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SOUND RECORDING OF VOCAL ACTIVITY OF ANIMALS INHABITING SUBTROPICAL FOREST ON IRIOMOTE ISLAND IN THE SOUTHERN RYUKYUS, JAPAN

SNEMANJE ZVOČNE DEJAVNOSTI ŽIVALI, KI NASELJUJEJO SUBTROPSKI GOZD OTOKA IRIOMOTE V JUŽNEM OBMOČJU RYUKYU OTOČJA NA JAPONSKEM

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ABSTRACT

Sound recording of vocal activity of animals inhabiting subtropical forest on Iriomote Island in the southern Ryukyus, Japan

We developed a system to monitor distribution and activity of animals in a forest ecosystem using sound recorders. The study was conducted at 14 sites along a river in Iriomote Island in the southern Ryukyus, Japan, from September 2004 to July 2005. Vocal activity of animals was continuously recorded for a specific interval with a weatherproof automatic recording system. From the recorded data, we identified calls of 38 species of mammals, birds, reptiles, amphibians, and insects. For each species, we compared vocal activity during study periods in order to investigate the migratory periods of several species of birds, and also breeding activities of birds, frogs, and Orthoptera. In addition, we studied daily vocal activity to investigate variation during the study period. This system allows long-term consecutive and simultaneous monitoring at multiple locations without man-power, which is a great advantage for cost-effective monitoring of regional biodiversity.

Key words: Animal community, automatic recording system, diurnal activity, environmental evaluation, seasonal change.

IZVLEČEK

Snemanje zvočne dejavnosti živali, ki naseljujejo subtropski gozd otoka Iriomote v južnem območju Ryukyu otočja na Japonskem

Razvili smo učinkovit sistem za sledenje razporeditve in akustične dejavnosti živali v gozdnem ekosistemu z uporabo zvočnega snemanja. Poskus smo izvedli na 14 krajih vzdolž reke na otoku Iriomote v območju južnih Ryukyu otokov na Japonskem v času od septembra 2004 do julija 2005. Z avtomatskim sistemom za snemanje, odpornim na vplive podnebja, smo v določenem času zvezno snemali zvoke. Med posnetimi zvoki smo identificirali oglašanje 38 vrst, ki pripadajo sesalcem, ptičem, plazilcem, dvoživkam in žuželkam. Za vsako vrsto smo primerjali njihovo oglašanje v času te študije, da bi ugotovili selitvena obdobja več vrst ptic in tudi obdobja parjenja ali gnezdenja ptičev, žab in kobilic. Poleg tega smo primerjali zvočno dejavnost posameznih vrst med vsako uro dneva, da bi ugotovili njihov dnevni ritem. Uporabljeni sistem omogoča dolgotrajno spremljanje zvočne dejavnosti sočasno na več krajih brez človekovega nadzora, kar je seveda velika prednost za ceneno sledenje biotske pestrosti na določenem območju.

Ključne besede: živalske združbe, avtomatsko zvočno snemanje, dnevni ritem, okoljsko vrednotenje, sezonske spremembe.

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INTRODUCTION

People hear birds singing as sun rises, and insects singing as sun goes down. They feel the arrival of autumn as shrill buzzing of cicadas is replaced by the soft chirping of crickets. So we know natural communities are filled with a huge variety of natural sounds.

Natural communities contain a spectrum of life forms and biologies that interact with each other (BEGON ET AL. 1996). Many scientists agree that an essential part of ecology is studying interactions among species in the communities (see in RICKLEFS & SCHLUTER 1993). In many parts of the world, aggregates of animals in a particular district, i.e. an animal community have been studied seeking to understand the complicated interspecific interactions in various ecosystems.

Animal communities in tropical forests have extremely complex interactions involving vast numbers of species (LEIGH et al. 1996, REGAN & WAIDE 1996). Meanwhile, huge areas of forests have been cut recently, and vast numbers of forest species have become extinct. In addition to the direct impact of clear cutting, the lack of the interspecific interactions the regional ecosystem will be disrupted (PRIMACK 2004). Therefore, beyond the mere theoretical ecological interest, studying animal community is important for conservation and management of regional environments.

One way to evaluate an animal community is simply to count or list the species that are present in an area. As traditional methods of monitoring animals, we count numbers of animals observed visually along preset routes or at points, which is an effective way for monitoring activities of various types of animals (BOOKHOUT 1996, BUCKLAND et al. 2001). However, it is often surprisingly difficult, mainly due to technical problem for monitoring. This seems especially obvious when dealing with nocturnal animals or species living in dense forests where they are difficult to be directly observed.

For monitoring these species, counting calls of animals is often an effective method, because acoustic communications have been used among various types of animals in mammals, birds, amphibians, fishes, and insects (KREBS & DAVIES 1993, SEARCY & NOWICKI 2005). In particular, the method is commonly used to investigate birds and amphibians as well as visual counts (see in BIBBY et al. 2000, HEYER et al. 1994). This method requires an observer to physically listen and identify species calls in the field. Therefore, it has a disadvantage that the result would be affected by the ability of the observer to identify the species. In addition, with this method it is difficult to investigate the calls of animals simultaneously in multiple locations and for a long term. In order to address this methodological limitation, we have developed a system to monitor distributions and activities of animals in a forest ecosystem effectively by using sound recorders. Herein, we report the preliminary results obtained with this system.

MATERIALS AND METHODS

Study site

The study had been conducted monthly from September 2004 to July 2005 in eastern part of Iriomote Island (24°20’ N, 123°55’ E) in the southern Ryukyus in Japan. The climate is seasonal mainly with the summer season from June to September and the winter season from December to March. Average monthly temperature is highest in July (28.3°C) and lowest in January (18.0°C). Average annual rainfall is 2342 mm (Iriomote Meteorological Station). Iriomote Island mainly consists of highly folded mountains and its highest peak (Mt. Komi) is 469 m above sea level. Its vegetation is mostly subtropical evergreen broadleaved forest (83% of the island in area) (Miyawaki 1989). We set sound recorders at 14 sites in forests along the river. We selected different types of vegetations for recording, from broad-leaved evergreen forest in the upstream to mangrove forest in the estuary (Table 1).

Recording

The weatherproof automatic recording system monitored vocal activity of animals continuously for a specific interval. The recording device consisting of a cassette tape recorder with auto-reverse function and a recording speed controller (TCM-500, SONY Co, Ltd) was placed in a plastic box. A capacitor microphone connected to the cassette tape recorder through an insulated audio cable was attached to a living tree, 2 m above ground level. The recording system contained an automatic programmable switching system that enabled the electric power of the device to be switched on or off. The recording schedule was programmable and set before the study by the user. The total cost of a set of recording device was about US$ 130.

Recording was performed for 60-sec every hour, for four consecutive days. The recording speed was set to 50% of the normal speed. The system was able to record sounds for 310 min at the maximum time period with the longest duration cassette tape (150-min). The actual recordable time period was longer than the time shown on the label of the tape (UR 150-min Normal position type I, Hitachi Maxell Ltd.), the cassette tape can record for an extra 5-min in addition to 150-min. Therefore, the 150-min tape was able to record 155-min at the normal speed and 310-min at 50% of the normal speed: the virtual 310-min tape can record 60-sec every hour in 13 days at most. However, the recording on this study was performed for four days with this unique setting.

Analysis

The retrieved cassette tapes were digitized through a PC based built-in cassette deck (Plusdeck2, BOT Co, Ltd) that directly converts recorded sounds from analogue cassette tapes into digital WAV format files. The digital files were played by a computer software (SoundEngine Free, Cycle of 5th). One of us (S.W.) listened to all recorded digital files and identified vocal activities of all animals. The species identification was made with reference to several datasets of animal calls (Kabaya & Matsuda 1996a, 1996b, for birds; Matsui et al. 2004, for frogs; Kabaya & Kuribayashi 1994 for insects). When the sounds recorded in the field included high levels of low-frequency background noise caused by rain, wind, and jet planes and these masked the vocalizations of animals, we excluded these data from the analysis.

To perform a statistical analysis of vocalizations of animals, we defined the frequency of occurrence of vocalizations (FOV). FOV represents daily and seasonal variations of animals from the presence or absence of occurrence of vocalizations in the each of 60-sec recording files. To check the presence or absence of occurrence of vocalizations in each 60-sec recoding files, only the presence/absence of the vocalizations of each species identified in the 60-sec was scored; the frequency of the vocalizations of each species within the 60-sec was not measured. For example, if the call of a given species was recorded once or many times in the 60-sec interval, the occurrence of the species in the interval was recorded as “present”. On the other hand, if no call of the species was recorded in the interval, the species was scored “absent” in the interval. Calling activity is a clear indicator of presence, but absence of calling does not necessarily mean absence, except in species which call reliably and frequently. Thus, we calculated FOV for species whose calls were relatively frequently recorded.

We also performed Principal Component Analysis (PCA) to classify the species in terms of their relative similarities of the temporal variations. The PCA on the FOV data in each study period and in each hour of a day was performed with the standard VARIMAX rotation in SPSS for Windows 11.5 (SPSS, Inc). The degree to which PCA could explain the variation in vocal activities of animals was assessed by using the first two principal components (PC1 and PC2) based on Eigenvalues of the PCAs (PCA: Sokal & Rohlf 1995).

RESULTS

Species identified

From the recorded data, we identified vocalizations of 38 species in various types of animals: one species of mammal (only flying foxes), 23 species of birds, one reptile species (only geckos), 7 species of amphibians (only frogs), and 10 species of insects (only Orthoptera and cicadas) (Table 2).

To assess the performance of this method for monitoring biodiversity, we described a relationship between recording periods and accumulated number of species identified by the recording system (Fig. 1). In the first study period, 58% of the total number of species identified was recorded, and then, 74% and 84% of the total number of species were recorded in the second and third study periods, respectively.

Seasonal variation

For the following analysis, we focused on 22 species of the identified 38 species; 12 species of birds, 6 species of frogs, 2 species of cicadas, and 2 species of Orthoptera, whose calls were relatively and frequently recorded. For these species, we calculated FOVs in each study period to investigate seasonal variations in vocal activity (Table 3). The data matrix in Table 3 was applied to PCA, and the result is shown in Table 4. The first and second principal component factors explained 34.3% and 23.3% of the total variability, respectively. The scores of the first and second factors of each species are plotted in Fig. 2. We classified mainly four groups that depend on locations of score plots as follows:

1) It includes 4 species of birds and one species of Orthoptera: their vocal activities peak in May and July.
2) It includes 4 species of birds and one species of frogs: their vocal activities have no clear peak but it is relatively high from April to November.
3) It includes one species of birds, 3 species of frogs, one species of Orthoptera, and one species of cicadas: their vocal activities have no clear peak related to any seasons.
4) It includes one species of birds and 2 species of frogs: their vocal activities peak in December and February.

There are 3 species that remain outside these groups. *Otus manadenis* and *Meimuna iwasakii* are located in second and third groups, and *Terpsiphone atrocaudata* is located in the first and fourth group.

Diurnal variation

We calculated FOVs of 22 species in each hour of a day to investigate diurnal variation of their vocal activities (Table 5). The FOVs varied hourly, which depended on the species. For typical examples, vocalizations of diurnal birds, such as *Hypsipetes amaurotis* and *Corvus macrorhynchos*, were only recorded during day hours. Contrary, those of nocturnal birds, such as *Otus manadenis*, were only recorded during the night. In addition to these distinct diurnal activities, vocal activity of *Amaurornis phoenicurus* is higher during dawn and dusk, respectively.

A more detailed picture of circadian variations of vocal activities emerges from applying a PCA model to the data matrix in Table 5. The first and second principal component factors explained 58.6% and 13.1% of the total variability, respectively (Table 4). The scores of the first and second factors of each species are plotted in Fig. 2. We classified them mainly into three groups depending on locations of score plots as follows:
1) It includes one species of birds and one species of cicadas: their vocal activities have two peaks in dawn and dusk, respectively.
2) It includes 8 species of birds and one species of cicadas: they vocalize only during day, i.e. diurnal species.
3) It includes 2 species of birds, all 6 species of frogs, 2 species of Orthoptera: they vocalize only during night, i.e. nocturnal species.

Only *Spilornis cheela* remains outside these groups. Its vocal activity peaks only around noon.

DISCUSSION

Species identified

The calls of birds, frogs, and 2 taxa of insects were frequently recorded because they mainly use vocalization for their communication (e.g. KREBS & DAVIES 1993, SEARCY & NOWICKI 2005). However, the identified number of species of birds and Orthoptera are considerably low according to the lists of birds and insects on Iriomote Island (Committee for Check-List of Japanese Birds 2000, AZUMA 2002). Contrary, 7 of 8 species of amphibians in the island were identified from our recording data (Maeda & Matsui 1999). The causes of this fluctuation may come from the identification ability and the selection of recording location in the field. First, the recorded sounds included many unidentified species of birds and Orthoptera whose vocalizations were difficult to distinguish by the observer hearing from those of taxonomically similar species. If our ability of the hearing identification improves, the number of identifiable species in these taxa would be increased. Second, although recording was carried out in various types of vegetations, there are several types of vegetations which are absent in the recording area. If we extend the recording area, higher number of species would be recorded by the system. For instance, the frog *Rana utsunomiyaorum* which was not recorded in our data chiefly lives in the riparian forests in high mountains (Maeda & Matsui 1999). If we put a recorder in upper stream of the river, we could record their calls. Moreover, from the comparisons of the listed species recorded by the system in each habitat type or in each region on the island, the recording system would be beneficial when applied to study for a regional biodiversity.

In contrary to birds, amphibians, and insects, the system recorded only a small proportion of mammals and reptiles. In mammals, chattering and flapping sounds of flying foxes were recorded only at site 11 during night. There are several trees of the genus *Ficus* in fruit around the site, and this is presumably the main food source for the species (Abe 2005). In reptiles, vocalizations of house geckos were only recorded at site 3 located in a village. The species is more abundant in human settlement than in forests in the island (Hikida 1996). We observed many house geckos in houses and on house walls but they were hardly observed in the forest. Although several species of mammals and many species of reptiles live in the island (Abe 2005, Hikida 1996), they may not rely much on acoustic communication. Therefore, in this study area, recording is not effective way to monitor activities of mammals and reptiles apart from the aforementioned two species.

Temporal variations of vocal activity

The FOVs varied seasonally, and seasonal variation was species-specific. Especially, FOVs of two bird species, *Amaurornis phoenicurus* and *Halcyon coromanda*, varied largely, and peaked in May. From a road transect survey to estimate population size of *A. phoenicurus*, we know that the population increases from March to May due to immigration of adult animals and their activity in the breeding period (Sakaguchi & Nishihira 1988). In addition, *H. coromanda* immigrates to and breeds in the island during the summer season (Takano 1982, Watanabe pers. comm.). It is thus likely that the great vocal activity of these species in May was related to the peak of their breeding activities. In contrast, vocal activities of one bird species *Turdus pallidus* and one frog species *Rhacophorus owstoni* were highest in December. *Turdus pallidus* immigrates to the island during autumn and winter (Takano 1982, Watanabe pers. comm.). Mating males of *R. owstoni* are observed from December to February (Watanabe et al. 2005). It is thus likely that the great vocal activities of *T. pallidus* and *R. owstoni* in December were related to the peak of migration and breeding activities, respectively.

A more detailed picture of temporal variations of their vocal activities emerges from the results of PCAs. Our observation method using recording systems is very effective to analyse temporal variations of animal activity on two scales, months and hours, and the results show temporal dynamics of the animal community in detail. Activities of animals vary temporally, because intensities of interactions in different components of the forest community largely depend on temporal changes in the physical environment such as temperature and rainfall and on the resultant changes in food supply and abundance of predator (LEIGH et al. 1982). It is, thus, important to analyse temporal variations of activities among the species and beneficial to observe the regional biodiversity.

Limitations and possibilities of the system

From the results above, automatic acoustic monitoring of animal vocalizations at fixed sites can provide continuous estimates of relative abundance, breeding activity, and migration periods, for many types of animals. The system has several advantages when compared with manual sampling procedures, e.g. visual count observation in BOOKHOUT 1996. We list mainly three as follows:

1) It allows continuous 24-hour sampling; 2) it can be used to monitor several sites simultaneously; and 3) it frees the investigator from monitoring all the time.

In the present study, vocal activity was quantified using frequency of vocalization per unit time. Accordingly, it cannot estimate number of calling individuals when animals aggregate in a site and call all together. For these animals (e.g. frogs), it could be possible to use quantification of vocal intensity (i.e. sound energy) effectively as a measure to estimate number of calling males at a breeding site. If fixed recording sites are placed where vocal activity of target species was frequently recorded, the system could also be an effective way to investigate seasonal variation of the population size.

This system also provides detailed information of diurnal and seasonal activities of animals that reflect the influence of day-to-day climatic conditions. However, the system can only monitor continuously up to 13 days in the present setting, due to the capacity of cassette tape. Thus, we need to come to the field and replace the cassette tape every time for monthly surveys. The system can be used for a longer period if we decrease the frequency of recording or decrease the time of each recording with the use of a programmable timer. However, instead of the present system, we are going to introduce digital audio recorders that can record for a much longer period. Besides, the digitally recorded data are much easier to analyse than those by analogue recorders.

In addition to prolonging recording period, if climatic conditions would be automatically simultaneously recorded with long-term vocal activity of a target species, the relationship between weather parameters and activity could be investigated. Temperature is one of the most important factors influencing the activity of ectothermic animals such as amphibians (DUELLMAN & TRUEB 1994). In practice, the thermal environments of terrestrial amphibians are more complex because a variety of factors interact to determine body temperatures (HEYER ET AL. 1994). Therefore, we are planning to develop a new digital system which will simultaneously record various biotic and abiotic factors including sounds, air temperature, humidity, wind speed, and rainfall.

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Table 1: Environmental characteristics of 14 recording sites along a river on Iriomote Island.

Site	Altitude (m)	Distance from the river (m)	Distance from the river mouth (m)	Distance from human activity (m)	Vegetation type
1	2	70	29	116	Mangrove
2	1	14	60	249	Mangrove
3	20	205	185	0	Shrub, cultivated field, settlement
4	21	95	194	10	Secondary forest, cultivated field
5	25	262	653	13	Pine forest, cultivated field
6	40	305	993	33	Pine forest, cultivated field
7	10	228	1345	285	Swampy forest
8	23	230	1391	348	Swampy forest
9	16	165	1560	417	Swampy forest
10	23	103	1647	467	Swampy forest
11	40	82	1667	537	Broad-leaved evergreen forest
12	17	6	1683	593	Broad-leaved evergreen forest
13	23	23	1824	780	Broad-leaved evergreen forest
14	25	14	1853	803	Broad-leaved evergreen forest

Table 2: A list of identified animal species recorded by the sound recording system set in 14 sites along a river on Iriomote Island.

Taxon	Species	
Mammal	Yaeyama Flying Fox	*Pteropus dasymallus*
Bird	Cinnamon Bittern	*Ixobrychus cinnamomeus*
	Malay Night Heron	*Gorsakius melanolophus*
	Black-Crowned Night-Heron	*Nycticorax nycticorax*
	Japanese Sparrowhawk	*Accipiter gularis*
	Crested Serpent Eagle	*Spilornis cheela*
	Slaty Legged Crake	*Rallina eurizonoides*
	White Breasted Waterhen	*Amaurornis phoenicurus*
	Oriental Turtle Dove	*Streptopelia orientalis*
	Emerald Dove	*Chalcophaps indica*
	Red Capped Green Pigeon	*Sphenurus formosae*
	Elegant Scops Owl	*Otus elegans*
	Brown Hawk Owl	*Ninox scutulata*
	Ruddy Kingfisher	*Halcyon coromanda*
	Japanese Pygmy Woodpecker	*Dendrocopos kizuki*
	Ashy Minivet	*Pericrocotus divaricatus*
	Brown Eared Bulbul	*Hypsipetes amaurotis*
	Pale Thrush	*Turdus pallidus*
	Japanese Bush Warbler	*Cettia diphone*
	Japanese Paradise Flycatcher	*Terpsiphone atrocaudata*
	Varied Tit	*Parus varius*
	Great Tit	*Parus major*
	Japanese White Eye	*Zosterops japonica*
	Large Billed Crow	*Corvus macrorhynchos*
Reptile	House Gecko	*Hemidactylus frenatus*
Frog	Indian Rice Frog	*Rana limnocharis*
	Yaeyama Harpist Frog	*Rana psaltes*
	Large Tip Nosed Frog	*Rana supranarina*
	Eiffinger's Tree Frog	*Chirixalus eiffingeri*
	Owston's Green Tree Frog	*Rhacophorus owstoni*
	Ryukyu Kajika Frog	*Buergeria japonica*
	Ornate Narrow Mouthed Frog	*Microhyla ornata*
Insect	Gryllidae	*Loxoblemmus equester*
	Eneopteridae	*Duolandrevus ivani*
		Phaloria ryukyuensis
	Mogoplistidae	*Ornebius kanetataki*
	Trigonidiidae	*Homoeoxipha obliterata*
	Gryllotalpidae	*Gryllotalpa orientalis*
	Cicadidae	*Cryptotympana facialis*
		Meimuna iwasakii
		Platypleura yayeyamana
		Pomponia linearis

Table 3: Frequency of occurrence of vocalizations (FOV) for 22 species in each study period.

Species	Study period										
	sep.04	okt.04	dec.04	jan.05	feb.05	mar.05	apr.05	maj.05	jun.05	jul.05	avg.05
Birds											
Spilornis cheela	,000	,027	,013	,000	,032	,024	,033	,032	,004	,015	,016
Rallina eurizonoides	,050	,000	,000	,000	,008	,000	,056	,029	,000	,000	,000
Amaurornis phoenicurus	,000	,008	,010	,000	,005	,003	,011	,152	,004	,033	,000
Streptopelia orientalis	,025	,071	,005	,000	,001	,000	,011	,029	,016	,039	,078
Chalcophaps indica	,000	,025	,000	,000	,000	,000	,000	,060	,040	,128	,016
Sphenurus formosae	,025	,022	,000	,000	,001	,000	,000	,026	,008	,030	,000
Otus elegans	,550	,231	,068	,022	,070	,089	,300	,269	,206	,337	,188
Halcyon coromanda	,025	,003	,000	,000	,001	,000	,000	,169	,020	,075	,094
Hypsipetes amaurotis	,300	,324	,242	,026	,256	,195	,467	,438	,142	,433	,297
Turdus pallidus	,000	,005	,066	,002	,011	,006	,000	,000	,000	,000	,000
Parus major	,000	,019	,019	,000	,015	,012	,022	,011	,016	,116	,031
Corvus macrorhynchos	,350	,330	,172	,040	,143	,115	,089	,398	,166	,433	,328
Frogs											
Rana limnocharis	,075	,000	,000	,000	,000	,000	,000	,106	,000	,078	,109
Rana psaltes	,650	,069	,000	,000	,000	,004	,278	,000	,000	,000	,000
Rana supranarina	,000	,000	,002	,002	,020	,013	,000	,000	,000	,000	,000
Chirixalus eiffingeri	,375	,184	,241	,176	,218	,247	,344	,109	,154	,248	,266
Rhacophorus owstoni	,000	,003	,170	,048	,075	,004	,000	,029	,000	,003	,000
Microhyla ornata	,475	,069	,107	,006	,074	,010	,000	,160	,012	,078	,031
Orthoptera											
Duolandrevus ivani	,125	,038	,285	,019	,028	,096	,089	,352	,178	,254	,281
Ornebius kanetataki	,650	,190	,057	,000	,000	,000	,000	,000	,000	,000	,000
Cicadas											
Meimuna iwasakii	,150	,319	,015	,000	,000	,000	,000	,106	,000	,006	,000
Pomponia linearis	,125	,022	,000	,000	,000	,000	,000	,006	,008	,021	,031

Table 4: Results of principal component analyses (PCA) of vocal activities recorded in 14 sites along a river on Iriomote Island, among study periods and hour of a day.

Species		PCA score	Study period		Hour of day	
			Factor1	Factor2	Factor1	Factor2
Birds						
(sc)	*Spilornis cheela*		-,062	,365	,636	-,352
(re)	*Rallina eurizonoides*		,489	-,477	-,555	,518
(ap)	*Amaurornis phoenicurus*		,408	,602	,469	,697
(so)	*Streptopelia orientalis*		,558	,280	,646	,131
(ci)	*Chalcophaps indica*		,485	,687	,835	,227
(sf)	*Sphenurus formosae*		,841	,180	,644	,141
(oe)	*Otus elegans*		,913	-,299	-,967	,110
(hc)	*Halcyon coromanda*		,598	,653	,750	,257
(ha)	*Hypsipetes amaurotis*		,644	,283	,954	,038
(tp)	*Turdus pallidus*		-,391	-,025	,722	,528
(pm)	*Parus major*		,302	,535	,801	-,033
(cm)	*Corvus macrorhynchos*		,871	,355	,955	,142
Frogs						
(rl)	*Rana limnocharis*		,775	,340	-,783	-,010
(rp)	*Rana psaltes*		,562	-,800	-,611	,512
(rs)	*Rana supranarina*		-,538	-,093	-,715	-,061
(ce)	*Chirixalus eiffingeri*		,267	-,673	-,960	,065
(ro)	*Rhacophorus owstoni*		-,487	,027	-,919	,051
(mo)	*Microhyla ornata*		,690	-,526	-,858	,264
Orthoptera						
(di)	*Duolandrevus ivani*		,418	,595	-,856	,392
(ok)	*Ornebius kanetataki*		,594	-,743	-,737	,545
Cicadas						
(mi)	*Meimuna iwasakii*		,480	-,178	,791	,483
(pl)	*Pomponia linearis*		,722	-,611	,224	,709
Eigenvalue			12,90	2,88	7,54	5,12
% Explained variance			58,62	13,08	34,27	23,28

Table 5: Frequency of occurrence of vocalizations (FOV) for 22 species in each hour of a day.

Species	Hour of day 0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Birds																								
Spilornis cheela	,000	,000	,000	,000	,002	,000	,000	,012	,017	,025	,037	,119	,061	,082	,082	,035	,025	,000	,000	,000	,000	,000	,000	,000
Rallina eurizonoides	,004	,000	,007	,012	,006	,012	,014	,012	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,016	,022	,006	,011	,014	,024
Amaurornis phoenicurus	,008	,012	,007	,000	,002	,012	,014	,049	,028	,074	,019	,036	,013	,012	,027	,012	,019	,057	,049	,089	,014	,023	,000	,012
Streptopelia orientalis	,000	,000	,000	,000	,004	,036	,043	,037	,026	,074	,028	,000	,025	,012	,027	,023	,017	,046	,016	,000	,000	,000	,000	,000
Chalcophaps indica	,000	,000	,000	,000	,000	,012	,028	,074	,034	,025	,037	,048	,017	,024	,045	,047	,038	,034	,049	,011	,000	,000	,000	,000
Sphenurus formosae	,000	,000	,000	,000	,002	,012	,000	,012	,006	,025	,019	,036	,006	,000	,000	,023	,021	,023	,000	,011	,000	,000	,000	,000
Otus elegans	,241	,386	,217	,329	,196	,250	,078	,037	,004	,000	,009	,000	,000	,000	,000	,012	,004	,023	,041	,222	,261	,364	,222	,376
Halcyon coromanda	,000	,000	,000	,000	,000	,036	,057	,074	,045	,074	,065	,060	,017	,035	,045	,047	,013	,034	,024	,067	,008	,000	,000	,000
Hypsipetes amaurotis	,000	,000	,000	,024	,008	,071	,142	,556	,460	,654	,537	,726	,416	,765	,600	,640	,389	,517	,439	,144	,002	,011	,000	,000
Turdus pallidus	,000	,000	,000	,000	,000	,000	,014	,136	,021	,074	,037	,048	,015	,082	,045	,058	,015	,092	,106	,022	,000	,011	,000	,000
Parus major	,000	,000	,000	,000	,000	,012	,014	,099	,049	,099	,074	,036	,032	,047	,045	,035	,034	,023	,008	,000	,000	,000	,000	,000
Corvus macrorhynchos	,002	,000	,000	,012	,008	,071	,163	,370	,379	,494	,296	,464	,317	,518	,364	,500	,330	,437	,390	,222	,010	,011	,000	,000
Frogs																								
Rana limnocharis	,028	,048	,028	,061	,038	,071	,014	,012	,004	,000	,000	,000	,000	,000	,000	,012	,000	,000	,000	,011	,012	,011	,021	,047
Rana psaltes	,032	,036	,021	,037	,024	,000	,000	,025	,000	,000	,009	,024	,002	,000	,000	,000	,004	,034	,024	,033	,031	,034	,021	,035
Rana supranarina	,006	,012	,007	,012	,018	,012	,000	,000	,002	,000	,000	,000	,000	,000	,000	,000	,002	,000	,000	,000	,010	,034	,000	,012
Chirixalus eiffingeri	,389	,458	,434	,463	,337	,417	,340	,136	,013	,000	,009	,012	,004	,000	,000	,000	,008	,000	,049	,400	,422	,455	,458	,435
Rhacophorus owstoni	,073	,193	,168	,244	,091	,179	,142	,025	,006	,012	,009	,000	,004	,000	,000	,000	,006	,000	,000	,122	,104	,148	,146	,153
Microhyla ornata	,081	,193	,126	,183	,105	,202	,078	,086	,011	,037	,019	,036	,011	,047	,036	,035	,013	,046	,089	,089	,081	,159	,097	,200
Orthoptera																								
Duolandrevus ivani	,219	,373	,238	,354	,179	,286	,163	,185	,036	,049	,028	,060	,021	,082	,109	,174	,069	,218	,154	,278	,187	,409	,285	,353
Ornebius kanetataki	,039	,108	,063	,098	,024	,071	,028	,062	,006	,000	,000	,036	,002	,035	,018	,023	,013	,057	,049	,111	,037	,091	,083	,106
Cicadas																								
Meimuna iwasakii	,002	,012	,007	,012	,004	,036	,021	,074	,056	,086	,083	,107	,055	,106	,082	,105	,032	,172	,130	,078	,002	,011	,007	,012
Pomponia linearis	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,002	,000	,000	,000	,004	,103	,089	,022	,002	,000	,000	,000

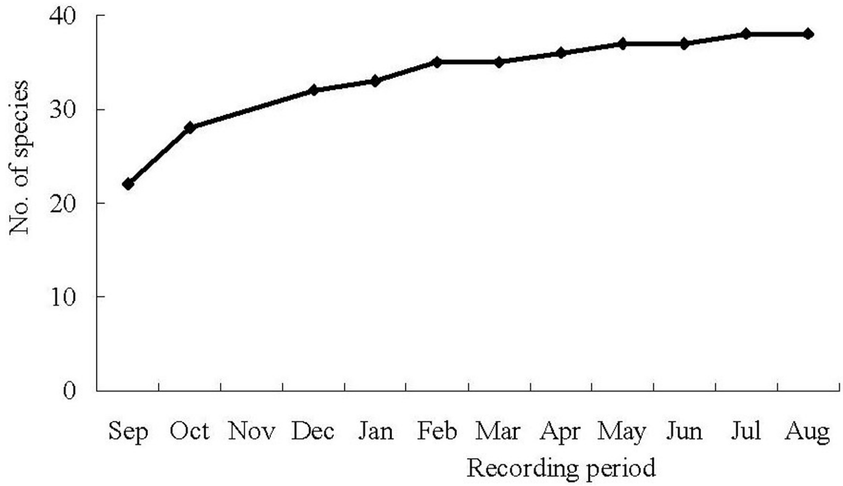

Figure 1: Relationship between recording periods and accumulated number of species identified by recording calls.

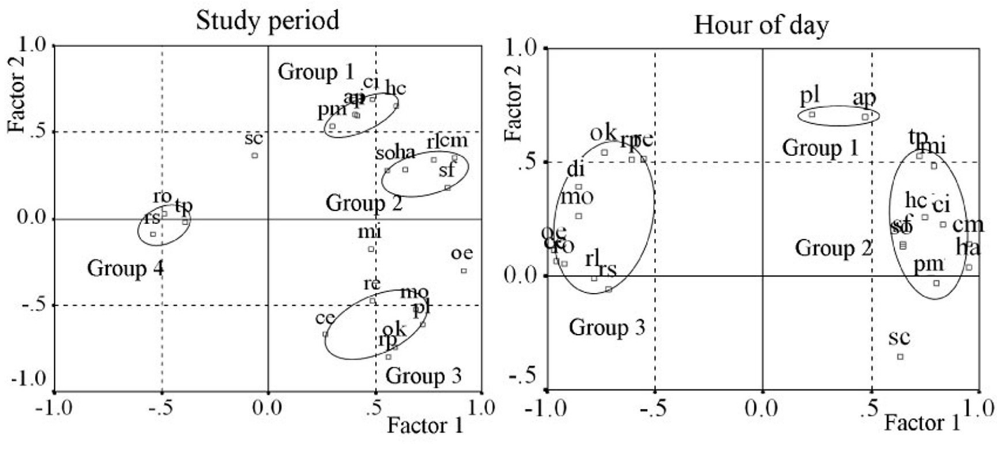

Figure 2: Two dimensional-plots of scores of principle component analyses (PCA) for each species in Table 4, in each study period and each hour of day, on first and second factors showing mainly four and three groups, respectively. Names of species are shown as initials of its scientific names shown in Table 3.