multiple sonotypes appear in one compiled view. For more sonotype examples and to view the original call series used to create these compiled views, see the folder "Costa Rica Bat Calls 2002" on course CD.



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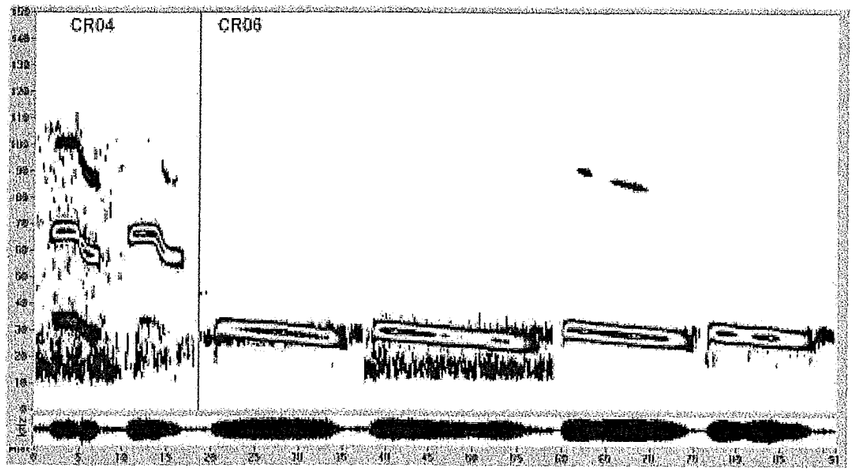
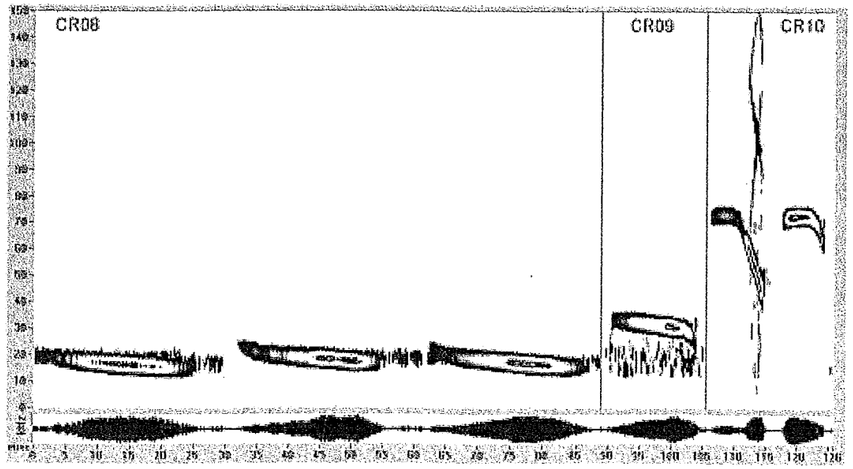
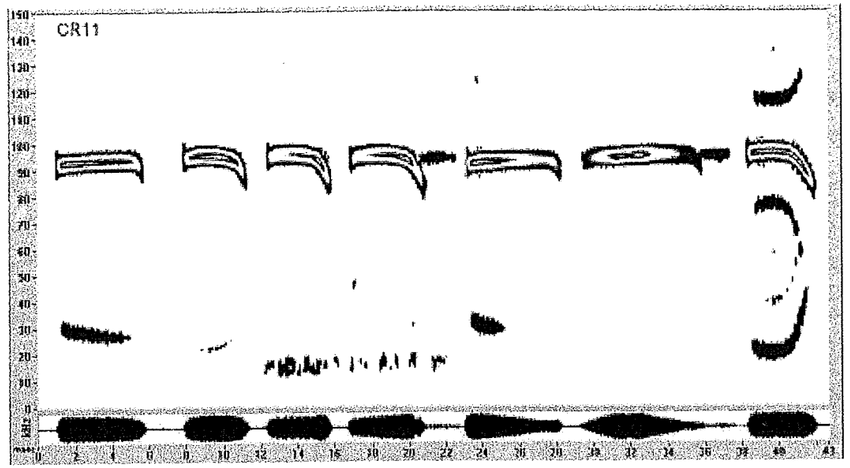
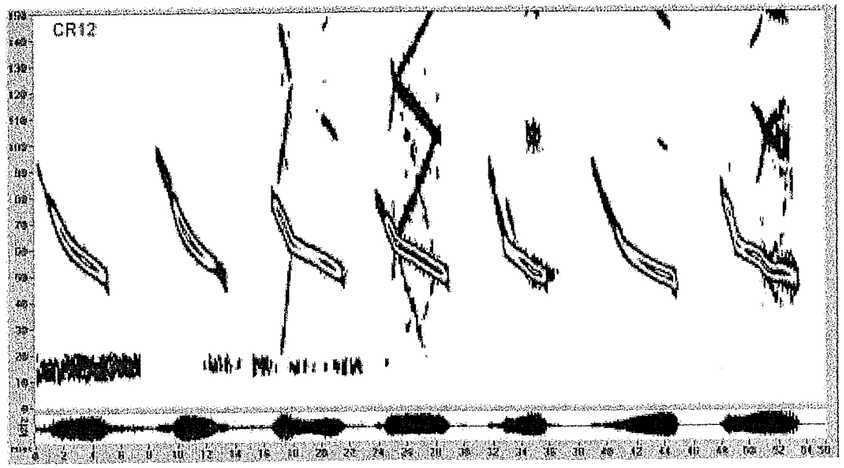
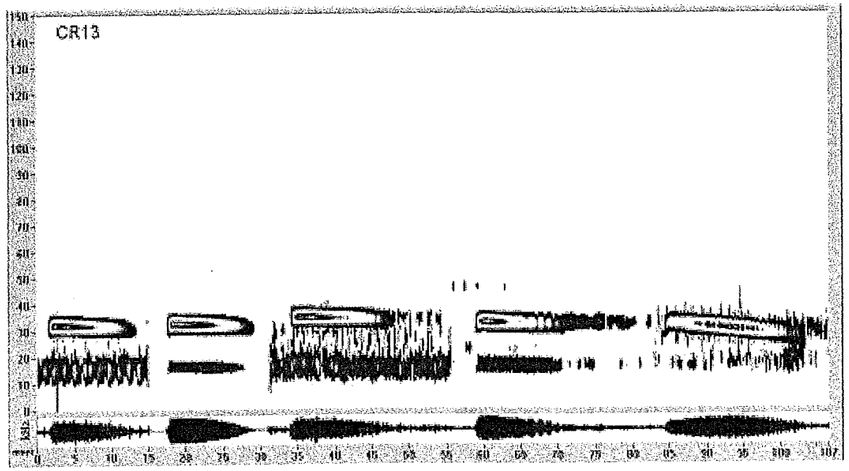

CR04
CR06


CR08
CR09
CR10


CR11


CR12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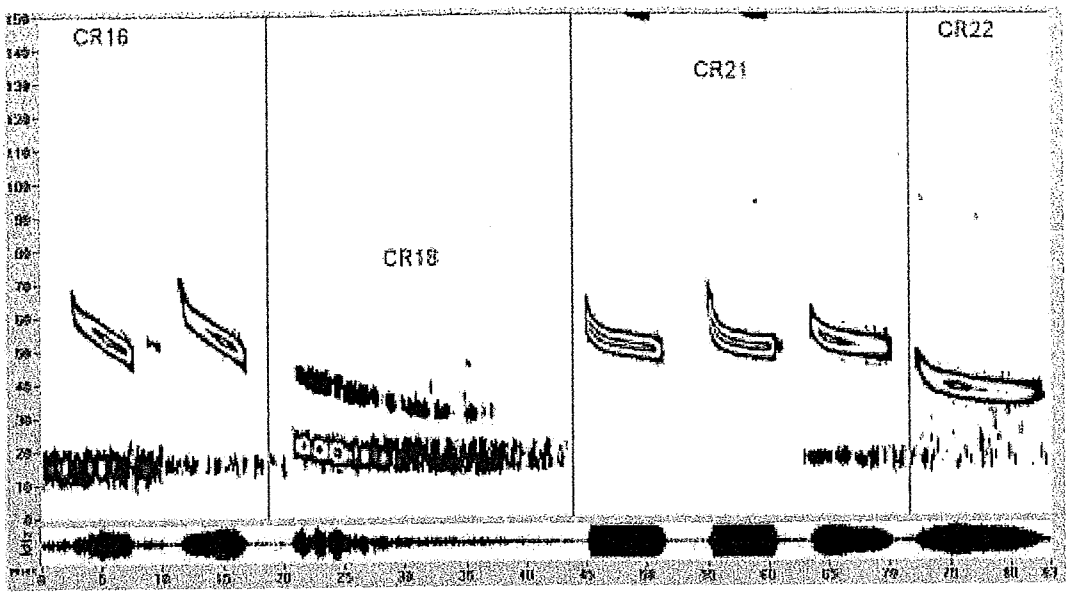
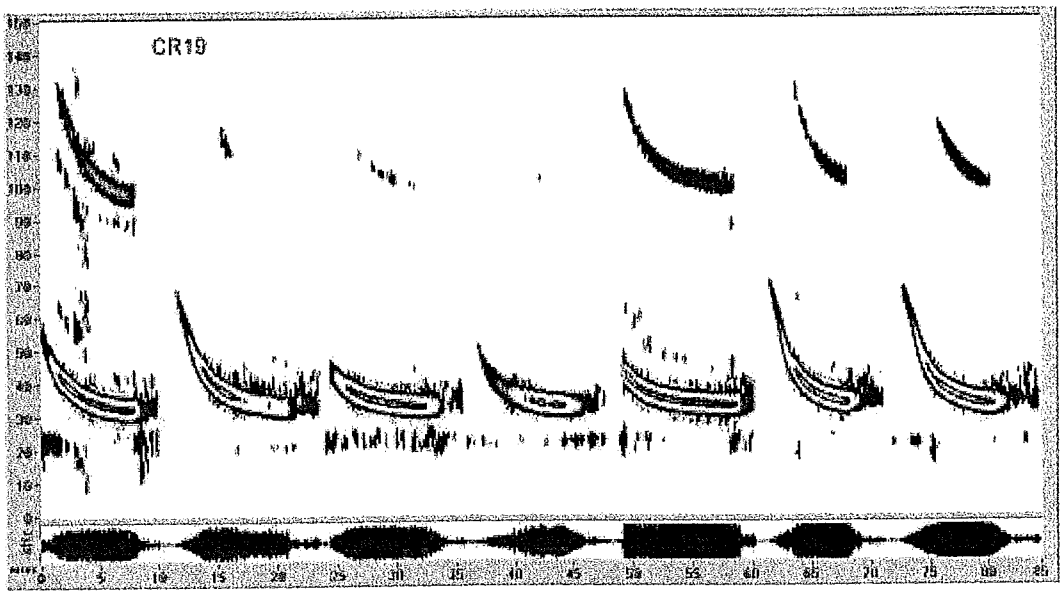

CR16
CR18
CR21
CR22


CR19