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What is the Natural Sound Diversity? A Consideration for the Local Natural Amenity

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Abstract Natural amenity has an ultimate foundation in the conservation of biodiversity in nature and concerns local attributes of natural environment. The present paper attempts to discuss local natural amenity based on a detailed study of natural sounds of familiar environment in the framework of landscape ecology. Being a unit range of local human activities, the primary school block is one of the landscape areas for the study of local environment. Three primary school blocks which differ in landscape qualities and biodiversity were selected from agricultural community, residential area and new town in Chiba City to the east of Tokyo metropolis, and sound environment was monitorred monthly in 1991–1993. Natural sound diversity in terms of number and composition of sound source species was high in the agricultural community and lower in the residential area and much lower in the new town. Such differences in natural sound diversity corresponded with landscape qualities and richness of natural environment. With regard to avian sounds, natural sound diversity was examined in ecological terms: the locality bond and trophic levels. Sounds of species which had the stronger locality bond and occupied higher consumer levels contributed more in the agricultural community and less in the residential area and very little in the new town. The results provide not only a view to evaluate the local sound environment but acoustic indices of local natural environment. For natural amenity, sustainably stable nature based on the optimal local biodiversity and peculiar local attributes is indispensable.

Key words: natural amenity, biodiversity, landscape ecology, natural sound diversity.

The concept of amenity has been developed in different applied fields. Hitherto discussions of amenity tended to be human-centred and poorly based on the detailed knowledge and comprehension of natural environment: invention of artificial devices and simulation of comfortable environment was the main interest. For creation of comfortable environment in human societies, however, it is highly necessary to review our basic stance that we live as a part of nature and that we belong to a particular locality of specific natural background. Natural amenity considers what local nature provides humans with for their survival and safety. There are two important aspects to secure natural amenity. Firstly, natural amenity highly depends on biodiversity which supports sustainably stable nature. Secondly, natural amenity is founded on local attributes which contributes to the locality:

1) Biodiversity

The living world displays a considerable range of variation and differences at a variety of biological levels. Such state of biological diversity is the basic feature of natural environment and is broadly referred to biodiversity. In the well-conserved natural condition, a set of living organisms survive to display the optimal biodiversity in stable manners in terms of number, variety and variability. Such biodiversity is the base of sustainably stable nature.

2) Local attributes

Living organisms are distributed in particular ranges. Some are endemic to an area, others invading. Some stay in the area for life, others stop there seasonally or pass regularly at certain times of the year. They are all bound to local habitats in different ways. Whether it is rural or urban, it is the local attributes that brings forth natural amenity which characterizes the locality.

Natural amenity does not selectively deal with comfortable and familiar components of nature, but exclusively derives from the total living condition granted by the local bio-

diversity. It combines the comfort of human societies with the survival need for both human and other beings. In order to obtain amenity resources to full extent, each locality on the globe should maintain its natural environment enriched with local features.

It has been a common practice to utilize natural sounds for amenity materials. For example, bird songs, insect calls, streams and wave sound are popularly applied to ambient sound broadcasting in town and at home. Fluctuation characteristics of natural sounds have attracted engineers to device a new technology for noise control of indoor environment (Watanabe, 1987; Yamaguchi *et al.*, 1992). Also, natural white noise like waterfall and stream sound is widely used to mask unnecessary noises in public places (Yoshimura, 1990). Further, physiological and psychological studies have revealed some favourable effects of natural sounds with strong implication of sound therapy (Nuki, 1987). These aspects are useful and effective, whereas there is a risk of alienating natural sounds from ecological processes in nature.

So, what are natural sounds primarily in consideration of sound environment? We live among great many organisms on the globe. Many of them are deaf. Yet, some invertebrates such as insects and crustaceans and most of the vertebrates including frogs, birds and primates have evolved a great variety of acoustic behaviour. Sounds are used as indices to monitor safety, food and other resources. They also function as means for communication to space out or contact conspecific individuals, find and associate with mates, bring up offsprings and so on (Sebeok, 1968; Brown, 1975; Leroy, 1979). In conservation biology, natural sounds have survival values and are important resources for sustainable living.

To discuss sound environment, natural sounds need to be investigated in the frame of landscape ecology. The first attempt has been made in a study on the natural sound environment of the three primary school blocks in Chiba City. The primary school block is an administrative area for a municipal primary school to collect local pupils, and can be taken as a unit area of local human activities centred at the school. Land use patterns may characterize individual primary school blocks from agricultural community to urban residential area for example. Primary school block residents tend to associate as family, children, parents, teachers, schoolmates and other social categories. Their activities range from education to recreation and welfare in one hand, and from production to consumption on the other hand.

The present paper presents a view on local natural amenity using data from the above study. Natural sound diversity is introduced as possible environmental index for further discussion towards establishment of the objective method to evaluate landscape quality. Comparison of natural sound diversity is made in the three primary school blocks of different landscape qualities and natural richness. Natural sound diversity is monitorred in terms of number and composition of sound source species. The following four questions will be asked: 1) Are there any differences in natural sound diversity with different landscape qualities? 2) How can we relate natural sound diversity to ecological backgrounds? 3) How can we evaluate local sound environment? 4) What is natural amenity in acoustic aspects?

Study areas

Primary school blocks were chosen from three different areas of Chiba City to the east of Tokyo metropolis (140°6′E, 35°36′N): Hirayama block (HY) from the agricultural area, Tsuga block (TG) from the residential area with several islands of postwar housing development in the neighbourhood of urbanized city-centres, and Takasu-Daiichi block (TD) from the newly developed area in the reclaimed land of Tokyo Bay tidal flat in late 1970's (Fig. 1).

HY was an agricultural community retaining the typical agricultural village landscape, which we used to see in many parts of Chiba. On the plateau, village houses were built surrounded by garden trees, coppices and bamboo thickets. Cultivated fields were found on the higher ground and paddy fields in the valleys. A village separated itself from adjacent villages by woodlands. Despite some changes

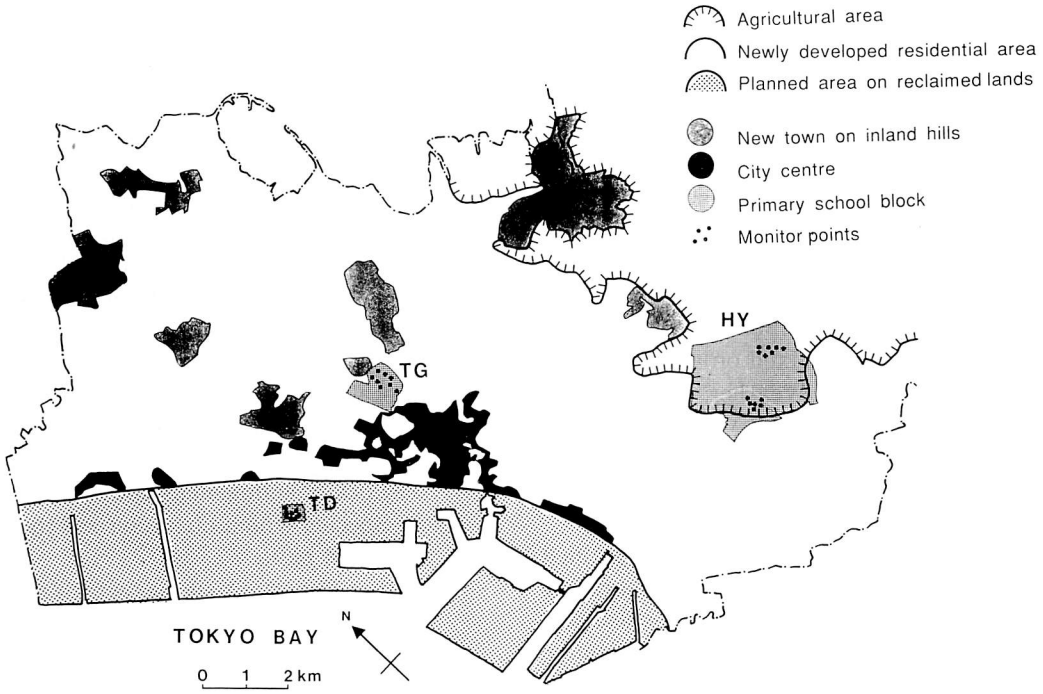

Fig. 1. Three primary school blocks in Chiba: Hirayama block (HY); Tsuga block (TG); Takasu-Daiichi block (TD).

made by construction of a golf course, HY was diverse in landscape containing a variety of natural environment over extensive ranges.

TG gradually developed in the last forty years after the war. The block used to be an agricultural village similar to HY. Now, original cultivated fields and coppices were sacrificed to build low to medium-storied housing in many patches. Yet, garden trees, hedges and fragmentary coppices provided important habitats for living organisms.

TD was a typical new town having no common social background with adjacent local communities previously. The block was planned in compact and convenient manners. Medium to high-storied apartment houses were mainly built with communal facilities to accommodate high population. Public gardens, playgrounds and arrays of street trees at least provided local inhabitants with minimum natural environment. However, they were stereotyped with typical garden trees to create a monotonous landscape. Some environment enrichment facilities like shallow water pools were not in use for safety measures.

For each primary school block, monitor points were chosen to cover different landscape characteristics. In HY, thirteen points consisted of four in coppices, three in temporarily abandoned paddy fields, two in cultivated fields surrounded by village houses and woodlands, two in a village quarters, one in an evergreen conifer plantation of *Cryptomeria japonica*, and one in a bamboo thicket. In TG, eight points included two in cultivated fields, one in an orchard, one in a coppice patch, one in an isolated evergreen woodland, one in a shrine woodland of evergreen broad-leaved trees, one in a housing quarter, and one in a public garden. In TD, eight points were used: six in public gardens and pathways of different sizes, one in an athletic field, and one in a hedge of evergreen broad-leaved trees.

Materials and methods

Three primary school blocks were visited every month from May 1991 to April 1993. Sound environment of respective blocks was monitorred on different dates within a week. Rainy and windy days were avoided. During

the first three hours of daylight, the researcher stopped at monitor points consecutively in the routine order. At each point she carefully listened to ambient sounds for six minutes, covering loud and quiet sounds in the vicinity and loud ones in the distance (Oba, 1994a). As she made written notes of sound sources and other important events, recording was made on digital audio tape Sony DT-90/120 using a digital audio recorder Sony TCD-D10 with a stereo microphone Sony ECM-MS5. The microphone with a windshield was fixed on a tripod at 1.5 m above the ground. Weather, ambient temperature and relative humidity were noted. All the recordings were kept as sound environment recording collection in the museum sound archive.

Sound source species were usually identified on the spot, however later in the laboratory recordings were also examined to check for unnoticed sounds. The list of sound source species was made for each primary school block by pooling data from all the monitor points for the whole visits. Sound source species were assorted according to the group of organisms such as insects, birds, amphibians and mammals. In the present paper, human vocal and non-vocal sounds were excluded from consideration.

In measuring natural sound diversity, we can refer to the method proposed for the analysis of biodiversity. Weight can be given to the relative abundance of species in different aspects, such as size classes, trophic levels, taxonomic groups or growth forms (Jenkins, 1992). Here, with regard to bird sounds, relative abundance of sound source species were analyzed for different categories of the locality bond and also for different trophic levels (see Appendix).

The locality bond of natural sound sources

The locality bond is an index to evaluate natural sound sources for their potential to characterize acoustically the local natural environment. It is neither their numerical popularity nor temporal frequency and duration of natural sound source species seen or heard in the area that determines the locality bond, but their status in terms of local nature conservation and human impact. In application, the status of sound source species were independently checked with each area, that is the respective primary school block in question.

In order to compare different areas with potentially heterogeneous biota, natural sounds were examined for natural elements (I) and human alteration (II) of the local natural sound environment. The natural sound source species were then classified into the following seven categories, which are arranged in the alphabetical order from the highest locality bond (A) to the lowest (G):

I) The natural bond to the locality
  A) Locally most important species
    —Rare, vulnerable and endangered species
    —Locally endogeneus species
    —Species which characterizes the national biota
  B) Other important species which are essential to form the local rural fauna
  C) Species which are considerably adaptable or selective to human presence and urban environment
  D) Novel species
    —Stray species which happen to visit the area from adjacent areas by chance
    —Invading species which are recently noticed for expanding distribution from adjacent areas

II) Human alteration
  E) Naturalized species which were originally distributed in remote areas without possibilities of natural invasion to the locality but brought in at some stage in history to survive successfully in the new habitat
  F) Local residents in captivity. Although this category is not usually considered as diversity index, it is still popular to keep wild species such as songbirds for their famous beautiful songs regardless of the ban
  G) Domesticated and pet species of exotic origins

Trophic levels of natural sound sources

The trophic pyramid indicates peculiar and specific interrelationships with other organisms through food habits. The sound source species were examined for their status in the

food pyramid. In application, those sound source species of the locality bond in the categories of F and G were excluded, as they are fed by humans and disregarded as members of natural ecosystem in the primary school blocks. The following four trophic levels were adopted and arranged in the alphabetic order from the highest level (a) to the lowest (d):

a) The highest consumers (predators feeding on medium-sized animals as large as mice, small birds, snakes and frogs or larger ones),
b) Tertiary consumers (carnivores),
c) Secondary consumers (omnivores, insectivores),
d) Primary consumers (herbivores).

Species at higher trophic levels must be sustained by those of lower levels. The ecosystem with many species at higher trophic levels is thus notable for the complex structure at lower trophic levels. Also, the ecosystem of diverse trophic pyramid is considered to have more complex and unique interrelationships through food habits than that of simpler trophic pyramid.

Results

1. Number and Composition of Sound Source Species

Varieties of natural sounds were observed from different groups of animals. Birds produced songs and calls and often flight noises. Insect sounds included ventral vibration of cicadas, stridulation of crickets and grasshoppers, hoverring and flight noises of flies and bees. Frogs emitted croaking noises, and mammals such as pet dogs and cats were noted for their variable vocalizations.

In Table 1, the number of sound source species is shown for different groups of animals in the three primary school blocks. For the total number, HY recorded the highest number 80, TG the second 53, and TD the lowest 43. For respective groups, HY tended to show the highest numbers and the other two followed. As a whole, birds were clearly the main source of natural sounds, insects came in the second, and pet dogs and cats were always there. However, frogs' sound was totally missing from TG and TD. In HY, the following three frog species were heard: a tree frog *Hyla japonica*, a pond frog *Rana porosa porosa* and a green frog *Rhacophorus schlegelii*.

Table 1. Total number of sound source species.

Taxonomic groups	Primary school blocks		
	HY	TG	TD
Mammals	2	2	2
Birds	49	35	29
Amphibians	3	0	0
Insects	26	16	12
Cicadas	5	4	4
Crickets and grasshoppers	16	10	8
Others	5	2	0
Total	80	53	43

In the study areas, composition of sound source species seasonally changed. Frogs were mainly heard in April-May, cicadas in June-September, and crickets and grasshoppers in June-October. Despite actual changes in the composition of species, birds as a group were noted for their sounds throughout the year.

2. The Locality Bond of Sound Source Species

Table 2 shows the number of avian sound sources in different categories of the locality bond. As some of the sound source species appear in different categories, the total number of sound source species differed from that of Table 1. For example, pigeons *Columba livia* var. *domestica* were likely to appear in different categories of C and G, while songbirds such as the White Eye *Zosterops japonica*, Bush Warbler *Cettia diphone*, and Siberian Meadow Bunting *Emberiza cioides* are in those of B and F. Further, there were different species which were exclusively found in each primary school block. For respective primary school blocks, both block-specific and block-total numbers are shown.

As for category A, there was only one species, Varied Tit *Parus varius*, which characterizes the national biota. In HY their vocalizations were heard both in the breeding and non-breeding seasons, while it was only attributed to winter visitors in TD.

In category B, the primary school blocks were largely different from one another. In HY,

Table 2. Distribution of avian sound sources in different locality bonds categories.

Locality bond categories	Primary school block					
	HY		TG		TD	
	Specific	Total	Specific	Total	Specific	Total
A		1				1
B	18	35	4	20	1	11
C		10		10		10
D		1				1
E		1	1	2		
F		2		3		3
G		1	2	4	3	5
Total	18	51	7	39	4	31

locally essential species were recorded in the highest number of 35, 18 of which were block-specific. TG was the second highest number of 20 with 4 block-specific. TD showed the lowest contribution of 11 species with only one block-specific, however most of them were winter visitors or migrants stopping during migration.

Out of 22 common species throughout the primary school blocks, ten belonged to category C. They were the Barn Swallow *Hirundo rustica*, Brown-eared Bulbul *Hypsipetes amaurotis*, Great Tit *Parus major*, Tree Sparrow *Passer montanus*, Grey Starling *Sturnus cineraceus*, Azure-winged Magpie *Cyanopica cyana*, Jungle Crow *Corvus macrorhynchos*, Feral Pigeon, Rufous Turtle Dove *Streptopelia orientalis* and Oriental Green Finch *Carduelis sinica*.

As for category D, the House Martin *Delichon urbica* was observed in HY and TD blocks during the breeding season.

In the study areas, there were two naturalized species for category E. They were quite different in history. The Bamboo Partridge *Bambusicola thoracica*, a long-term naturalized species from the continent, was heard in HY and TG. The Rose-ringed Parakeet *Psittacula krameri*, a latest naturalized species in urban areas, was heard in TG, where it has been nesting over five years.

As for category F, the White Eye and Siberian Meadow Bunting were invariably heard from cages hung in windows in the three primary school blocks. There was no difference among the people of these blocks in the habit of keeping local wild bird species for their beautiful songs.

Finally, there was a clear difference in the three primary school blocks with category G. In HY, only the Domestic Fowl *Gallus gallus* var. *domesticus*, a descendant of Red Jungle Fowl *G. gallus* of South East Asia, was noticed. However, in the other two primary school blocks, different kinds of exotic pet birds including Homing Pigeons, Budgerigars *Melopsittacus undulatus*, parrots and canaries were additionally heard.

3. Trophic Levels of Sound Source Species

The distribution of avian sound source species at different trophic levels is summarized in Table 3. In all the primary school blocks, the highest consumer level (a) was occupied by one or two sound source species. At the tertiary consumer level (b), HY had approximately 10% of block total sound source species, TG approximately 6% and none in TD. In all the primary school blocks, somewhat 70–80% of the block total sound source species were classified for the secondary consumer level (c) and around 15% for the primary consumer level (d). There

Table 3. Distribution of avian sound sources at different trophic levels.

Trophic levels	Primary school block		
	HY	TG	TD
a	2	2	1
b	5	2	0
c	34	22	19
d	7	6	3
Total	48	32	23

were more or less clear differences in the number of sound source species at each trophic level in a declining order of HY, TG and TD. In particular, the higher two trophic levels (a and b), which can be referred to as general carnivores, were distinctively high number of seven sound source species in HY compared to four in TG and only one in TD.

Discussion

1. Viewpoints of Natural Sound Diversity

The result shows that differences in the sound environment of the three primary school blocks are clearly indicated by the number and composition of sound source species. This measure combines quantitative and qualitative aspects of natural sounds to present a straightforward index of natural sound diversity. Here, the three primary school blocks are arranged in the following descending order: HY, TG and TD. However, we ought to pay close attention to the following properties of natural sound diversity.

Firstly, the number of sound source species is discussed for taxonomic diversity. In the present case, amphibians were only heard in HY. Complete loss of a higher taxon in TG and TD is very serious in consideration of natural sound diversity. Obviously, missing three frogs cannot be replaced by three species of any other taxa. This view is applicable to other levels of taxonomy such as families and genera. Secondly, the composition of sound source species is discussed for ecological significances. Given two different lists of sound source species of the same number, the two sound environments are not necessarily at an equally high level of natural sound diversity. It is the ecological status of individual sound source species that matters to the natural sound diversity:

The locality bond of natural sound sources

Sound source species of the higher category should weigh more than those of lower one. HY is distinguished for the weighted distribution towards higher categories. TG is characterized as clear reduction in higher categories and some increase in the lower ones. TD is noted for great losses in higher categories and gains in the lower ones.

Further, the presence of block-specific sound source species are considered important for the peculiarity of respective local natural sound environment. HY is noted for a very large number of block-specific sound source species regarded as important species which are essential to form local rural biota (B) and none for the lower categories. TG and TD are noted for smaller number of block-specific sound source species in higher category B, while holding three in the lower categories of E and G.

By the present analysis of the locality bond, the differences in natural sound diversity are further augmented among these primary school blocks.

Trophic levels of natural sound sources

The sound environment in which sound source species are distributed at different trophic levels should weigh more than those with sound source species shifted to fewer trophic levels. HY and TG are noted for having their sound source species ditributed at all trophic levels (a–d). TD, however, is different to lack the tertiary consumer level (b).

The sound environment in which more sound source species occupy at higher trophic levels should weigh more than that of lower levels. Considering their ecological roles in controlling and adjusting the ecosystem, general carnivores of the higher two trophic levels (a and b) are indispensable for sustainable presence of their counterparts at the lower two levels. Among three primary school blocks, HY is distinguished for the largest number of 7 general carnivores as sound source species. This indicates that HY has a potential for its ecosystem to support up to 48 sound source species at the lower two consumer levels. TG with the smaller number of 4 general carnivores manages to hold as many as 28 sound source species at the lower two levels. TD with only one general carnivore has a further low potential to keep the smallest number of 22 sound source species in the lower two levels.

Further, the sound environment in which more sound source species are found at respective trophic levels should weigh more than that of few species. Inter-block differences in the number of sound source species are clear at respective trophic levels. Three primary

Table 4. Number of bird species in the combined ranks of the locality bond and trophic level.

Combined Rank	Primary school block					
	Hy		TG		TD	
	Specific	Total	Specific	Total	Specific	Total
Ac		1				1
Ba	1	2	1	2		1
Bb	3	5		2		
Bc	12	24	2	14	1	10
Bd	2	4	1	2		
Cc		7		7		7
Cd		3		3		3
Dc		1				1
Ec		1		1		
Ed			1	1		
Fc		2		3		3
Gc					1	1
Gd		1	2	4	2	4
Total	18	51	7	39	4	31

school blocks can be ordered from the highest HY to the lowest TD via TG. This clearly corresponds with the order of natural sound diversity in view of the locality bond.

In Table 4, sound source species are classified in the combined categories of the locality bond and trophic level. It is speculated that sound source species at the higher trophic level tend to have the higher locality bond. Also, those of the lower locality bond tend to be at lower trophic levels, including omnivores, insectivores and herbivores. Natural sound diversity in this way relates to the ecological background of local nature.

2. Natural Sound Diversity vs. Landscape Quality of the Primary School Block

HY is noted for the highest natural sound diversity. The most extensive and continuous use of lands in complex and diverse patterns by the agricultural community clearly raises landscape quality to the top of the three primary school blocks. Here, the most diverse habitats are available to sound producing organisms and the consequence is enriched sound environment.

TG is halfway between HY and TD in view of natural sound diversity. Under apparent pressure of urbanization, remnant pieces of natural environment which are scattered in and around the residential area manage to maintain landscape quality. Such segmented habitats with patchy resources are the last resort for sound producing organisms. Here, species less resistant to urbanization, such as birds with the higher locality bond, make way for urban birds with strong adaptability.

TD is the lowest in natural sound diversity. The highest human population density and poorest natural environment reduces landscape quality to the lowest. Here, breeding habitats are only available to a small number of peculiar species which are adaptable to the poorest habitat. Winter visitors and temporarily stopping migrants manage to push up natural sound diversity.

As examined above, the landscape quality of respective primary school blocks is somehow correlated with natural sound diversity. Regarded as a landscape area, the primary school block offers food, materials, spaces, climates and other physical conditions to living organisms. Whether they produce sounds as residents or visitors, availability of such items within a primary school block must be guaranteed for their survival. Besides, where human habitation occurs as in the present study areas, the availability of natural resources is subject to land use patterns. The landscape quality evidently differs among the

three primary school blocks. The primary school block with the higher landscape quality offers natural resources sufficiently enough to support more sound producing species in addition to many silent organisms. It is supposed that natural sound diversity offers acoustic indices for landscape qualities.

3. Natural Sound Diversity and Biodiversity

In the study of natural sound environment, only the acoustic phenomena in nature are dealt with. Those species which contribute their sounds to the local sound environment actually represent a small part of local ecosystem contrary to laymen's impression. To consider biodiversity, we ought to include many other organisms which can neither perceive nor positively produce sounds. Also, there are some which keep quiet for some reasons regardless of acoustic abilities. So, how can natural sound diversity based on acoustic species be related to biodiversity including all members of local ecosystem?

What natural sounds primarily indicate is the identity, presence and activities of their source species. In this sense, the comparative study of sound source species in the locality bond and trophic levels simply considers natural sound diversity within local sound environment. However, natural sounds also reflect background interspecific relationships with other organisms outside the acoustic world, such as those of food, social and other contexts. Here, the analysis of sound source species is relevant to local biodiversity as indirect measure.

Firstly, information concerning biodiversity can be obtained from analysis of the locality bond as shown for avian sounds. Natural sound diversity enriched by sound source species of the high locality bond is most meaningful to indicate that local biodiversity is supported by locally specific and unique composition of species.

Secondly, as can be suggested from the present analysis of trophic levels of avian sounds, sound source species at each trophic level are the acoustic sample of local trophic pyramid structure. The ratio in the numbers of sound source species among trophic levels is not necessarily in the pyramid form from the smallest number at the highest trophic level to the largest number at the lowest. In fact, as only the avian sounds are adopted for the analysis, the primary consumer level is relatively smaller in the number of sound source species. However, the important thing is that these sound producing birds are in complex interrelationships with silent organisms through food habits. They are all sustained by each other in the local ecosystem.

4. Evaluation of the Local Sound Environment

In relevance to biodiversity, natural sound diversity is a feasible index to evaluate local sound environment. Analyses of avian sounds demonstrate that the locality bond and trophic levels are useful aspects for evaluation. It can be suggested that analyses of the locality bond and trophic levels are similarly applied to sounds of different taxa. However, there are several points to consider for general application.

Firstly, ranks with regard to the locality bond should be interpreted for future application:

1) In Chiba, some of the urban species are normally distributed, and their presence does not necessarily mean urbanization. Nevertheless, they should be noted for their adaptability to inhabit in towns and residential areas. Contribution of urban species to local sound environment is not more than a base line. In view of biodiversity, we ought to set more values on the sound of those species in higher ranks which are sensitive to urbanization.

2) Addition of sounds of novel species does not always reflect enriched biodiversity. Although adaptability of such species to the new locality or changing environment must be checked, novel species are regarded as changing factors of local sound environment.

3) Sounds of naturalized species may be familiarized during the history of naturalizaion, however their lower status with regard to the locality bond least contributes to the local sound environment.

4) Vocalizations of captive local residents are simulated natural phenomena in tradition-

al acts and play a cultural part in local sound environment.

5) Sounds of domesticated and pet species are clear indices of human habitation.

Secondly, evaluation methods should be revised according to the characteristics of sound environment. For example, in the temperate regions like Japan, seasonal changes naturally affect the sound environment. Some groups of organisms are present all year round, others migrate or die out in some time of the year. Some animals like frogs and insects tend to use their sounds in breeding contexts and set the specific time of year for intense sound production. Others like resident birds constantly emit sounds but change their types between songs and calls for example. In evaluation, it is necessary to deal with such a dynamic changes in seasonal diversity of natural sounds (Oba, 1994b).

Thirdly, a short-term evaluation may be made possible by focusing in avian sounds. Although songs are usually heard in the breeding season, calls are used throughout the year as daily social behaviour. By monitorring calls of resident birds in winter, we can have a reasonable speculation on the sound environment.

5. Natural Amenity and Natural Sounds

To us humans, sound is important in verval and non-verval communication. We enjoy music and natural sounds as pastime and often utilize them as stimulant or comfort in our daily life. So far we may easily accept sound as one of the fundamental fields for amenity. In the age of global environmental crisis, however, it may not be satisfactory to limit our discussion of comfortable sound environment within the conventional scope of noise control and sound amenity in urban areas. We are challenged to present a new vision and measures to deal with sound environment from ecological points of view.

In the latest understanding, conserving biodiversity is the central context of building a sustainable society (World Resources Institute, 1992). Without sustainable living, comfortable life in human part is sooner or later terminated or unreasonably lasts longer in sacrifice of our irreplaceable counterparts. To achieve natural amenity, conservation of natural environment is fundamental. Design of amenity is one of the noticeable opportunities for such attempts as to bridge between sustainable living and comfortable living of human societies. It should urgently be directed towards actual practices to materialize coexistence of nature and man in our familiar environment of urban societies. Recent remarkable development of landscape ecology also recognizes that man and their behaviour are important factors of local ecosystem in view of conservation and restoration (Takeuchi, 1991; Numata, 1967).

Here, I would like to propose that it is the local nature that should supply important sound resources for the design of amenity. Maintenance of rich natural sound environment specific to the local landscape is fundamental. Species of the higher locality bond and those of higher trophic levels provide sound resources of high amenity quality.

However, there are areas where original natural sound environment has been lost. We need to sort out the way to combine restoration and reintroduction works with amenity projects. In order to develop optimally high natural sound diversity in a particular area, it is necessary to conserve natural environment so much as to accommodate locally-specific general carnivores. As can be suggested from the present analysis of trophic levels in three primary school blocks, the more sound source species are conserved at the higher trophic levels (a and b), the more they are complimented by enrichment of sound source species at the lower two consumer levels (c and d). The latter is likely to compose over 85% of total sound source species eventually.

Finally, we ought to discuss the human alteration of local sound environment. Whether or not we enjoy their sounds, all our conducts introducing exotic animals, appreciating beautiful sounds of local resident species, and keeping pets and domestic animals influence the local ecosystem and its acoustic community. To design sound amenity, we need to have different measures for each category:

1) Naturalized species inevitably produce sounds heterogeneous to local sound environment, corresponding to their taxonomic and

geographic distance from the local counterparts. Careless introduction should bring in irreversible change in sound environment.

2) Captive songsters in window cages appear to discourage wild individuals from settling down in the vicinity, as their songs manage to function as acoustic defence of the territory. Despite real sounds produced by living birds, local residents in captivity are not so significant as sound resources from the viewpoint of conservation of local biodiversity. This implies that careless outdoor broadcast of natural sounds is likely to cause confusion and stresses in wild populations particularly in the breeding seasons when they are sensitive to sounds of conspecific or closely related species.

3) Both pet and domestic species are not so essential members of local sound environment as to be relevant to local biodiversity. While they provide a personal or community comfort, their sounds must be controlled to avoid noise dispute.

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自然の音の多様性とは何か？ 地域の自然のアメニティを考える

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自然のアメニティの基礎は，保全された生物学的多様性と自然環境の地域属性に深く関わる．これにはまず自然現象を質的にも量的にも把握することが重要である．本稿は，景観生態学の観点に基づいて，身近な環境における自然の音を調査した結果から，地域の自然のアメニティを考察するものである．小学校区は，地域人間活動と自然の関わりを比較する上での重要単位として取り上げられる．ここでは，景観的にも生物学的多様度についても質の異なる小学校区を，千葉市内の純農村地域・住宅地域・埋立ニュータウン地域から選び，1991年5月から2年間その音環境を毎月モニターした．聴取録音された音の中で，動物の音源について系統別に種類数を比

較するとともに，多様性の観点から分析した．自然の音の音源となる動物は，純農村地域では種類相が最も多様で種類数も多かったが，住宅地域では貧しく少なくなり，ニュータウン地域ではさらに程度が落ちた．すなわち，自然の音の多様性に見られる差は，景観の質や自然の豊かさと対応していた．とくに鳥類の音源構成を，生態学的な観点から分析すると，地域属性については，純農村地域において地域とのつながりの深い種が多く，住宅地域では少なく，ニュータウン地域では非常に少なかった．また，栄養段階別に音源をみると，純農村地域において肉食の種が多く，住宅地域では約半数となり，ニュータウン地域では1種のみで第3次消費者については欠けていた．これらから自然の音の多様性が，地域の音環境の評価ならびに地域の自然環境の音による指標として有益な観点であることが示唆される．自然のアメニティにとって，地域属性と生物学的多様性とに裏付けられた，安定で持続的な地域の自然が不可欠である．

Appendix. The locality bond category and trophic level of sound source species in birds.

Common name	Scientific name	Locality bond category	Trophic level
1 Japanese Night Heron	*Nycticorax nycticorax*	B	b
2 Little Egret	*Egretta garzetta*	B	b
3 Mallard	*Anas platyrhynchos*	B	c
4 Sport-billed Duck	*Anas poecilorhyncha*	B	d
5 Green-winged Teal	*Anas crecca*	B	c
6 Gray-faced Buzzard-eagle	*Butastur indicus*	B	a
7 (Eurasian) Kestrel	*Falco tinnunculus*	B	a
8 Common Quail	*Coturnix coturnix*	B	c
9 Bamboo Partridge	*Bambusicola thoracica*	E	c
10 Domestic Fowl	*Gallus gallus* var. *domestica*	G	(d)
11 Common Pheasant	*Phasianus colchicus*	B	d
12 Little-ringed Plover	*Charadrius dubius*	B	c
13 Feral Pigeon or Homing Pigeon	*Columba livia* var. *domesticus*	C/G	d
14 Turtle Dove	*Streptopelia orientalis*	C	d
15 Japanese Green Pigeon	*Sphenurus sieboldii*	B	d
16 Parrots (Family Cacatuidae)		G	(d)
17 Budgerigar	*Melopsittacus undulatus*	G	(d)
18 Rose-ringed Parakeet	*Psittacula krameri*	E	d
19 Love birds (Family Cacatuidae)		G	(d)
20 Little Cuckoo	*Cuculus poliocephalus*	B	c
21 Brown Hawk Owl	*Ninox scutulata*	B	b
22 Common Kingfisher	*Alcedo atthis*	B	b
23 Japanese Pygmy Woodpecker	*Dendrocopos kizuki*	B	c
24 Skylark	*Alauda arvensis*	B	c
25 Barn Swallow	*Hirundo rustica*	C	c
26 House Martin	*Delichon urbica*	D	c
27 White Wagtail	*Motacilla alba*	B	c
28 Japanese Wagtail	*Motacilla grandis*	B	c
29 Water Pipit	*Anthus spinoletta*	B	c
30 Brown-eared Bubul	*Hypsipetes amaurotis*	C	c
31 Bull-headed Shrike	*Lanius bucephalus*	B	a
32 Daurian Redstart	*Phoenicurus auroreus*	B	c
33 White's Ground Thrush	*Turdus dauma*	B	c
34 Brown Thrush	*Turdus chrysolaus*	B	c
35 Pale Thrush	*Turdus pallidus*	B	c
36 Dusky Thrush	*Turdus naumanni*	B	c
37 Short-tailed Bush Warbler	*Cettia squameiceps*	B	c
38 Bush Warbler	*Cettia diphone*	B/F	c
39 Great Reed Warbler	*Acrocephalus arundinaceus*	B	c
40 Arctic Warbler	*Phylloscopus borealis*	B	c
41 Goldcrest	*Regulus regulus*	B	c
42 Long-tailed Tit	*Aegithalos caudatus*	B	c

Appendix. (continued)

Common name	Scientific name	Locality bond category	Trophic level
43 Varied Tit	*Parus varius*	A	c
44 Great Tit	*Parus major*	C	c
45 Japanese White-eye	*Zosterops japonica*	B/F	c
46 Siberian Meadow Bunting	*Emberiza cioides*	B/F	c
47 Rustic Bunting	*Emberiza rustica*	B	c
48 Black-faced Bunting	*Emberiza spodocephala*	B	c
49 Gray Bunting	*Emberiza variabillis*	B	c
50 Canary	*Serinus canaria*	G	(d)
51 Oriental Greenfinch	*Carduelis sinica*	C	d
52 Bullfinch	*Pyrrhula pyrrhula*	B	d
53 Hawfinch	*Coccothraustes coccothraustes*	B	d
54 (Eurasian) Tree Sparrow	*Passer montanus*	C	c
55 Grey Starling	*Sturnus cineraceus*	C	c
56 Hill Mynah	*Gracula religiosa*	G	(c)
57 Jay	*Garrulus glandarius*	B	c
58 Azure-winged Magpie	*Cyanopica cyana*	C	c
59 Carrion Crow	*Corvus corone*	B	c
60 Jungle Crow	*Corvus macrorhynchos*	C	c