Habitats of frogs and toads that consists of the combination of a paddy field with an irrigation canal, a levee embankment grassland and a forest in a rural landscape of Japan.

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Abstract: Paddy fields can be roughly divided into 3 types according to the abiotic environmental potential and the presence of forests in Japan. Valley-bottom paddy fields and lowland paddy fields are substitutional wetland that has been converted from a natural wetland, and terraced paddy fields are created wetland in dry land. It is remarkable that various species of frogs and toads live in the paddy field though this is a space of the crop production. The long expansion of the edge line between the paddy field and the forest is one of the key factors affecting the richness of species composition of frogs and toads in valley-bottom paddy fields and terraced paddy fields. The forest-paddy field complex formed along the edge line is important habitats for forest-dependent frogs and toads. Moreover, various semi-natural grasslands such as levees, farm roads, waterway walls, verge meadows and fallow fields become biotopes for frogs and toads which usually inhabit grasslands. In particular, levee embankment grasslands in terraced paddy fields influence them positively. The irrigation canal is an effective refuge site for frogs to escape from predators. Levees bordering irrigation canals are suitable habitats for frogs and toads because the traditional irrigation canals such as a dugout earth waterway has a diversity of environments. To conserve the biodiversity of frogs and toads in a rural landscape, it is importance to preserve and restore the combination of paddy fields and other landscape elements.
Keywords: substitutional wetland, abiotic environmental potential, landscape element, amphibian

1. Introduction

Frogs and toads are the symbols of wildlife in the rural landscape of Japan. Moreover, they are commonly found in the paddy fields. Frogs and toads are not the only small animals that live in the paddy fields; however, ‘There is a frog and a toad in the paddy field’ is not an exaggeration to say the cultural and mental scenery for Japanese people. They are most closely associated with the fields in the minds of Japanese people. Japanese people have acquired the sense of the seasons and the nature experience in the childhood by hearing chorus of frogs in early summer and capturing tadpoles in spring, etc. On the other hand, since frogs and toads are amphibians, both water and terrestrial habitats are necessary in their life history, excluding completely aquatic species. It is an important point because it is impossible for frogs and toads to survive if either of these environments is absent. Then, does the paddy field that has both environments in the rural landscape of Japan greet eyes of frogs and toads that have such a habitat requirement as what space? The relationship between the paddy fields and the landscape elements that surround them has been discussed in this report from the perspective of finding suitable habitats for frogs and toads.

2. The developmental history of paddy fields on ecological value

Japanese agriculture is predominantly dependent on the cultivation of rice and has been developed on a basic ecosystem in an environment characterised by clement moist conditions of the East Asian monsoon climate. As a result, a unique rural landscape that consists of a mosaic of paddy fields, grasslands and forests has been formed. Certainly, these rural landscapes were not suddenly formed. Land has been greatly remodelled over a long time (Table 1). This requires enormous manpower, up to the engineering level, in order to adapt and control the characteristics of the natural environment of Japan. A general view of the developmental history of the paddy fields in Japan shows that the ecological location, where the reclamation of the paddy fields is possible, has been gradually expanding because of flood control and irrigation (Hidaka et al., 2008, Okubo et al., 2008).

The first major turning point of ecological value is the conversion of a natural wetland, where the groundwater level is high, to a paddy field. This conversion has been applied to small and medium-scale rivers that often do not flood and to the bottom of small valleys. Next, mesic land on an alluvial plain in a basin was selected the target of reclamation by developing the irrigation system such as irrigation canals and reservoir etc. in the Nara and Heian eras. Additionally, the wetlands in floodplains and the delta regions of larger rivers were converted to paddy fields by a large-scale flood control earthwork from the medieval period to the Edo era. As a result, the majority of the original natural wetlands were replaced by paddy fields, except for the areas surrounding the lake and the uncultivated fields in Hokkaido. This is the reason why the paddy fields are called ‘substitutional wetland’ in Japan. The second turning point was the expansion of the paddy fields into the dry land by digging long irrigation canals in the Edo era. As a

result, the paddy fields were extended to the foot of mountains and surfaces of plateaus in various areas of Japan. In particular, the expansion of terraced paddy fields in the middle and end of the Edo era was remarkable. Because of the adequate precipitation brought by the East Asian monsoon, paddy fields were reclaimed to the maximum limit of land in Japan. Thus, we can see paddy fields everywhere in the rural landscape.

3. Status of frogs and toads in each paddy field type

As described above, the paddy fields are a man-made environment. There were 3 types of reactions of the biological community as a result of the conversion of wilderness to agroecosystem and rural landscape by human activities. First, there was a group that was not able to survive in the new environment, second, a group that was largely unaffected, third, a group that expanded their range of distribution by actively adapting to the new environment. This final group includes organisms that have an advantage because they can adapt to man-made environments such as paddy fields, grasslands and coppice forests, etc. It is thought that these organisms require an initial stage in vegetation succession as a habitat or as a breeding space. Most species of frogs and toads that breed in standing water bodies are included in this group. The appearance of the paddy fields that are shallow, sunny and temporary standing water bodies in rural landscape should have had a big impact on the habitat distribution of frogs and toads. Several frogs and toads inhabit the current rural landscape. Specifically, 4 family 10 species including 4 subspecies, shown in Table 2, are known as native species that breed in standing water bodies that include the paddy fields in Honshu, Shikoku and Kyushu in Japan. There are 5 endemic species found only in Japan. In contrast, there are only 3 species, *Rana tagoi tagoi*, *R. sakuraii* and *Buergeria buergeri*, that do not breed in the paddy field in Honshu, Shikoku and Kyushu.

However, various forms of paddy fields exist, as described in the developmental history section (Table.1). The ecological traits of the paddy fields are primarily determined by their geographical features. When a paddy field is divided, from the perspective of a habitat for frogs and toads, the following two are thought to be the main axes. That is, was the original location a wetland, where the groundwater level is high, or a dry land? And, is it adjacent to the forest in a hilly area, at the foot of a mountain, etc. or are there no forests in the surrounding area? In particular, because the water status of the paddy fields during the non-irrigation period is controlled, the dry or wet conditions of the location, as an abiotic environmental potential, are important. Moreover, the presence or absence of adjacent forest determines the possibility of inhabitation by forest-dependent amphibians. When a matrix of these 2 axes is prepared, the paddy field is largely classified into 4 types. Since a paddy field type that is not adjacent to a forest and is in a dry location does not usually exist, they can be generally classified into 1 of the 3 types (Table 3). The typical landscape of each paddy field type is valley-bottom paddy fields, terraced paddy fields and lowland paddy fields, respectively. In particular, valley-bottom paddy fields and lowland paddy fields are substitutional wetlands in locations that were originally assessed to be wetland vegetation.

Osawa (2008) compared the species composition of frogs and toads at some domestic investigation sites and reported that the biodiversity of paddy fields is in the order: valley-bottom paddy fields > terraced paddy fields > lowland paddy fields. That is, the species composition is richest in valley-bottom paddy fields, which forms a forest-paddy field complex on substitutional wetlands. It is thus, believed that the original fauna of frogs and toads is maintained in valley-bottom paddy fields. On the other hand, the species composition was the poorest in lowland paddy fields that were not mixed with forest, even though they were originally located on natural wetlands such as floodplains and deltas. The species composition of frogs and toads was poor in lowland paddy fields because only few species can inhabit the area, highlighting the negative impact of modern land consolidation with improved drainage and industrial commercialisation of irrigation system (Fujioka and Lane, 1997, Hasegawa et al., 2000). It is necessary to pay attention to the fact that the species composition of frogs and toads in terraced paddy fields is almost as rich as that in valley-bottom paddy fields, though terraced paddy fields were originally dry land in which amphibians cannot breed. This is the evidence that frogs and toads have expanded their habitat distribution to reclaimed paddy fields.

4. Importance of the combination of paddy fields and other landscape elements for inhabitation by frogs and toads

1) The combination of a paddy field and a forest

For forest-dependent amphibians, the existence of paddy fields as water bodies for breeding and forests that are biotope for non-breeding period is indispensable. Therefore, valley-bottom and terraced paddy fields with the forest-paddy field complex are important habitats for them. However, they do not migrate deep into the forest during the non-breeding period. For instance, the distance travelled into the forest is 100 m or more for *Rhacophorus arboreus* (Kusano, 1998), about 200 m for *Bufo japonicas formosus* (Kusano et al., 1995), and about 250 m for *R. japonica* and *R. Ornativentris* (Osawa and Katsuno, 2001). There are no forest-interior species in the fauna of frogs and toads in the rural landscape of Japan. That is, only the peripheral part of the forest near the paddy field is utilised by the

Table 1. The developmental history of paddy fields in Japan

division in age	the main object of reclamation and land consolidation of paddy fields	the characteristic of paddy field ecosystems
end of the Jomon period and the Yayoi period (from the 1st century at B.C. to the 3rd century)	・a damp area in along small and medium-scale river and a bottom of small valley ・marsh in a little hollow in the foot of a mountain	ill-drained paddy field where groundwater level is high
the Tumulus period (from the 4th century to the 6th century)	・gradual slope in the foot of a mountain	introduction of well-drained paddy field to the locattion of soil type with surface water
the Nara and Heian eras (from the 7th century to the 12th century)	・an alluvial plain in a basin	compartmentalization of paddy fields and construction of irrigation system such as reservoir etc.
the medieval period (from the 13th century to the 16th century)	・a floodplain in along small and medium-scale river ・unreclamation area in Kanto and Tohoku region	improvement of irrigation system with flood control
the Edo era (from the 17th century to the 19th century)	・dry land in the foot of a mountain and hilly area ・a floodplain and delta in the middle and downstream part of large river, and a tideland	reclamation of terraced paddy fields in dry land
the modern era (after the 20th century)	・uncultivated field in the north from Tohoku region ・a paddy field of old division	expansion of paddy fields to dry land by large-scale irrigation canal
(after the 1950's)	・brackish water region ・paddy field groups of in agriculture promotion area	improvement of drainege efficiency, and large-scale compartmentalization

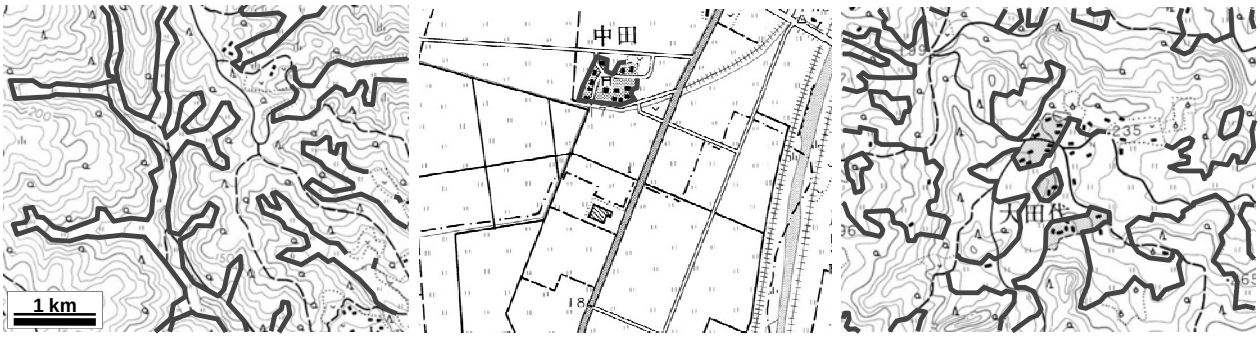
(From Hidaka et al., 2008 and Okubo et al., 2008)

Table 2. The native species list of frogs and toads that breed in paddy fields in the Honshu, Shikoku, and Kyushu

family	species/subspecies	name	notes
Bufonidae	*Bufo japonicus*		
	Bufo japonicus formosus	Eastern-Japanese common toad	endemic species of Japan
	Bufo japonicus japonicus	Western-Japanese common toad	endemic species of Japan
Hylidae	*Hyla japonica*	Japanese tree frog	
Ranidae	*Rana japonica*	Japanese brown frog	
	Rana ornativentris	Montane brown frog	endemic species of Japan
	Rana nigromaculata	Black-spotted pond frog	
	Rana porosa		
	Rana porosa porosa	Tokyo daruma pond frog	endemic species of Japan
	Rana porosa brevipoda	Daruma pond frog	endemic species of Japan
	Rana rugosa	Wrinkled frog	
	Fejervarya limnocharis	Indian rice frog	
Rhacophoridae	*Rhacophorus arboreus*	Forest green tree frog	endemic species of Japan
	Rhacophorus schlegelii	Schlegel's green tree frog	endemic species of Japan

Table 3. Matrix of paddy field types

abiotic environmental potential	it is adjacent to the forest	it is not adjacent to the forest
an original location is a wetland	valley-bottom paddy fields in hilly and plateau area	lowland paddy fields in vast plains
an original location is a dry land	terrace paddy fields in hilly area and the foot of a mountain	—



a) valley-bottom paddy fields b) lowland paddy fields c) terraced paddy fields

Fig. 1 Distribution of the edge line between paddy fields and forests in case sites of each paddy field type. The bold lines indicate the edge line between paddy fields and forests. The shown in the figure range is 1.25km×1km, respectively. A) valley-bottom paddy fields illustrated Mizunoki, Motegi, Tochigi Prefecture, b) lowland paddy fields illustrated Nakata, Yoita, Niigata Prefecture, and c) terraced paddy fields illustrated Ohtashiro, Kamogawa, Chiba Prefecture.

forest-dependent frogs and toads. This periphery part distributes along the boundary of forests and paddy fields as the edge line. Therefore, the extension of the edge line between the paddy field and the forest for each area immediately affects the size of the inhabitable space (Fig.1). The extension of the edge line inevitably becomes longer in hilly areas as valley-bottom paddy fields expanded the divergence. This is one of the key factors affecting the richness of species composition of frogs and toads in valley-bottom paddy fields. In contrast, the forest-paddy field complex rarely occurs in lowland paddy fields. On the other hand, the reclamation of terraced paddy fields at the foot of mountains has brought about a rapid increase in the extension of the edge line (Osawa, 2008). Surprisingly, our ancestors have expanded the inhabitable space for forest-dependent frogs and toads.

2) The combination of a paddy field and a levee embankment grassland

Not only the forest but also the combination of a grassland and a paddy field provide a valuable habitat for frogs and toads. Paddy fields are enclosed a levee as the line terrestrial grassland because the parcel of paddy fields is divided from the surrounding paddy fields by a levee. Moreover, besides levees various semi-natural grasslands such as farm roads, waterway walls, verge meadows and fallow fields contribute to the rural landscape. These areas are regularly weeded to allow farming in these grasslands. As a result, these semi-natural grasslands have been maintained because vegetation succession has been controlled. The levee is a foothold for yearlings when they develop from the aquatic phase to the terrestrial phase. Grasslands become biotopes for adults and juveniles of non-forest-dependent species. In lowland paddy fields, the levee functions as a biotope for *R. porosa porosa*, because it is the only terrestrial site near water during the irrigation period (Osawa et al., 2005). In valley-bottom paddy fields, various species of frogs and toads are inhabitable by forming the forest-paddy field-grassland complex, because grasslands join the forest-paddy field complex.

On the other hand, in terraced paddy fields with a steep slope, belts of grasslands such as a levee embankment inevitably have occurred because the ground level between the upper and lower paddy fields greatly differs. As a result, the total area of levee embankment grasslands increases in the terraced paddy fields zone. These levee embankment grasslands become the habitats of frogs and toads that like grasslands. For instance, *R. japonica* is found at a high density in terraced paddy fields in the south Boso Peninsula, because paddy fields as breeding sites are mixed with levee embankment grasslands that are biotopes for adults and juveniles (Osawa and Katsuno, 2007). Moreover, *R. nigromaculata* and *Fejervarya limnocharis* are commonly distributed in the terraced paddy field zone in northwest Kyushu (Osawa and Katsuno, 2005). Terraced paddy fields are not a substitutional wetland, but have been artificially and recently created. Terraced paddy fields mixed with grasslands are attractive spaces for frogs and toads, which usually inhabit grasslands.

3) The combination of a paddy field and an irrigation canal

Irrigation is essential for the cultivation of the rice plant *Oryza sativa* in the paddy field. Therefore, irrigation canals are widely distributed in the paddy field zone. Since water remains in irrigation canals during the mid-summer drainage period, irrigation canals are used as an evacuation site for many aquatic organisms. In particular, they are an effective refuge site for frogs to escape from predators. For instance, *R. porosa porosa* prefers levees bordering irrigation canals to levees placed between the paddy fields without irrigation channels (Osawa et al., 2005). That is, even if it is the same paddy field, the preference of the frog species greatly differs according to whether it touches the irrigation canal. The following are the characteristics of irrigation canals: (1) it has flowing water; (2) it is deeper

than the rice field; (3) vegetation grows thickly on the bank; (4) various conditions such as width, flow quantity, flow velocity and the waterside plants exist on the cannels ; and (5) there are always water bodies during the irrigation period. Irrigation cannels have a diversity of environments compared with paddy fields where it is easy to become a monotonous environment by planting the rice plant only. Levees bordering irrigation canals are suitable habitats for frogs and toads.

Though the irrigation canal located beside the paddy field was traditionally a dugout earth waterway, this is now being replaced by concrete channels. It is obvious that concrete channels have negative impacts to frogs and toads (Fujioka and Lane, 1997, Osawa et al., 2005). Because various environments that the dugout earth waterway has are lost. The irrigation canals are difficult to cross due to their vertical concrete walls. In addition, there are a lot of instances where the open irrigation canals have been replaced by new pipeline irrigation systems. The disappearance of the combination of a paddy field and an irrigation canal is occurring across Japan, and is a cause of concern for the negative impact that this will have on frogs and toads.

3. Conclusions

Paddy fields can be roughly divided into 3 types according to their location. These mainly differ according to the groundwater level as abiotic environment potential. Natural wetlands have been converted to valley-bottom paddy fields and lowland paddy fields, and dry land becomes terraced paddy field. Terraced paddy fields are the created wetlands whereas valley-bottom paddy fields and lowland paddy fields are the substitutional wetlands. Moreover, the time when each paddy field type reclaimed is different in the paddy field developmental history. Frogs and toads have shifted their habitat from natural wetlands to the paddy fields, substitutional and created wetlands, and they have prospered. These frogs and toads seem to strongly depend on the paddy fields because today most natural wetlands have replaced paddy fields in Japan.

In terms of the relationship between the agroecosystem and biodiversity of frogs and toads, it is remarkable that various species live in the paddy field though this is a space of the crop production. This is because frogs and toads actively expanded their habitat to the paddy fields following displacement from natural wetlands to these substitutional and created wetlands in the paddy field developmental history. However, frogs and toads live mainly in terrestrial areas using the paddy fields as breeding areas and habitats for their larval stages. Therefore, the presence of other landscape elements surrounding the paddy field such as forests, grasslands and irrigation canals has facilitated the inhabitation of specific frogs and toads. Not only the rice fields but also various landscape elements of the rural landscape should be maintained to preserve the richness of species composition. Our task in the future is to understand the relationship between biodiversity of frogs and toads and ecosystem functions.

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