Frog Habitats in the Rural Landscape Known as Yato "dell with paddy fields" in Suburban Area in South Kanto Plain.

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ABSTRACT

Residents of urban areas like to be near rural animals during their daily life, so it is important to conserve the suburban *Yato* landscape in Japan. This study targets the species of frogs that are commonly found in *Yato* paddies. It is necessary to various frogs inhabiting in *Yato*, because frogs are popular among Japanese, who as children enjoy capturing tadpoles and frogs. Its purpose is to clarify how the composition of frog species changes when the functionality of a frog habitat is diminished by urbanization.

The survey, conducted in the Eastern Kanagawa area in central Japan, determined the distribution of each species of frog in grid cells measuring 0.5-km^2. It shows wide distributing species (*Hyla japonica*; they always inhabit in all paddies), the middle range distributing species (*Rhacophorus schlegelii* and *Rana porosa p.*), the limited range distributing species (*R. rugosa*; they are most critical species, since they are recognized only two cells), and so on. Correspondence analysis based on the frog species composition in each cell was performed to ascertain the adaptability of each species to various paddy field conditions. The results allowed us to classify cells into four groups according to the composition of the inhabiting species. And we recognized that the process by which frogs disappear occurs in reaction to either of two patterns of change. As paddy fields are improved by farmland consolidation, *R. rugosa*, *R. ornativentris*, *R. japonica*, and *Bufo. japonica f.* decline rapidly. In plateau areas, as more and more paddies are converted into strong, well-drained fields, only *H. japonica* and *R. porosa p.* remain. But in hilly areas, the species composition becomes only *H. japonica* and *R. schlegelii*. Finally, we discuss the concept of ecological urban design in the context of the conservation of frog species in *Yato* paddies.

Key Words : Amphibians, Rural landscape, Paddy fields, Ecological urban design

I. INTRODUCTION

In Japan, a combination called "rural landscape with rural ecosystem," characterized by paddy field cultivation, is attracting considerable public attention because it is able to satisfy the requirements of both farm production and biodiversity. The "rural landscape and ecosystem" combination consists of paddy fields and woodland that have been cultivated for a long time. The combination, which maintains the cycle of materials as well as a rich biota, is termed "secondary nature." Most Japanese people consider the rural landscape to be the scenery most conducive to relaxation. Today in regional planning, people attach importance to rural landscapes and rural ecosystems as essential for the preservation of Amenity in an urban area.

On the Kanto Plain, *Yato* ("dell with paddy fields") are found widely; typically a *Yato* landscape consists of paddy fields along the bottoms of long valleys along with the wooded sideslopes of the valley. Therefore, *Yato* are considered to represent a unified ecotope. In rural districts, people accumulate experiences from childhood, become sensitive to seasonal variations, and develop their view of nature from their encounters with animals and plants during their daily life. In order for people to live comfortably in the urban districts where there is little rural landscape, it is important to maintain the biota of the remaining *Yato* (Osawa and Katsuno, 2000c). The *Yato* landscape, which is visited by many city dwellers for outdoor recreation of a rural nature, preserves greenery as part of ecological urban design in this area (Osawa and Katsuno, 2000a). Therefore, it is now necessary to study the characteristics of *Yato* paddy fields, which constitute a balanced ecological model, based on the correspondence between the paddy field landscape and the biota that inhabit it, and thus to promote environmental conservation and restoration.

This study targets frogs commonly found in *Yato* with paddy fields. Its purpose is to clarify how the composition of frog species changes when the functionality of a frog habitat is diminished by urbanization. That is, *Yato* paddy fields are considered in terms of the quality of the frog habitat that they provide, and ecological urban design is defined in terms of biodiversity. Therefore, the correspondence between paddy fields and frog species composition in the southern Kanto Plain as well as the causes of negative impacts on the habitat are studied. The reasons for choosing frogs for this study are as follows:

- Frogs are customarily observed in paddy fields, and they are popular among Japanese, who as children enjoy capturing tadpoles and frogs and listening to their croaking.
- Frogs inhabit both *Yato* environments, namely both paddy fields and forests, the former from spawning to the larval stage, and the latter from metamorphosis to maturity. Frogs also characterize the *Yato* (Osawa and Katsuno, 1997).
- Frogs are an important food source for predators (e.g., predacious aquatic insects, snakes, herons, hawks [eastern buzzard hawk], badger, weasel) and are thought to be species supporting each local ecosystem (Blaustein and Wake, 1990).

II. MATERIALS AND METHODS

1. Survey Area

The current status of frogs inhabiting paddy fields in the suburbs was researched by targeting a 360 km^2 area in Eastern Kanagawa Prefecture (Figure 1). The Eastern Kanagawa area is a residential area for people who commute to work in Tokyo or Kanagawa, and it has been progressively developed since the era of high economic growth in Japan. The total area of *Yato* paddy fields in this survey area has gradually decreased since the 1960's (Osawa and Katsuno, 2000c). However, development has been restricted in the suburbs by controls on urbanization, and today the few landscapes having natural *Yato* in this area have been preserved.

The Eastern Kanagawa area is roughly divided into the western plateau area, called the Sagamihara Plateau, and the central/eastern hilly area, called the Tama/Miura Hills. *Yato* landscapes are found both on the plateaus and in the hills. The research area was divided into watersheds: a grid of 0.5 x 0.5 km cells was superimposed on the watersheds of the rivers that rise in the Southern Tama Hills (e.g., the Katabira, Ooka, and Kasio rivers) and on the river basins of the Sakai (except in the north, in Machida City) and Hikichi rivers, which flow across the Sagamihara Plateau.

2. Surveys

Initially, several maps were used, and reconnaissance was conducted beforehand to confirm the distribution and size of all the paddy fields in the research area. The condition of each paddy field, whether poorly drained or well drained, was also recorded. Subsequently, several investigations were conducted in each *Yato* paddy field during the frog-breeding season. In early spring, before puddling for rice transplantation begins, we went around to all the pools in the paddy fields. Egg masses and tadpoles, which have noticeable morphological differences in each species, were visually inspected in all pools during

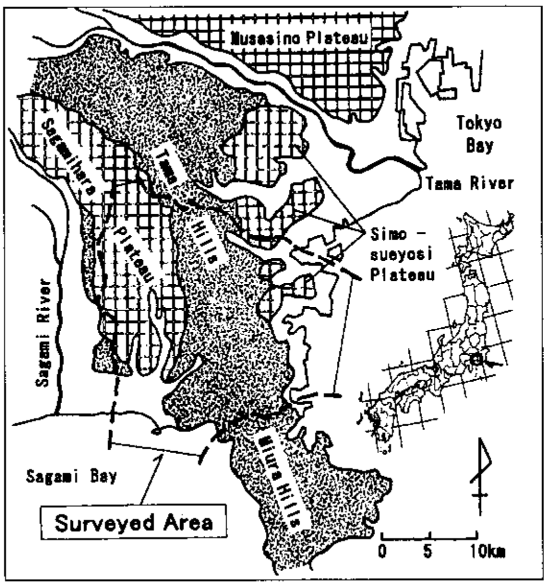

Figure 1. Study area at Tama/Miura hills and Sagamihara plateau in Eastern Kanagawa

Table 1. Number of cells in which each size of paddies was calculated

Landform	Rank of paddy fields size					total cell	Area of paddies per cells (mean±SD)
	≤0.1 ha	0.1-0.5 ha	0.5-1.0 ha	1.0-5.0 ha	0.5-10.0 ha		
Hilly area	14	17	6	7	0	44	0.51±0.62 ha*
Plateau area	4	17	17	36	7	81	1.83±1.95 ha*
tatal	18	34	23	43	7	125	1.37±1.73 ha

*: Area of paddies in tow landform are significantly different (Mann-Whitney U-test. P<0.01)

Table 2. Number of cells in which each frog spesles recorded

species	The position Cell in landform		Conditions od paddy fields in cells		
	Number of cells in plateau area(n=81)	Number of cells in hilly area(n=44)	Number of cells with well drained addies(n=94)	Number of cells with pooiry drained paddies(n=31)	total cells (n=125)
Bufo japonica formous	1 (1%)	13 (%)	0	14 (45%)	14 (11%)
Hyla japonica	81 (100%)	42 (95%)	93 (99%)	30 (97%)	123 (98%)
Rana japonica	0	9 (25%)	0	9 (29%)	9 (7%)
Rana ornativentris	0	11 (25%)	0	11 (35%)	11 (9%)
Rana porosa porosa	19 (23%)	1 (2%)	20 (21%)	0	20 (16%)
Rana rugosa	1 (1%)	1 (2%)	0	2 (6%)	2 (2%)
Rhacophorus schlegelii	11 (14%)	39 (89%)	21 (22%)	29 (94%)	50 (40%)

Table 3. The contribution and the correlation coefficient analyzed by the correspondence analysis

No. of axis	Eigenvalue	Contribution	Cumulative Contribution	Correlation coefficient
First axis	0.573	37.4%	37.4%	0.757
Second axis	0.357	23.3%	60.7%	0.598
Third axis	0.21	13.7%	74.4%	0.459

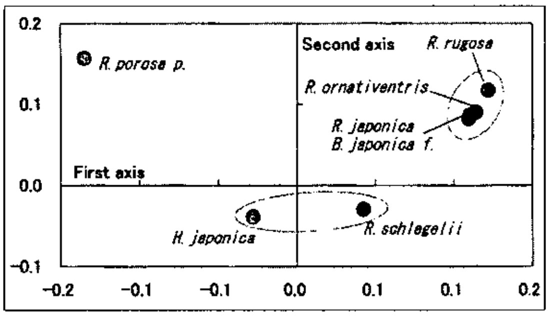

Figure 2. The sample score configuration analyzed data on the presence or absence of frog species in each cell by the correspondence analysis

the daytime. After April, when the cultivation of paddy fields begins, we walked along levees during the daytime and captured tadpoles, metamorphosed juveniles and adult frogs. In addition, we conducted audio strip transects by recording characteristic vocalizations of male frogs at night in each cell. Finally, an inventory of frog species was compiled for each 0.5-km^2 grid cell to prepare the data for analysis.

The investigations were conducted in all target areas during three periods: late winter (February and March), spring (April and May), and early summer (June and July) in 1999. Also contributing to this study was similar research conducted in the Kasio River basin, where many small *Yato* paddy fields remain, in 1998. Two or more studies were conducted in each research area during each period to improve the accuracy of the species inventory compiled for each cell. We spent 32 days in 1998 and 70 days in 1999 for this survey, but the survey times per day varied from a few hours to 10 hours or more. We made sure especially to confirm the absence of any frog species in each cell.

3. Data Analysis

The purpose of this study was to analyze differences among the cells with respect to the species composition, to confirm how many species of frogs have become locally extinct due to environmental changes in the paddy fields. After conducting an analysis of the species composition and the biosystem as described above, the pattern of changes in the biota space were identified and classified by performing a multivariate analysis (Gauch, 1982). However, when studying frog species, it is difficult to rank frog species based on their relative numbers or population densities. Because most adult frogs prefer hiding, they are

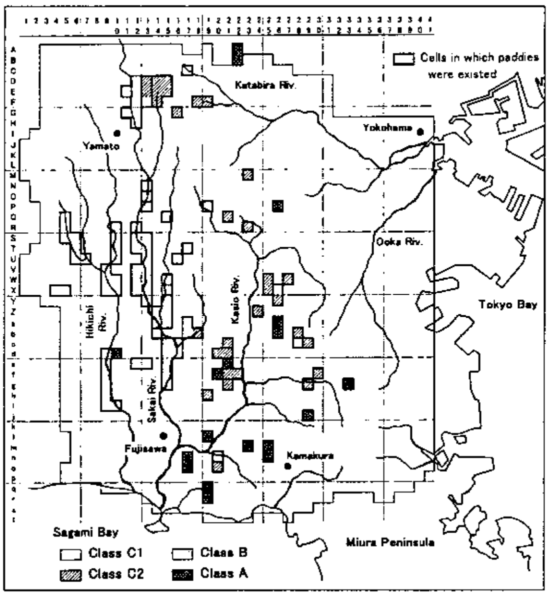

Figure 3. The distribution of the each group of species compositions in survey area. Class A for cells is characterized by inhabiting *R. porosa p.*. Class C-1 for cells inhabited only by *H. japonica* and Class C-2 for cells inhabited by *H. japonica* and *R. schlegelii*.

Table 4. Frog species composition of four groups classified by presence of characteristic species

Landform	Plateau area					Hilly area										
Classification	B		C-1	C-2	A	B	C-1	C-2		A						
B.japonica f.					●					●	●		●		●	●
R.japonica											●	●			●	●
R.ornativentris													●	●	●	●
R.rugosa					●											●
R.porosa p.	●	●				●										
H.japonica	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●
R.schlegelii	●			●	●	●		●	●	●	●	●	●	●	●	●
Cell code *	e9	(Ⅰ)	(Ⅱ)	(Ⅲ)	d10	X26	(Ⅳ)	(Ⅴ)	M23	(Ⅵ)	o17	(Ⅶ)	(Ⅷ)	(Ⅸ)	(Ⅹ)	m23

*Cell code correspond with Fig. 3.
Ⅰ:D12,S12,T12,T13,W12,W13,X12,X13,Y13,Z14,Z15,a14,a15,f9,g9,h9,j9,i10
Ⅱ:E11,E12,F12,F13,G11,G12,H12,N13,O13,P13,Q5,Q15,R5,R10,R12,S5,S6,S10,S13,T8,T10,T17,U6,U7,U10,U13,U16,V9,V12,V13,W9,W10,W15,X4,X5,X9,X10,X15,Y15,a17,b14,b17,c15,c16,d8,d15,d16,e12,e13,e15,f15,g15
Ⅲ:D13,D14,D15,E13,E14,E15,F14,G16,b16　Ⅳ:C17,P19,c28,f21,n20
Ⅴ:F16,F19,O21,R23,W25,W21,X25,Y26,Z24,b28,c21,c29,d20,d21,f22,f30,g21,g29,h19,o20
Ⅵ:P26,a21,f20　Ⅶ:l19,n17　Ⅷ:g33,j29,r19　Ⅸ:m25,n25　Ⅹ:A22,B22,a26,b26,q19

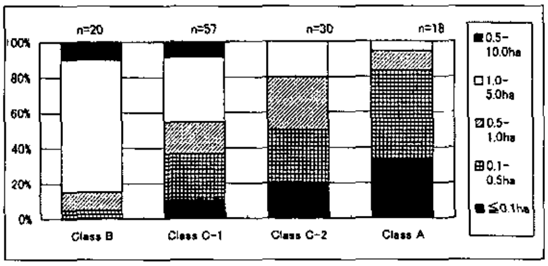

Figure 4. Percentages of paddy field size contained in each group. Paddy field size was ranked in five ranks: ≦0.1ha, 0.1-0.5ha, 0.5-1.0ha, 1.0-5.0ha, 5.0-10.0ha

difficult to observe, and not many tadpoles survive to grow into adults.

To identify the species of frogs that inhabit paddy fields in Japan, the differentiating characteristics of each species' eggs and tadpoles are often recorded, as are the mating calls of the male adults, which are also unique to each species. Therefore, it is easy to collect reliable data on the presence or absence of frog species. Thus, by compiling a species inventory for each cell, similar patterns of species composition can be identified. Data on the species of frogs present in each cell were therefore analyzed, and each species was plotted on a graph using the correspondence analysis method (reciprocal averaging: Hill, 1973). The data for correspondence analysis generally are abundance data. In this study, we applied presence/absence data of frog species to correspondence analysis. This technique is known as quantification theory type III (Hayashi, 1956).

III. RESULTS

Using the results of field surveys and other studies, paddy fields were selected from 125 cells. Most paddy fields located in the plateau area were distributed in succession along the rivers. On the other hand, most paddy fields in the hilly area were isolated from other paddy fields, because they appeared to be small paddy fields extending to the ridges. There were few paddy fields left in the low-lying areas in the easternmost area that faces Tokyo Bay and is being progressively urbanized. The area of paddy fields in each cell was calculated on a map with a scale of 1:10,000. The total area of paddies in the surveyed area was about 170 ha. The numbers of cells that contained paddy fields of certain sizes indicated patterns that differed between two types of landforms (Table 1). In the hilly area, many of the cells had small paddy fields (0.51±0.62 ha/cell, n=44, mean±SD), and most cells indicated 0.5

Table 5. Number of cells in which each group classified by frog species composition

Classification	Pateau area		Hilly area		Total cells
	Number of cells with well-drained paddies	Number of cells with poorly drained paddies	Number of cells with well-drained paddies	Number of cells with poorly drained paddies	
Class A	0	1 (33%)	0	17 (61%)	18
Class B	19 (24%)	0	1 (6%)	0	20
Class C-1	51 (65%)	1 (33%)	4 (25%)	1 (3%)	57
Class C-2	8 (10%)	1 (33%)	11 (69%)	10 (36%)	30
Total cells	78 (100%)	3 (100%)	16 (100%)	28 (100%)	125

ha/cell or less. In contrast, the plateau area had many cells with larger paddy fields (1.83±1.95 ha/cell, n=81), and most cells indicated a higher rank (1.0 to 5.0 ha/cell).

Seven native species of frogs were identified from the paddy fields in the cells (Table 2). H. japonica inhabited nearly all cells, and R. schlegelii inhabited 40% of the cells, but other species inhabited smaller numbers of cells or only a few. Especially, *R. rugosa* could be observed in only two cells. *R. japonica, R. ornativentris* and *B. japonica f.* tended to be found in cells in the hilly area and cells with poorly drained paddies, and *R. schlegelii* had a comparatively similar tendency. However, *R. porosa p.* indicated the opposite tendency, leaning toward cells in the plateau area and cells with well-drained paddies. In addition to the indigenous species, we identified two foreign species (*Rana limnocharis limnocharis* and *Rana catesbeiana*).

To analyze communities of native frogs, a correspondence analysis was conducted according to the species composition (presence/absence) in each cell. As a result, the correlation coefficient of first and second axes was more than 0.5 (Table 3). The cumulative contribution of these two axes was calculated as 60.7%. Therefore, these axes explain about 60% of the variance in the data. Several configurations were plotted on the first and second axes based on the score that each species received (Figure 4). First, the close proximity to one another of *R. rugosa, R. ornativentris, R. japonica* and *B. japonica f.* were reflected by the positive high scores. It is considered that these species have similar habitat requirements for paddy conditions. Second, the position of *R. porosa p.* was, in contrast, the negative high score of the first axis. Third, the positions of *H. japonica* and *R. schlegelii* were low scores of the first axis and negative scores of the second axis. Since *R. schlegelii* indicates a positive score of the first axis, it seems that the habitat requirements of *R. schlegelii* are near those species such as *R. japonica, B. japonica f.* and so on.

We tabulated the species composition in each cell in the hilly area and in the plateau area, based on the results of the correspondence analysis (Table 4). We identified four groups: Class A for the species *R. rugosa, R. ornativentris, R. japonica* and *B. japonica f.*, Class B for *R.porosa p.* and Class C for the absence of *R. japonica, B. japonica f., R.porosa p.* and so on. Class C was divided into two groups: Class C-1 for cells inhabitated only by *H. japonica* and Class C-2 for cells inhabited by *H. japonica* and *R. schlegelii.*

Figure 3 shows the distribution of each group in the surveyed area. Most cells of Classes A and C-2 were located in the hilly area, but some of Class C-2 was located in the plateau area near the hilly area. Most cells of Classes B and C-1 were located along the Sakai River and Hikichi River in the plateau area. The number of cells with well-drained paddies and the number with poorly drained paddies were calculated in each group (Table 5). It was recognized that most cells of Classes B and C-1 were occupied by well-drained paddies, whereas most cells of Class A were occupied by poorly drained paddies. Fig. 4 shows percentages of paddy field size contained in each class. The paddy fields in cells of Class A were very small, most being smaller than 0.5 ha. In contrast, about 85% of the cells in Class B had large paddy fields (1.0 ha or more).The paddy field sizes in Classes C-1 and C-2 tended to fall in between the Class A and Class B sizes.

IV. DISCUSSION

1. Changing Patterns of Species Structure of Frogs

Using a multivariate analysis of the frog species composition of the paddy fields in each cell, we arrived at four groups of frog communities. The presence or absence of frog species in each of these groups was determined in order to confirm each species' adaptability and tendency to inhabit in each paddy condition.

Class A, characterized by *R. rugosa, R. ornativentris, R. japonica* and *B. japonica f.*, was recognized mostly in cells with small, poorly drained paddy fields scattered about the hilly area (Table 5; Figure 3; Figure 4) that were not included during farmland consolidation. This suggests that these frog species cannot live in well-drained paddy fields (Table 2). However, we dont know what these species dislike about large paddies. Because large paddies have already been subsumed by farmland consolidation in this survey area, nothing is left except for small paddy fields with poor drainage.

Class B, characterized by *R. porosa p.*, was recognized only in cells with large, well-drained

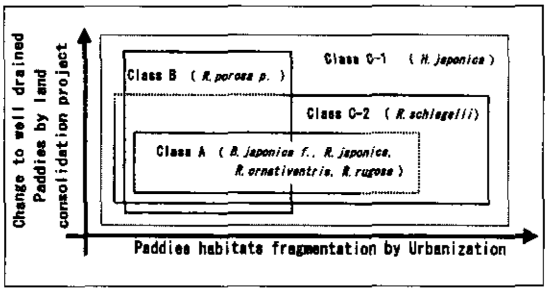

Figure 5. Model of declining patterns for frog species in south Kanto Plain. Change in agronomic practices was caused mainly in plateau area. Habitats fragmentation by Urbanization was caused mainly in hilly area

paddy fields along rivers in the plateau area. Since Class B does not have cells with small paddies, it is guessed that *R. porosa p.* cannot live in small paddy fields (Figure 4). This difference in the paddy sizes in cells distinguishes Class B from Class C-1.

Class C is considered to represent the changing state of frog communities by the decline of *R. rugosa, R. ornativentris, R. japonica, B. japonica f.* and *R. porosa p.* What distinguishes Class C-1 from Class C-2 is the absence of *R. schlegelii* (Table 4). Since *R. schlegelii* was observed mostly in cells in the hilly area and in poorly drained paddy fields (Table 2), it was considered that this species is less apt to inhabit well-drained paddy fields than is *H. japonica.*

On the basis of each group characteristic, we created a model (Figure 5) to show the correspondence between the change in agronomic practices by farmland consolidation and urbanization. Urbanization reduces the land area used for paddy fields and isolates one paddy field from another. Both these phenomena are thought to negatively impact the native species of frogs. Under these influences, the species composition changes.

In the first case, when urbanization of an area is delayed, there are typically several clusters of large paddy fields, and most of them are well-drained; the species (*R. rugosa, R. ornativentris, R. japonica* and *B. japonica f.*) that characterize Class A disappear at an early stage. Then, *R. schlegelii*, which stops spawning in strong, well-drained paddy fields (Osawa and Katsuno, 2000b), disappears. Therefore, these fields shift to Classes B and C-1, having the species *R. porosa p.* and *H. japonica.* After the paddy fields have been further improved and nearly all have been converted into strong, well-drained paddies, the species composition (Class C-1) includes only *H. japonica*, which is able to inhabit such paddies (Fujioka and Lane, 1997). *H.*

japonica showed the most adaptability in this study, since it was able to inhabit fields in areas of farmland consolidation. This pattern is recognized in the plateau area in this study area.

The second case is when a paddy field has not been subsumed by farmland consolidation, but has been isolated from others and reduced in size somewhat because of urbanization. In this case, *R. porosa p.* disappears, and the species composition shifts to Classes A and C-2. The composition may finally shift to Class C-2, which consists only of the species *H. japonica* and *R. schlegelii*. The factors involved in a shift from Class A to Class C-2 are not clear in this study, but we guess that the decrease in breeding opportunities due to the isolation of habitats will have an influence on the species that characterize Class A. This pattern is recognized in the hilly area in this study area.

The correspondence between the environment of the paddy fields in the *Yato* areas in the suburbs and the status of the frog species was also examined. The results show that the pattern of species disappearance caused by the change in agronomic practices is different from the pattern caused by urbanization. However, the two causes really are thought to act together. Frog habitats in the suburbs may finally deteriorate to such an extent that only the Class C-1 habitat, inhabitable only by *H. japonica*, remains. The present research shows that the patterns by which some species become extinct differ according to the geographical location of the habitat, namely, a plateau area versus a hilly area. This difference suggests that, as time passes, the changes in agronomic practices and farming in the suburban and urban districts will differ according to the topography of the region.

2. Frog Conservation and Landscape Architecture

Paddy fields in Japan also serve as frog habitats. Paddy fields are cultivated and irrigated before rice planting every year, thus ensuring that open shallow waters will be available where the tadpoles can live comfortably and grow safely before the early metamorphosis period. The seven native species identified during the present study reproduce mainly in paddy fields (Maeda and Matsui, 1989) and, perhaps, used to comfortably inhabit most *Yato*. Nevertheless, changes in farming practices and urbanization have caused the deterioration of paddy fields in *Yato* as good habitats for frogs.

In this study area in the suburbs of Eastern Kanagawa, most of the target research area (a total of about 1,300 cells), except for 125 cells still containing paddy fields, has been urbanized. It is now either residential land, dry farmland or woodland without paddies. Such small patches of habitats are often occupied, but are associated with higher probabilities of extinction (Verboom *et al*., 1993). Hitchings and Beebee (1998) reported the loss of genetic diversity in the common toad (Bufo bufo) in urban populations isolated by habitat fragmentation. It is feared that habitat fragmentation in this study area has had a similar negative effect on the frog population. For the conservation of amphibians, it is therefore important to preserve interconnecting habitats and populations in the wider regional area with consideration to the wider meta-population (Green, 1997). Additionally if frogs can immigrate along corridors into neighboring *Yato*, so can other small animals (e.g., newts, snakes, turtles and small mammals).

The purpose of ecological urban design for the southern Kanto plain is to build a city that includes natural *Yato* rice fields that biota such as frogs can inhabit. If frog species are to be conserved or restored by propagation in the *Yato* paddy fields, several measures must be planned with respect to land use. This research has shown that appropriate design concepts for conserving frog habitats differ depending on whether the habitat is in a plateau area or a hilly area. Thus, the goal of frog species conservation must be taken into account in conservation design. We conclude that some well-drained paddy fields must be changed into poorly drained fields in plateau areas, and separated habitats in a *Yato* area must be interconnected via habitat corridors in hilly areas. Osawa and Katsuno (2001) reported that *R. ornativentris* and *R. japonica* had dispersal capabilities of about 500m or more in a hilly area, so reservation of spawning sites at intervals of about 500m was effective for conserving both species. It is important to accumulate such studies on migration abilities of frog species to format an ecological network. The presence of frogs living and reproducing in *Yato* paddy fields is important not only from the viewpoint of the biodiversity of frogs, but also from the point of view of cultural and spiritual values, such as tadpole catching by children and listening to the croaking of frogs. In an urban area, visiting a *Yato* paddy field in which frogs and other rural fauna live is a pleasure, a comfort and also an opportunity to play as well as to learn about the environment (Osawa and Katsuno, 2000c). The unity of various frogs coexisting with human urban activities may be a future image of an urban Japan blessed with harmony and calmness.

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