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Acoustical Investigation of Bats in Selçuklu District of Konya Province

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ABSTRACT

Based on the shape and model of echolocation calls, the acoustic definition of insectivorous bat species has become a successful tool for revealing the use of different habitats, activity and behaviour patterns. Many researchers have used ultrasonic detectors to identify bat species and assess habitat use. This method has become particularly valuable for species that are difficult to capture. In this study, a total of 3167 bat passages were recorded in the Selçuklu district of Konya province, by using an ultrasonic detector. As a result of the survey, 6 species (*Myotis myotis / blythii, Barbastella barbastellus, Pipistrellus pipistrellus, Hypsugo savii, Eptesicus serotinus* and *Miniopterus schreibersii*) were analysed. *B. barbastellus* and *E. serotinus* were recorded acoustically for the first time in the study area. ANOVA analysis showed that there were no significant differences in the call parameters between the locations where *M. myotis / blythii, B. barbastellus, P. pipistrellus* and *M. schreibersii* species were recorded. Discriminant Function Analysis (DFA) was performed to classify 5 species (*M. myotis / blythii, B. barbastellus, P. pipistrellus, H. savii* and *M. schreibersii*). As a result of the DFA, the species were classified as 100%.

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Konya İli Selçuklu İlçesindeki Yarasaların Akustik Olarak Araştırılması

ÖZET

Ekolokasyon çağrılarının şekil ve modeline dayalı olarak böcekçil yarasa türlerini akustik yönden tanımlamak, farklı yaşam alanlarının kullanımını, etkinlik ve davranış kalıplarını ortaya çıkarmak için başarılı bir araç haline gelmiştir. Birçok araştırmacı yarasa türlerini tespit etmek ve habitat kullanımını değerlendirmek için ultrasonik detektörleri kullanmış ve bu yöntem özellikle yakalanması zor türler için değerli hale gelmiştir. Konya ili Selçuklu ilçesinde ultrasonik dedektör kullanılarak yapılan çalışmada, toplam 3167 yarasa geçişi kaydedilmiştir. Çalışma sonucunda 6 tür (*Myotis myotis / blythii*, *Barbastella barbastellus*, *Pipistrellus pipistrellus*, *Hypsugo savii*, *Eptesicus serotinus* ve *Miniopterus schreibersii*) analiz edildi. *B. barbastellus* ve *E. serotinus* çalışma bölgesinde akustik olarak ilk defa kaydedildi. ANOVA analizi ile *M. myotis / blythii*, *B. barbastellus*, *P. pipistrellus* ve *M. schreibersii* türlerinin çağrılarının kaydedildiği lokasyonlar arasında çağrı parametreleri yönünden anlamlı bir farklılığın olmadığı tespit edilmiştir. 5 türü (*M. myotis / blythii*, *B. barbastellus*, *P. pipistrellus*, *H. savii* ve *M. schreibersii*) sınıflandırmak için Diskriminant Fonksiyon Analizi (DFA) yapılmıştır. DFA sonucunda, türler %100 oranında sınıflandırmıştır.

Araştırma Makalesi

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INTRODUCTION

Towards the end of the 18th century, Lazzaro Spallanzani showed that insectivorous bats use their ears rather than their eyes to locate obstacles or prey (Pye, 1960). Hartridge (1920) observed bats in flight and said that they can produce high frequency calls that people cannot hear. The discovery of the echolocation started with Pierce and Griffin (1938).

Griffin (1944) added the term "echolocation" to the literature. In addition, Griffin (1958) was the first to use a "sonic amplifier" to study ultrasonic sounds. Aerial insectivorous bats are often hunted in a forest canopy, and even when mist-nets and harp traps are within the sampling range, they can easily detect and avoid such devices (MacSwiney et al., 2008). Because many species fly over mist-nets or are better than others in detecting mist-nets, they can cause sampling mistakes (Larsen et al., 2007). In habitats such as open areas, large water bodies or long canopies, sampling cannot be done easily or effectively using capture methods (Wordley et al., 2014). Therefore ultrasonic detectors can be used in areas that are difficult to sample by capture methods (Fenton, 1990; MacSwiney et al., 2008). Bats use two types of calls including social and echolocation calls. They use social calls in their communication with each other (Russ, 2012). Echolocation calls are used by microchiropteran bats (Schnitzler et al., 2003). They use echolocation calls to collect information about their prey and habitat. Echolocation calls of bat species vary according to amplitude, duration, and frequency. This variation is related to foraging strategies and mostly habitat. Bat species mainly use FM (frequency modulated), CF (constant frequency) and QCF (quasi-constant frequency) frequencies and their combinations. Bats, which are mostly foraging in a clutter habitat, generally use FM components, while those that forage in open areas care about to use QCF components in their calls. For example, *Myotis myotis* uses FM calls, while *Pipistrellus pipistrellus* uses FM / QCF combination (Russ, 2012). CF calls are used to detect targets and distinguish between moving and fixed objects (Feldhamer at al., 2007).

Bats using echolocation have species-specific calls and acoustic monitoring of bats is relatively easy (Fenton and Bell, 1981). However, structure of echolocation calls can be extremely flexible. Echolocation calls of bats are generally classified into three types: "Search phase" pulses used when searching for prey, "Approach-phase" pulses used when a prey is detected and “terminal (feed-buzz) phase” used until the detected prey is captured. "Search phase" pulses usually are emitted at a rate of 10– 20 per second. During the “approach phase”, the duration of each pulse and the time between pulses decreases. In the terminal phase, the pulses continue to decrease in frequency and time intervals until the prey is captured (Harvey at al., 2011).

Identifying echolocation call of bats allows us to access unknown information about the lives of bats. For example, echolocation calls are used to help identify the species, to locate roost sites, find commuting routes and foraging areas, to study foraging behaviour, identify species distribution and monitoring annual variations in bat populations. These calls are not only used to identify the species of bats but also used to measure male reproductive success, as well as to assess the male's conservation behaviour and the female's choice of mate. It can also give an idea of female and young interactions, food competition at foraging sites and levels of distress levels (Russ, 2012).

A total of 39 bat species were recorded by different researchers in Turkey (Çoraman et al., 2013; Yorulmaz and Arslan, 2016; IUCN 2020). Overall, 13 of these species were identified in Konya. These species were *Rhinolophus ferrumequinum, R. hipposideros, Myotis myotis, M. mystacinus, M. emerginatus, M. capaccinii, M. aurascens, M. blythii, Pipistrellus pipistrellus, Hypsugo savii, Plecotus auritus, Miniopterus schreibersii and Tadarida teniotis* (von Helversen, 1989; Albayrak, 1993; Benda and Karataş, 2005; Aşan Baydemir and Albayrak, 2006).

Although there are many studies about the acoustic identification of bats in the world today, studies in Turkey are limited. The purpose of this study was to determine and classify the bat species that is spread in Selçuklu District of Konya province acoustically.

MATERIALS and METHODS

Field recordings

This study was conducted in Selçuklu district of Konya province (between 36° 52’ N and 32° 29’ E). 28 different locations were determined to study the bat activity. This study was conducted in open areas. There is no forest and residential area in the habitat. All calls were recorded between April and October. To avoid recording the same bats, only calls recorded one night were analysed. The study was conducted with the permission of Republic of Turkey, Ministry of Forest, and Water Works (Permit no. 21264211-288.04-E.346220). This permission also replaces the permission of the local ethics committee. Bat activity was monitored with the Batcorder 3.1 (EcoObs GmbH, Nuremberg, Germany). This detector can record sound in the 16-150 kHz range.

The detector was mounted on a rod to prevent bat calls from recording echoes reflected from a surface (Figure1). Records were made at distances higher than three meters from reflecting surfaces such as ground surfaces, trees, or water. The device is located at open areas where there is no clutter at all records points (Brabant at al., 2018). The detector was set to automatically record calls from sunset to sunrise.

Sound analysis

BcAdmin 3.0 (EcoObs GmbH) and bcAnalyze2 (EcoObs GmbH) software were used for the extraction, analysis and automated identification of recorded audio files including bat calls. In the analysis, echolocation calls in the search phase of bats were used.From all records, files that did not contain bat pass were extracted first.

During the identification process, consisting of less than 2 call signals made by individuals of a species, all indeterminate and fragmented call sequences were removed due to intraspecific and interspecific call diversity. A sequence of call signals emitted by one or more bats during a single recording event was defined as a 'call'. To describe the multiple species recorded in a single file, each call file was independently examined to identify all species. Where the call files are indefinite, fragmented, or where less than 2 call signs occur, they are defined as "unknown bats". Sequences containing two or more consecutive call signals of 90% or higher quality were identified as species and the best quality call signal was selected in the sequences.

Figure 1. Detector mounted on a dead tree
Şekil 1. Ölü bir ağaca monte edilmiş dedektör

Six parameters were measured for each call: Start Frequency (F_{start}), End Frequency (F_{end}), Peak Frequency (F_{peak}), Duration (D), Inter-Pulse Interval (IPI), Mean Frequency (F_{mean}) (Vaughan et al., 1997; Parsons and Jones, 2000; Russo and Jones, 2002; Obrist et al., 2004; Papadatou et al., 2008; Redgwell et al., 2009; Russ, 2012).

Statistical analysis

Statistical analyses were performed using IBM SPSS 22.0. The values of 6 parameters (D, IPI, F_{start}, F_{end}, F_{mean}, F_{peak}) of each bat species obtained as a result of the analysis of bat calls were studied separately. ANOVA (One Way) analysis was used to test whether at least one of these locations was different from the others. This analysis was performed for 4 species detected in more than 10 in each location (*Barbastella barbastellus, Myotis myotis / blythii, Miniopterus schreibersii* and *Pipistrellus pipistrellus)*. *B. barbastellus and E. serotinus* could not be evaluated statistically because there is not enough data. Shapiro-Wilk test was used to research normality in small sample sizes. In addition to the Shapiro-Wilk test, Skewness and Kurtosis values were also researched. ANOVA was used for normally distributed variables and Kruskal-Wallis test, which is the non-parametric equivalent of ANOVA, for variables that was not normally distributed or did not have homogeneous variances. In ANOVA analysis, homogeneity was checked by Levene Statistics. Post Hoc test was used to detect the sources of difference between the groups. If the variance of the parameters to be tested was homogeneously distributed, Bonferroni test was used in Post Hoc test. Discriminant Function Analysis was used to classify the calls belonging to different groups. Variables of 5 species with sufficient sample size were included in the tests (*M. myotis / blythii, M. schreibersii*, *P. pipistrellus, H. savii* and *B. barbastellus*). *E. serotinus* could not be evaluated statistically because there is not enough data.

RESULTS

As a result of passive acoustic listening performed for 28 nights in the study area, approximately 3167 bat passes were recorded. As a result of the extraction and analysis, 6 species were identified with the probability estimated by over 90% by Batident 3.0 (EcoObs GmbH) and bcAnalyze2 (EcoObs GmbH) software. These species are *M. myotis / blythii, B. barbastellus, P. pipistrellus, H. savii, E. serotinus and M. schreibersii*. "Unknown bat" passes were 65.61% (2079) of all analysed passes. The distribution of other genera and species identified are as follows: *Myotis sp.* 15.16% (480), *Pipistrellus, Hypsugo* and *Miniopterus* 4.42% (140), *Nyctalus, Eptesicus* and *Vespertilio sp.* 1.45% (46), *M. schreibersii* 6.66% (211), *M. myotis / blythii* 4.70% (149), *P. pipistrellus* 0.88% (28), *B. barbastellus* 0.79% (25), *H. savii* 0.22% (7) and *E. serotinus* 0.06% (2).

Time and frequency statistics were formed as a result of the analysis of the classified species (Table 1). According to these statistics, *M. schreibersii* (F_{start} 75.50 kHz, F_{end} 50.05 kHz, F_{mean} 51.54 kHz and F_{peak} 51.04 kHz) had the highest average. The lowest F_{start} was found in *B. barbastellus* (36.79 kHz). The lowest F_{end} was *M. myotis / blythii* (26.13 kHz). The lowest F_{mean} and F_{peak} were found in *E. serotinus* (F_{mean} 32.10 kHz and F_{peak} 29.21 kHz).

Frequency duration (D) belonged to the highest *H. savii* (9.40 ms) and the lowest *B. barbastellus* (2.02 ms). The most variable parameter was IPI values. Except *E. serotinus*, the difference between the lowest

and highest values of IPI values were very high in other species. The IPI value was found in the highest *P. pipistrellus* (212.14 ms) and the lowest *B. barbastellus* (106.28 ms) (Table 1). When all parameters were compared between species, there were no similarities between F_{start}, F_{end} and F_{peak}. *M. myotis / blythii*'s F_{mean}, *H. savii*'s D and *B. barbastellus*' IPI values were like *E. serotinus* (Table 1).

Table 1. Descriptive statistics of time and frequency parameters of the species identified by analysis (Mean, ± standard deviation (SD) and minimum-maximum values are shown for each parameter.)
Çizelge 1. Analiz sonucunda tespit edilen türlerin zaman ve frekans parametrelerinin tanımlayıcı istatistikleri (Her parametre için ortalama, ± standart sapma (SD) ve minimum-maksimum değerler gösterilmiştir.)

Species	Number of calls	Call Structures	F_{start} (kHz)	F_{end} (kHz)	F_{mean} (kHz)	F_{peak} (kHz)	D (ms)	IPI (ms)
B. barbastellus	25	FM	36.79 (±2.13) 34.52-43.74	30.50 (±2.40) 27.74-39.78	32.14 (±1.86) 29.30-39.06	32.24 (±1.47) 29.97-34.86	2.02 (±0.42) 1.50-2.90	106.28(±68.86) 20-345
P. pipistrellus	28	FM / QCF	52.51 (±5.70) 45.48-65.33	46.28 (±1.27) 43.35-48.51	46.31 (±1.15) 43.27-48.10	46.40 (±0.80) 44.93-48.06	7.46 (±1.94) 3.90-12.10	212.14(±86.70) 87-370
E. serotinus	2	FM / QCF	54.53 (±8.85) 45.68-63.38	27.20 (±0.63) 26.57-27.83	32.10 (±2.93) 29.17-35.03	29.21 (±0.26) 28.94-29.47	9.00 (±1.30) 7.70-10.3	119.50(±21.50) 98-141
H. savii	7	FM / QCF	39.18 (±5.28) 34.10-51.38	34.49 (±0.93) 33.16-35.65	34.40 (±0.67) 33.80-35.89	34.64 (±0.25) 34.20-35.02	9.40 (±0.90) 7.80-10.80	193.43(±76.66) 99-334
M. schreibersii	211	FM / QCF	75.50 (±8.58) 58.58-101.07	50.05 (±1.43) 46.28-53.87	51.54 (±1.04) 48.89-54.93	51.04 (±0.82) 48.89-54.06	7.01 (±1.42) 3.90-10.70	202.33(±85.01) 25-438
M. myotis / blythii	149	FM	63.04 (±4.34) 51.90-72.48	26.13 (±1.30) 23.62-29.93	33.26 (±3.18) 28.20-38.45	33.98 (±0.92) 32.22-39.22	7.97 (±0.87) 5.60-10.00	142.78(±55.26) 51-345

F_{peak} values in the statistics were obtained manually from the peaks in the power spectra. The F_{peak} point of *M. myotis / blythii* is not apparent in the power spectrum (Figure 2.A).

The bats analysed according to the call structures were divided into two groups as FM calls (*M. myotis / blythii and B. barbastellus*) and FM / QCF calls (*M. schreibersii*, *P. pipistrellus, H. savii* and *E. serotinus*).

M. myotis / blythii and *B. barbastellus* emitted typical short and steep sigmoid FM calls (Figure 2.A). The calls of *M. schreibersii*, *P. pipistrellus*, *H. savii* and *E. serotinus* were characterized by two components consisting of a vertical frequency modulation (FM) followed by a shallow frequency modulation (QCF) (Figure 2.B, 1.C, 1.D, 1.E and 1.F). The FM part was more prominent in *P. pipistrellus* and *M. schreibersii* calls than other species (Figure 2.E and 1.F). *H. savii*'s echolocation calls are often characterized by a narrow bandwidth and a longer duration (Figure 2.D).

Analysis Results

Before ANOVA test, normality test was performed for call parameters of *B. barbastellus, M. myotis / blythii, M. schreibersii* and *P. pipistrellus*. As a result of the normality test, IPI (Shapiro Wilk p = 0.000, Skewness: 1.468, Kurtosis: 2.909) and F_{mean} (Shapiro Wilk: p = 0.000, Skewness: - 0.016, Kurtosis: - 1.650) parameters of *M. myotis / blythii* did not show normal distribution.

Before the ANOVA test, Levene Statistics test was used to control whether the variances of the groups were distributed homogeneously. The groups were homogeneous in all parameters except *M. schreibersii*'s F_{start} value (p = 0.024), *M. myotis / blythii*'s IPI (p = 0.000) and F_{mean} value (p = 0.016).

As a result of the ANOVA analysis, there was no significant difference except for F_{start} (df = 7, F = 3083, p = 0.005) and F_{end} (df = 7, F = 3027, p = 0.006) parameters of *M. myotis / blythii*. Post-Hoc (Benferroni) test was used to find the source of the difference in F_{start} and F_{end} parameters of *M. myotis / blythii*. There was a significant difference between the 20 and 28 locations in both parameters.

According to Kruskal-Wallis analysis of non-normal distribution parameters, there was no significant difference between these groups for IPI (Chi-square = 11.314, df = 7, Asymp. sig. = 0.165) and F_{mean} (Chi-square = 13.295, df = 7, Asymp. sig. = 0.125) parameters of *M. myotis / blythii* and F_{start} (Chi-square = 16.382, df = 10, Asymp. sig. = 0.089) parameter of *M. schreibersii*.

Discriminant Function Analysis (DFA) was applied to classify 5 species (*M. myotis / blythii, M. schreibersii*, *P. pipistrellus, H. savii* and *B. barbastellus*) with sufficient sample size according to 6 parameters (D, IPI, F_{start}, F_{end}, F_{mean} and F_{peak}). There was no correlation between the groups (Table 2). The relationship between the DFA results and the groups was decided by looking at the Eigenvalues Table (Table 3). DFA calculated 4 functions between groups. The Canonical Correlation value of function 1 was 0.998.

To interpret this value, the square of the Canonical Correlation value ($0.998^2 = 0.996$) was calculated. Briefly, the first function can explain 99.6% of the variance in the dependent variable.

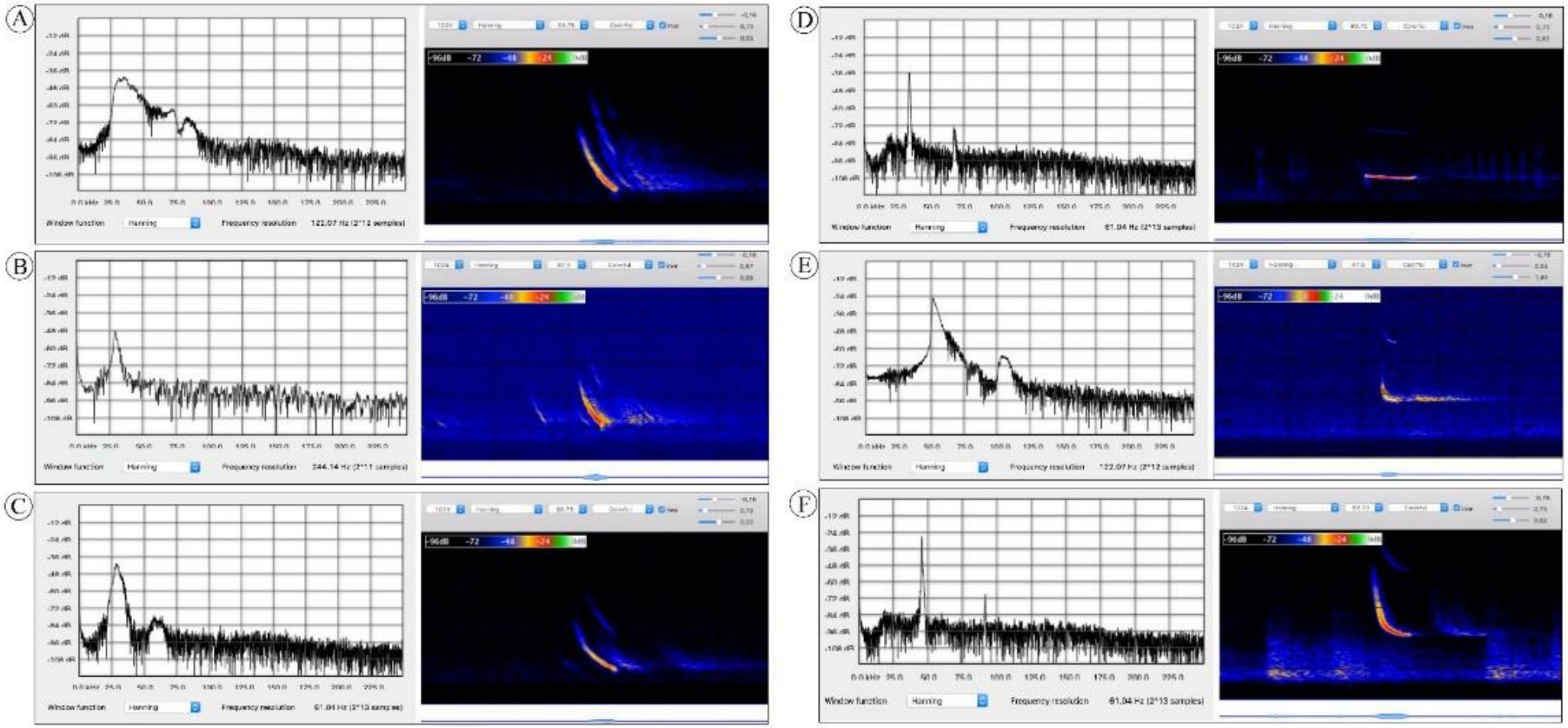

Figure 2. Power spectrum and sonogram of *M. myotis/blythii* (A), *B. barbastellus* (B), *E. serotinus* (C), *H. savii* (D), *M. schreibersii* (E), *P. pipistrellus* (F)
Şekil 2. M. myotis / blythii (A), *B. barbastellus* (B), *E. serotinus* (C), *H. savii* (D), *M. schreibersii* (E) *ve P. pipistrellus* (F) *'a ait güç spektrumu ve sonogram*

Table 2. Pooled within-groups matrices
Çizelge 2. Havuz içi grup matrisleri

		D (ms)	IPI (ms)	F_{start} (kHz)	F_{end} (kHz)	F_{mean} (kHz)	F_{peak} (kHz)
Correlation	D (ms)	1.000	.182	-.261	-.234	-.444	-.446
	IPI (ms)	.182	1.000	-.329	-.118	-.110	-.199
	F_{start} (kHz)	-.261	-.329	1.000	.220	.131	.333
	F_{end} (kHz)	-.234	-.118	.220	1.000	.292	.344
	F_{mean} kHz)	-.444	-.110	.131	.292	1.000	.330
	F_{peak} (kHz)	-.446	-.199	.333	.344	.330	1.000

Table 3. Eigenvalues
Çizelge 3. Özdeğerler

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	206.973	97.7	97.7	.998
2	4.433	2.1	99.8	.903
3	.453	.2	100.0	.558
4	.012	.0	100.0	.110

The second function ($0.903^2 = 0.815$) can explain 81.5% of the variance in the dependent variable. 97.7% of the explained variance was explained by the first function and 2.1% by the second function. Table 4 shows the importance of independent variables when estimating the dependent variable. In this table, the IPI variable is not included in the list because it is not important compared to other variables. In addition, this table shows how important variables are when forming functions. The most important variable in the formation of the first function was F_{peak} (0.965). Then the variables D (0.503), F_{end} (0.337) and F_{mean} (0.125) were effective. The least significant variable was F_{start} (- 0.207) parameter. Figure 3 shows how much the groups formed by functions 1 and 2 in Tables 3 and 4 can be separated from each other. DFA results are given in Table 5. These results indicate that the calls obtained in the study (371 calls) are 100% accurate by species.

Table 4. Standardized canonical discriminant function coefficients
Çizelge 4. Standardize edilmiş kanonik diskriminant fonksiyon analizi

	Function			
	1	2	3	4
D (ms)	.503	.858	.673	.000
F_{start} (kHz)	-.207	.760	-.543	.479
F_{end} (kHz)	.337	-.365	.326	.628
F_{mean} kHz)	.125	.528	.025	-.805
F_{peak} (kHz)	.965	-.007	-.167	-.171

Table 5. Discriminant function analysis results
Çizelge 5. Diskriminant fonksiyon analizi sonuçları

	Species	Predicted Group Membership					Total
		M. myotis / blythii	*M. schreibersii*	*P. pipistrellus*	*B. barbastellus*	*H. savii*	
Count	*M. myotis / blythii*	134	0	0	0	0	134
	M. schreibersii	0	187	0	0	0	187
	P. pipistrellus	0	0	21	0	0	21
	B. barbastellus	0	0	0	23	0	23
	H. savii	0	0	0	0	6	6
%	*M. myotis / blythii*	100.0	.0	.0	.0	.0	100.0
	M. schreibersii	.0	100.0	.0	.0	.0	100.0
	P. pipistrellus	.0	.0	100.0	.0	.0	100.0
	B. barbastellus	.0	.0	.0	100.0	.0	100.0
	H. savii	.0	.0	.0	.0	100.0	100.0

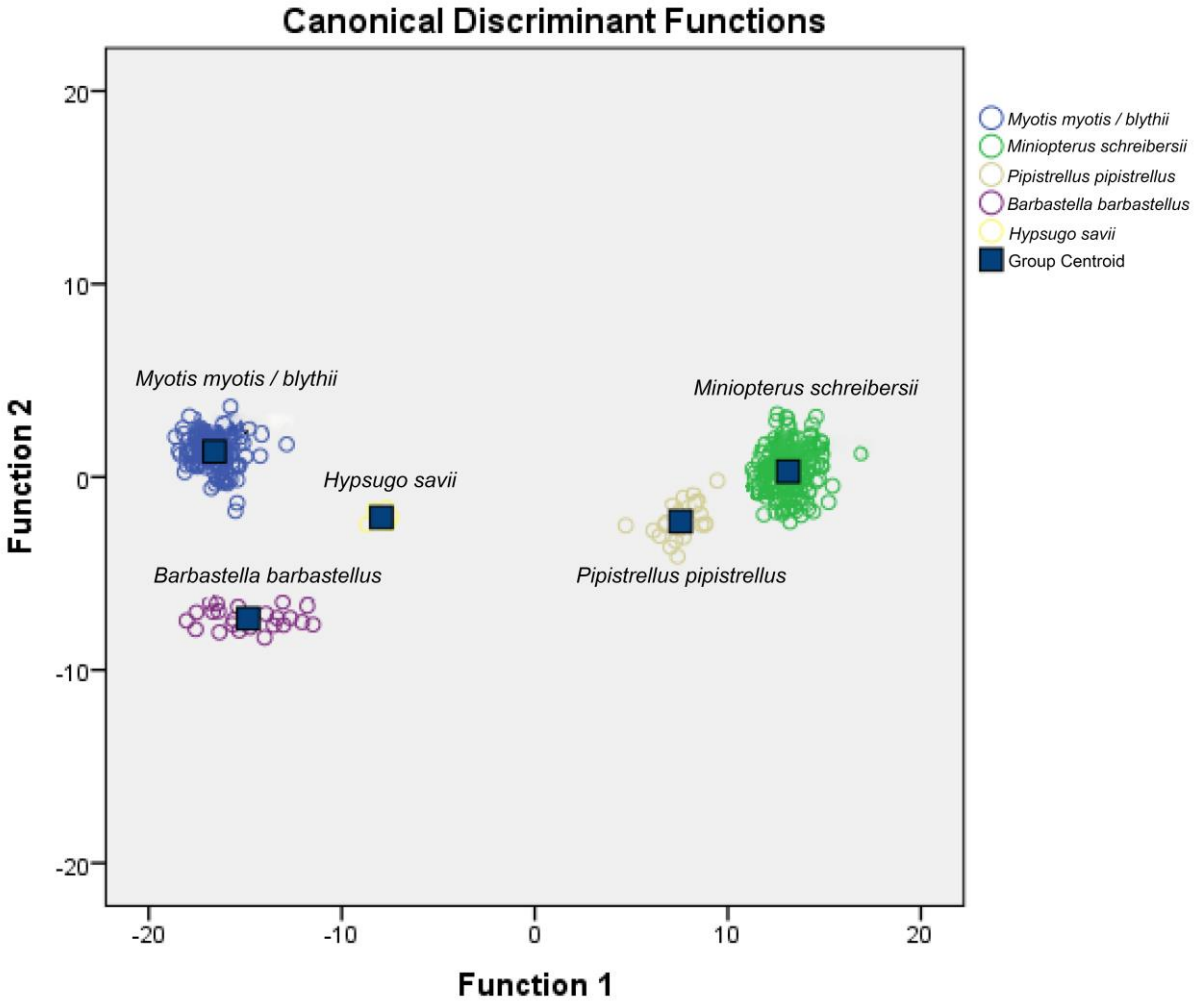

Figure 3. Canonical Discriminant Functions
Şekil 3. Kanonik Diskriminant Fonksiyonları

DISCUSSION and CONCLUSION

Since *M. myotis* and *M. blythii* are sibling species, it is difficult to distinguish acoustically (Russo and Jones, 2002; Russo et al., 2007; Bader et al., 2018). Therefore, the results of *M. myotis* and *M. blythii* in this study were given as *M. myotis / blythii*. As a result of the extraction and analysis, in this study, if *M. myotis* and *M. blythii* were accepted together, 6 species (*M. myotis / blythii, B. barbastellus, P. pipistrellus, H. savii* and *E. serotinus* from the family Vespertilionidae*; M. schreibersii* of the family Miniopteridae) were analysed.

ANOVA and Kruskal-Wallis tests of the analysed species showed that there was no significant difference between the locations of each species for other parameters except F_{start} and F_{end} parameters of *M. myotis / blythii*. By using Post Hoc (Benferroni) test, it was determined which locations were the difference in F_{start} and F_{end} parameters of *M. myotis / blythii*.

When the results of *M. myotis / blythii* obtained were compared with the studies in Italy (Russo and Jones, 2002), Switzerland (Obrist et al., 2004) and Greece (Papadatou et al., 2008); The frequency duration (D) results were similar to the study in Switzerland, but were approximately 3 ms higher than in Italy and Greece. While the F_{start} in this study was like Italy, it was about 10 kHz lower than the studies in Switzerland and Greece. The results of the F_{end} were like those in Italy and Greece, but about 2 kHz higher than in Switzerland. The F_{peak} was like the studies in Italy, Switzerland, and Greece. The IPI was only available in studies in Italy and Greece and was like both.

The results of *B. barbastellus* were similar to those reported in studies in Italy (Russo and Jones, 2002) and the UK (Parsons and Jones, 2000; Parsons, 2004; Redgwell et al., 2009). Only D was about 1 ms lower than (Russo and Jones, 2002). In their studies of Parsons and Jones (2000) and Russo and Jones (2002) reported both the FM and FM / QCF call types of *B. barbastellus*. In this study, only FM type calls were observed. There was no direct observation of *B.*

barbastellus in this region. The closest to this region was observed in Nevşehir (Benda and Horáček, 1998). The presence of *B. barbastellus* in this area should be directly observed.

P. pipistrellus was compared with the results of studies in Greece (Papadatou et al., 2008), Switzerland (Obrist et al., 2004), Italy (Russo and Jones, 2002) and England (Vaughan et al., 1997; Parsons and Jones, 2000; Redgwell et al., 2009). The D was like studies in Greece, Switzerland, Italy, and the UK. Only, it was approximately 3 ms higher than the study of Parsons and Jones (2000). F_{start} was approximately 20 kHz lower than other studies. F_{end} was about 2 kHz higher than in Switzerland. F_{peak} and F_{mean} were like those reported in other studies.

The results of *H. savii* were similar with the results of studies in Italy (Russo and Jones, 2002), Switzerland (Obrist et al., 2004) and Greece (Papadatou et al., 2008). D was about 1 ms higher than in Greece. F_{end} is about 3 kHz lower than the study in Switzerland.

Studies on *E. serotinus* in Greece (Papadatou et al., 2008), Switzerland (Obrist et al., 2004), Italy (Russo and Jones, 2002) and the UK (Parsons and Jones, 2000; Redgwell et al., 2009; Vaughan et al., 1997) had similar results. The D was about 1 ms lower than the results of Vaughan et al. (1997) and Parsons and Jones (2000) from the UK. The results of IPI, F_{start} and F_{mean} were similar with other studies. The F_{end} was about 4 kHz higher than in Switzerland. The F_{peak} was about 3 kHz lower than Parsons and Jones (2000). In this study, two echolocation calls of *E. serotinus* were analysed. *E. serotinus* was recorded in Ankara (Albayrak, 1985; von Helversen, 1989; Benda and Horáček, 1998; Aşan Baydemir and Albayrak, 2006), Eskişehir (Benda and Horáček, 1998) and Niğde (Karataş and Sözen, 2006), which are closest to the study area. It is also likely to be present in this area but needs to be confirmed by direct observation.

The results of *M. schreibersii* were compared with the results of studies in Italy (Russo and Jones, 2002), Switzerland (Obrist et al., 2004), Greece (Papadatou et al., 2008) and Turkey (Furman et al., 2010). The results were almost similar with results of other studies, except Turkey. Other parameters except F_{end} in study of Turkey was not similar with the results in this study. The difference may be due to the fact that Furman et al. (2010) made his recordings in flight rooms and hand-released bats.

In this study, most of the time and spectral measurements taken from the calls were similar with the results of previous studies (Vaughan et al., 1997; Parsons and Jones, 2000; von Helversen et al., 2001; Russo and Jones, 2002; Obrist et al., 2004; Parsons, 2004; Papadatou et al., 2008; Redgwell et al., 2009; Furman et al., 2010; Russ, 2012; Hafner et al., 2015; Nyssen et al,. 2015). The differences were usually small. This can easily be explained by the flexibility of the call structure. Since sufficient information about habitat structures of previous studies could not be obtained, it was not possible to compare habitats. In addition, different bat detectors used in researches can be effective in different results. As acoustic clutter increases, calls become shorter and broadband, and the frequency rate increases (Rydell, 1990; Kalko and Schnitzler, 1993). Morphology also affects call design and may lead to convergence between morphologically similar species in call design (Jones, 1996). Age has been shown to have an effect on the echolocation calls of bats regardless of morphology (Jones et al., 1992).

The success of the DFA statistical results in the classification of species in this study was close to or higher than previous studies in which the DFA was used (Parsons and Jones, 2000; Papadatou et al., 2008; Redgwell et al., 2009). Reasons why DFA has achieved higher accuracy than other studies may be relatively few species are used in the classification and 90% quality calls are selected for extraction. The results of DFA may be an appropriate method for the acoustic identification of the species in the Selçuklu district. This study shows that it is possible to examine species -specific habitat use models of bats using acoustic monitoring only in this study area.

As a result of the acoustic studies, it is possible to obtain information about species diversity and activity density in bats' natural environments without disturbing them. More intensive studies of this kind will allow us to learn more about the habitats of bats.

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Statement of Conflict of Interest

Authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal.

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