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Sampling Methods for the Study of the Natural Sound Environment in Japan: Consideration of the Sample Time Unit

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Abstract In order to characterize the structure of natural sound environments, it is required to measure scientifically how natural sounds are distributed in the acoustic dimensions and time. Natural sounds observed at a locality are considered to reflect the local biota and biological activities and these sounds change in time. In the present paper, optimum time unit was examined for the study of structure of local natural sound environment. Sound environment was recorded in the beech forest at Togakushi in Nagano. Fifteen-minute recording was analyzed for species composition, number, and frequency of appearance of sound-producing organisms. It was found that minimum necessary time-length was six minutes. The result was applicable to the study of sound environment of the following two locations: pond-shore and laurel woodland in the Ecology Park, museum's field study area, in Chiba.

Key words: Sound environment, sample time, methods, species composition.

As Leroy (1979) commented, sounds we hear in the natural environment seem so complicated and variable that it is difficult to understand the sound world in time and space. However, natural sounds reflect the local biota and biological activities, and those who are familiar with local natural history can tell many things from what they hear in the field. It is important to deal with such sounds scientifically and also to give objective measurements to understand acoustic phenomena in nature. As human activities release tremendous levels of noises into the surrounding environment whether it is in urban areas or country, we increasingly need to interpret natural sounds using adequate measures over appropriate time units to make possible contributions from the study of natural history. It is desirable to apply a sampling method relevant to recent noise studies such as those of office noises (Yamada and Ohmori, 1990).

For the study of the natural sound environment, there are several questions: 1) What are feasible measures of the natural sound environment ? 2) How can sound environment be characterized qualitatively and quantitatively? 3) How can we obtain optimum sample to represent natural sound environment at a locality at a particular time. In the present paper, these questions are examined and a basic method proposed for the analysis of natural sound environment in terms of the composition and number of sound sources.

Materials and methods

The recording of the natural sound environment was made at a mature beech forest in Togakushi, Nagano, in an early morning of 7 June 1991. Later, in 1993, further recordings were made in the Ecology Park, field study area of the Natural History Museum and Institute, Chiba, situated in Chiba City. Two locations were chosen from the woodland of laurel trees and pond-shore by the deciduous woodland, and they are separated from each other by 220 m.

Fifteen-minute recordings were made using digital audio recorder Sony TCD-D10 Pro connected to stereo microphone Sony ECM-MS5 with windshield. Microphone was set up on a tripod at the height of 1.5 m from the ground. Recording level adjustment was set at maximum (i.e. 10 on the recorder) in Togakushi, and adjusted to slightly lower level 9 in Chiba.

Recordist attended the microphone during the recording session and made written notes on the sources of sound and other relevant conditions in the field.

The recording was analyzed with a KAY DSP Sonagraph 5500 in the range of 0–16,000 Hz with transform size of 117 Hz to obtain sonagrams. Whole recording was investigated for every five second period, i.e. 180 periods in fifteen minutes. Sources of sounds were tried to identify as much as possible. Sounds were classified as loud, quiet and distant. Birds' songs and calls emitted in the vicinity were usually loud, but some calls sounded quiet. Those noises heard from the distance were noted as distant. Frequency of appearance of each sound source was obtained by the number of five-second periods where sounds were recorded.

Results

1. Species composition

One of the possible measures of natural sound environment, composition of sound sources was investigated for fifteen-minute recording made at a beech forest in Togakushi. Since the acoustic phenomena change in time, the composition was analyzed in a cumulative manner and presented for the following three classes: loud (Fig. 1), quiet (Fig. 2) and distant (Fig. 3). Here sources of sound were mainly birds with some contribution of flies and plants such as splitting seeds. There were also species which regularly produced sounds and those of irregular participants.

For the loud class, Bush Warbler *Cettia diphone* and Coal Tit *Parus ater* were regular singers, and later Siberian Blue Robin *Erithacus cyane* joined fairly constantly. Other species like Horsfield's Hawk Cuckoo *Cuculus fugax*, Oriental Cuckoo *C. saturatus*, Great Spotted Woodpecker *Dendrocopos major*, Pygmy Woodpecker *D. kizuki* and Great Tit *Parus major* appeared only occasionally.

In the quiet class, Great Tit made calls regularly and some flies often buzzed around in the forest undergrowth. There were also six other birds calling quietly: Siberian Blue Robin, Bush

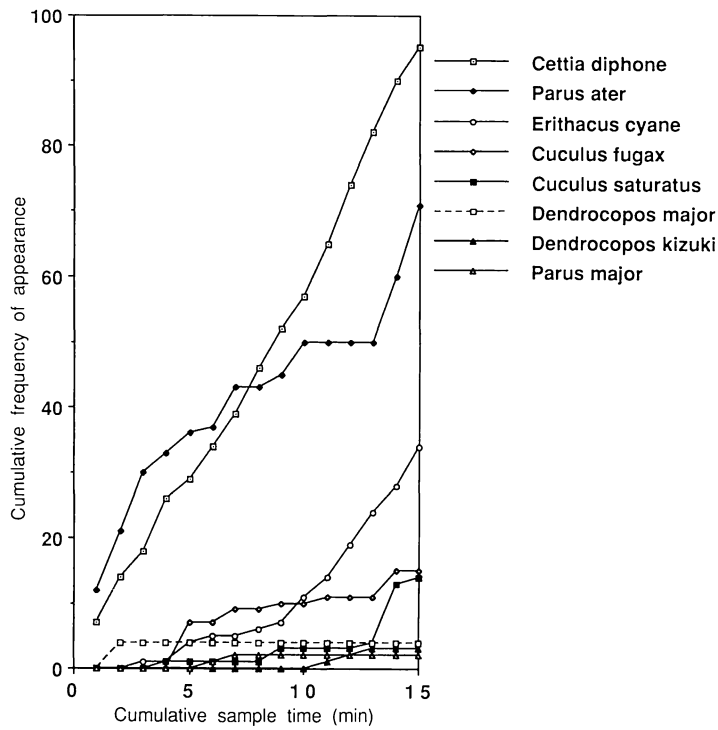

Fig. 1. Species composition in the loud class of the sound environment in the beech forest at Togakushi, Nagano: Frequency of appearance was obtained as number of five-second periods for each sound source.

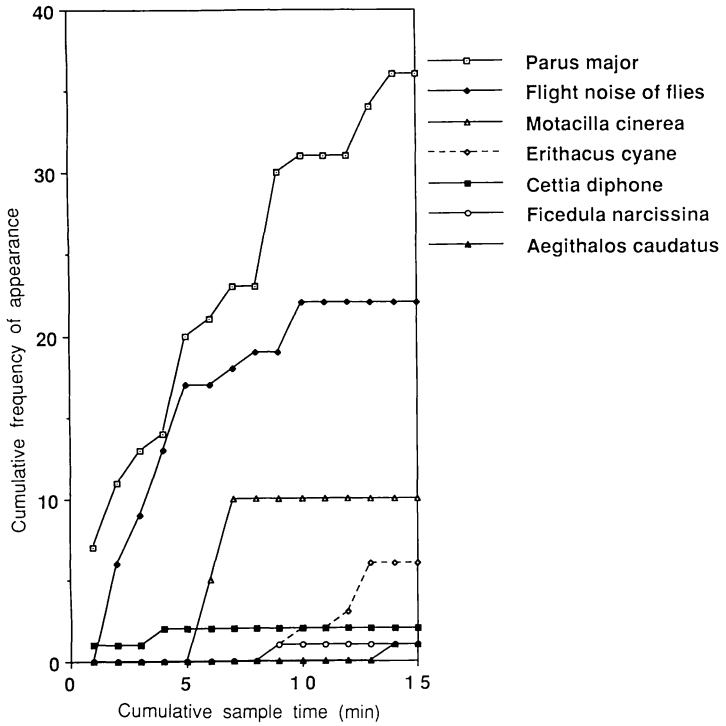

Fig. 2. Species composition in the quiet class of the sound environment in the beech forest at Todakushi, Nagano. (For frequency of appearance, see legend in Fig. 1)

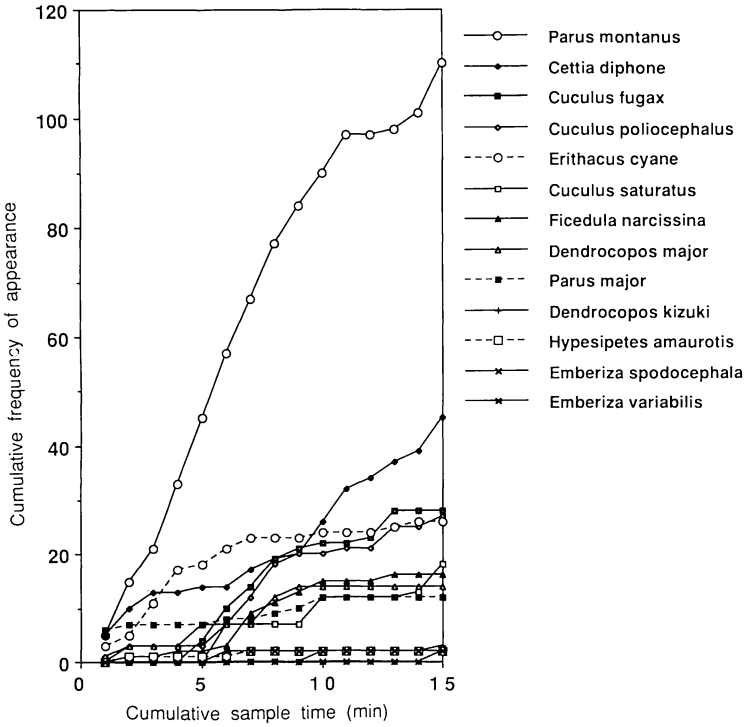

Fig. 3. Species composition in the distant class of the sound environment in the beech forest at Togakushi, Nagano. (For frequency of appearance, see legend in Fig. 1)

Warbler, Coal Tit, Grey Wagtail *Motacilla cinerea*, Narcissus Flycatcher *Ficedula narcissina*, Long-tailed Tit *Aegithalos caudatus*. There were further nine types of sounds, which mainly came from the above species but could not clearly be identified.

The distant class included many different sources apparently originated in the extensive area outside beech forest. It does not mean that such acoustic phenomena are irrelevant to understand the particular sound environment. For example, main singer Coal Tit of distant class was singing in response to that of loud class. However, in general, the distant class was not the core of sound environment at the particular spot. Moreover, sounds travelling the distance through vegetation in varying atmospheric conditions are inevitably subject to

Table 1. Compositions of sound sources of natural sound environment: pond-shore and laurel woodland of the Ecology Park, Chiba, and beech forest at Togakushi, Nagano. (double circle, regular contributor; single circle, occasional contributor)

English name	Scientific name	Ecology Park, Chiba						Togakushi Beech forest
		Pond-shore			Laurel woodland			
		13-Jun	12-Jul	15-Aug	13-Jun	12-Jul	15-Aug	7-Jun
Little Grebe	*Podiceps ruficollis*	○	○	○				
Grey Duck	*Anas poecilorhyncha*		○			○		
Bamboo Partridge	*Bambusicola thoracia*		◎		○	○		
Green Pheasant	*Phasianus colchicus*		○		○	○		
Turtle Dove	*Streptopelia orientalis*		○			○		
Oriental Cuckoo	*Cuculus saturatus*							○
Horsfield's Hawk Cuckoo	*Cuculus fugax*							○
Great Spotted Woodpecker	*Dendrocopos major*							○
Pygmy Woodpecker	*Dendrocopos kizuki*							○
Kingfisher	*Alcedo atthis*	○	○	○				
Skylark	*Alauda arvensis*	○			○			
Barn Swallow	*Hirundo rustica*	○	○				○	
Grey Wagtail	*Motacilla cinerea*							○
Brown-eared Bulbul	*Hypsipetes amaurotis*	◎	◎	◎	◎	◎	◎	
Siberian Blue Robin	*Erithacus cyane*							◎
Bush Warbler	*Cettia diphone*		◎			○		◎
Narcissus Flycatcher	*Ficedula narcissina*							○
Long-tailed Tit	*Aegithalos caudatus*							○
Coal Tit	*Parus ater*							◎
Great Tit	*Parus major*		○					◎
Siberian Meadow Bunting	*Emberiza cioides*	◎	◎	○	◎	◎	○	
Oriental Greenfinch	*Carduelis sinica*	○			○	○	○	
Tree Sparrow	*Passer montanus*	○	○		◎	◎	◎	
Grey Staring	*Sturnus cineraceus*	○	○		◎	◎	◎	
Carrion Crow	*Corvus corone*						○	
Jungle Crow	*Corvus machrorhynchos*			◎	○	○	○	
Bullfrog	*Rana catesbiana*	◎	◎	◎				
Ciccada (Higurashi)	*Tana japonensis*			◎			○	
Ciccada (Aburazemi)	*Graptopsaltria nigrofuscata*			◎				
Flies							○	
Flight noise of insects								◎
Seed splitting								○
Total		10	14	8	9	11	10	12

attenuation and masking. This was likely to affect audition and identification for objective measurement.

In Table 1, composition of sound sources in the loud and quiet classes are listed for pond-shore and laurel woodland of the Ecology Park in comparison to that of the beech forest at Togakushi in Nagano. The sources could be classified as regular and occasional contributors. In the Ecology Park, two locations only 220 m away from each other had several common sound sources. Most of the sources appearing in the laurel woodland were also found in the pond-shore. Deciduous woodland neighbouring the pond provided similar sound sources to the pond-shore sound environment. However, there are sounds specific to certain locations, such as the pond-shore, Little Grebe *Podiceps ruficollis*, Kingfisher *Alcedo atthis*, and Bullfrog *Rana catesbiana*. The difference was large between the Ecology Park and Togakushi beech forest, but the composition did not overlap except for Bush Warbler and Great Tit.

2. Cumulative number of sound sources: sampling time analysis

In Fig. 4, cumulative number of sound sources recorded in beech forest at Togakushi is plotted for cumulative periods from one to fifteen minutes. As for the loud class, recorded number of sound sources quickly increased with time for the first six minutes and appeared to stabilize afterwards. Seven out of the total eight species appeared before seven minutes. The plots fit well with the following logarithmic curve ($r^2=0.965$):

$$y=1.31+6.13\log(x)$$

Even if the sample time is extended longer than six minutes, it would not be likely to have new sound sources added to the first seven. With regard to the quiet class, number of sound sources appeared to follow the similar tendency to that of loud class for the first eight minutes. However, it turned to rise afterwards mainly due to the unspecifiable calls of the species which had most likely appeared in the first six minutes. In the case of distant sources, the number seemed to keep increasing through the sampling time. As already suggested for

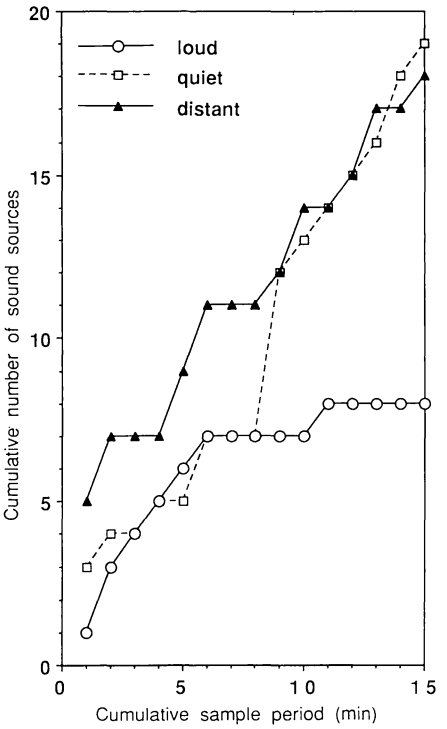

Fig. 4. Sample time analysis: cumulative of sound sources of loud, quiet and distant classes.

distant class in section 1, the wider range of different habitats and difficulty in identification is possible cause of such increase.

Thus, in considering the optimum sample for the sound environment, sound sources of loud and quiet classes are of prime importance. Provided that optimal sampling time is minimum time periods when most of the sound sources are densely contained, the results from Togakushi beech forest suggest that a minimum sampling time of six minutes is required.

To test the optimum sampling time of six minutes, the mode of appearance of sound sources was examined for two locations in the Ecology Park, Chiba. Here only the loud and quiet classes were considered. At the pond-shore, number of sound sources appearing in the fifteen-minute period was ten on June 13th, fourteen on July 12th, and eight on August 15th, and in the laurel woodland nine, eleven and ten correspondingly. As shown in Fig. 5, the recorded species were mostly observed after 8 minutes at the pond-shore (A) and 3–6

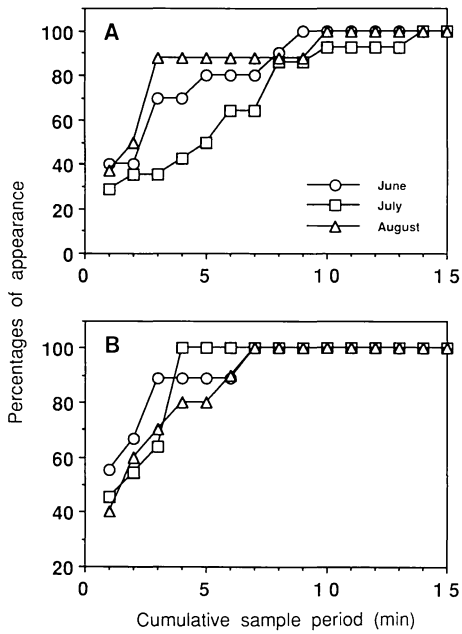

Fig. 5. Mode of appearance of composite species of the sound environment at the Ecology Park, Chiba (A, Pond-shore; B, Laurel woodland).

minutes in the laurel woodland (B). To ensure a thorough sample, ten-minutes or longer may be required. However, the results suggest that over 70–80% of sound sources tended to appear within 6 minutes.

Discussion

The composition of sound sources is one of the adequate qualitative measures needed to characterize structure of natural sound environment. Composition is unique to respective location and provides acoustic clue to the type of environment and locality.

To promote more detailed studies on sound environment, whether qualitatively or quantitatively, an optimal sample time must be used. The longer the sample time is chosen, the more thoroughly the local sound environment will be monitored. However, natural sound environment also changes with time and sometimes varies drastically. Optimal sample time shoud be as short as possible but still contain sufficient information including regular contributors. The results suggest that a six-minute period may be sufficient as minimum sample time to monitor natural sound environment in most cases.

Acknowledgments

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国内サンプルによる自然の音環境の測定法：基本測定時間の検討

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自然の音環境の構造を解明するにあたって，自然の音がどのように音響空間と時間の中に分布しているかを，科学的に測定する必要がある．ある地点において響いている自然の音は，その地域の生物相，ならびにそれら生物の生活を反映するものであり，時間的な変遷をともなうものである．本稿では，ある地点に形成される音環境の構造を調べるにあたって，基本的な時間単位について検討した．自然の豊かな長野県戸隠のブナ林において，その音環境を録音し，鳴声以外の音も含めて何らかの音を確認された生物の種類組成・種類数・頻度から，基本的な時間的な単位を検討した結果，必要最低の時間として 6 分間という目安を得ることができた．この単位時間は，都市化の中で自然の復元を試みる千葉県千葉市の生態園の水辺とシイタブ林の 2 地点などについても，十分適用できた．