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ASSESSMENT OF ARTIFICIAL ENVIRONMENT FOR REPRODUCTION OF FOREST GREEN TREEFROG ALONG NIKKO−UTSUNOMIYA ROAD USING HABITAT EVALUATION PROCEDURE

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ABSTRACT: This paper aimed to develop the SI (Suitability Index) models of Forest Green Treefrog and assess the reproduction and the environment created artificially along Nikko-Utsunomiya road using the models developed. The mitigation project was planned and carried out to create 4 artificial ponds for reproduction by the former Japan Highway Public Corporation near the roadside to protect Forest Green Treefrog since its reproduction environment was destructed by the road project. However, the mitigation project could not be evaluated quantitatively whether it was appropriate or not, because there was no environmental assessment method in Japan. Recently, in order to solve this problem, several organizations like the Ministry of Environment are trying to introduce the Habitat Evaluation Procedures (HEP). It can be applied to assess the quality and the value of the habitat for the target species by developing its SI models. Therefore, in this study, the SI models of Forest Green Treefrog were developed based on available information by reviewing existing studies, literatures, and interviewing the experts. Using developed SI models, the validity of HEP by utilizing the mitigation project along Nikko-Utsunomiya road was validated. Based on the results of the study, the applicability of HEP proved to be satisfactory.

Keywords: Habitat evaluation procedure, suitability index model, compensatory mitigation, forest green treefrog

INTRODUCTION

In Japan, it is necessary to establish an environmental assessment method which can evaluate impacts of human activities as well as study the effects of mitigation projects on nature and the ecosystem to be able to conserve it.

Given such situation, the Ministry of Land Infrastructure and Transport in Japan, recently established the Environmental Action Plan (Ministry of the Environment 2004), and declared the promotion of constructing “Green Banking System’’ as a part of its sustainable national land plans. This plan aims to manage the carrying capacity appropriately by encouraging natural restoration and creation in order to effectively protect the natural environment and ecosystem.

To carry-out this plan, the Ministry of Land Infrastructure and Transport, the Ministry of the Environment and several societies are trying to introduce the HEP (Habitat Evaluation Procedure), which was recently developed in the U.S. To be able to apply the HEP, construction of the SI (Suitability Index) models of each species is required (Komatsu et al. 2003).

However, HEP has not been utilized in actual projects yet, because only a few SI models have been developed in Japan. In addition, there are not so many existing studies related to the SI models (Nobuaki et al. 2004).

In this study, the SI models for Forest Green Treefrog were constructed. The applicability of HEP in Japan was assessed through applying the developed SI models to the mitigation project conducted along Nikko-Utsunomiya road.

SUMMARY DESCRIPTION OF FOREST GREEN TREEFROG

Forest Green Treefrogs (Photo. 1) are found on Honshu (excluding Ibaraki prefecture), Shikoku and a part of Kyushu in Japan. The scientific name is Rhacophorus arboreus. The size of the adult frog is about 60 millimeter. The breeding season of Forest Green Treefrog is usually from April to August, and it releases a white big spawn on the plant and the leaves overhung above the surface of the water such as a pool, marsh and rice paddy (Kanei 1982).

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Forest Green Treefrog is a unique frog that spawns on the tree. The size of a spawn is like a softball, and can have 300 to 500 small eggs (Kitano 2001). Forest Green Treefrog is declared as a protected amphibian or an endangered species in Japan because of the degradation of its habitat (especially water environment for spawning) caused by various development projects. Therefore, it is very important to develop the SI models of Forest Green Treefrog and to consider how to conserve it effectively in the future (Ono 1976).

Photo 1 Forest Green Treefrog and its spawn

DEVELOPMENT OF SI MODELS OF FOREST GREEN TREEFROG

Methodology for Development of SI Models

Before developing the SI models and assessing its applicability, the following tasks were done.

First, existing studies and literatures concerning Forest Green Treefrog were reviewed to choose the indispensable conditions for spawning.

Second, the upper limit value and the lower limit value of SI were set up on the basis of the data described in existing studies and literatures.

Third, the SI models were developed by using the data from Forest Green Treefrog feeders and through interview survey to experts.

And fourth, its applicability was evaluated by utilizing the artificial ponds created for protecting Forest Green Treefrog along Nikko-Utsunomiya road.

Determining the Indispensable Conditions for Spawning

The selected Indispensable conditions are water depth, water quality, water temperature, air temperature, humidity and the ratio of cover area of crown that decided by collecting the data from about 50 papers and literatures. These are shown in Table 1.

Water depth is one of the most important environmental factors since most data reported that Forest Green Treefrog spawns at the shallow spot, and appropriate water depth has a cushion effect for receiving the larvae that has fallen from leaves. The water quality which ranges from pH4.7-pH7.6 showed presence of the larvae and adult frog. Therefore, water quality is also one of the important factors for spawning.

In particular, water temperature is relative to the living condition of larvae. They can swim in the pond and grow in the range of 18-28 degrees Celsius. However, there is an experimental result that the larvae will be dead in less than 6 or more than 43 degrees Celsius.

The most suitable air temperature for spawn is between 13-25 degrees Celsius. According to the data of some literatures, it was found that the number of spawns depends on air temperature. The range of humidity observed for many spawns was 55%-93%.

The humidity is related to water volume within a spawn. If sunny weather continued over a long period, the spawn will dry-up and die. Therefore, humidity is also one of the most indispensable factors.

The ratio of forest coverage area means that the ratio of the area of branches and leaves that overhung above a pond. If there are no branches and leaves, it is described by some literatures that survival rate is less than 10 %. So, the ratio of the forest coverage area was specified as one of indispensable conditions.

Table 1 Indispensable conditions for spawning

V1 : Water Depth	For spawning on the tree above pond, and receiving the fallen larvae.
V2 : Water Quality	Larvae can survive only in the range of weak acid and neutral.
V3 : Water Temperature	Larvae can inhabit only the limited range of the water temperature.
V4 : Air Temperature	Adult frogs spawn only the limited range of the air temperature.
V5 : Humidity	High humidity is necessary for spawns in order to protect from the dry.
V6 : Ratio of Cover Area of Canopy	A canopy is necessity for spawning on the branches, and for defending natural enemies and direct sunlight.

Reviewing various references and, interview survey among the experts and feeders such as the aquarium staff were conducted in order to establish SI values. As a result, the upper and the lower limit values of SI and all the indispensable conditions were confirmed (Table 2). Only the ratio of forest coverage area was determined through the interview survey because there were no values specified in any related literatures and papers. That is, the lower limit value is 0% and the upper limit value is 100%.

Table 2 SI value of each necessary condition

Indispensable Conditions	Data from Existing Studies and Literatures	Results of Interview-Survey	SI Value Lower Limit	SI Value Upper Limit
V_1: Water Depth (cm)	5-450	10-60 60 100	0	500
V_2: Water Quality (pH)	4.7～6.4 7.6	4.7-7.6 6.4 7.6	3	9
V_3: Water Temperature (℃)	18-28 more than 6 less than 43	22.4-29.2 23.0-29.4 13.4-26.1 20.0-25.0	6	43
V_4: Air Temperature (℃)	13-29.5 more than 7	32 25 23 19-27.5	7	35
V_5: Humidity (%)	55-93 77-90	77-100 90	55	100
V_6: Ratio of Cover Area of Canopy (%)	The height of the tree spawned is between the range of 50cm-20m. The branches and leaves that overhung above the pond are important for spawning.	The amount of canopy and the location between the tree and pond are very important.	0	100

DEVELOPMENT OF SI MODELS

SI Model of Water Depth

The SI model of water depth was developed based on all data and verified data offered by Mr. Sato who is a feeder (Fig. 1). The analysis showed that the range of water depth for many Forest Green Treefrogs was from 10cm to 60cm. Therefore, this range was set as most suitable and SI value is 1.0. If water depth is 0cm, SI value is established to be 0. It was set that SI value increased in the range of 0-10cm. And in the case of water depth, few Forest Green Treefrogs were observed in the range of 100-450cm. So SI value was set so that it also decreased in range (Fig. 2).

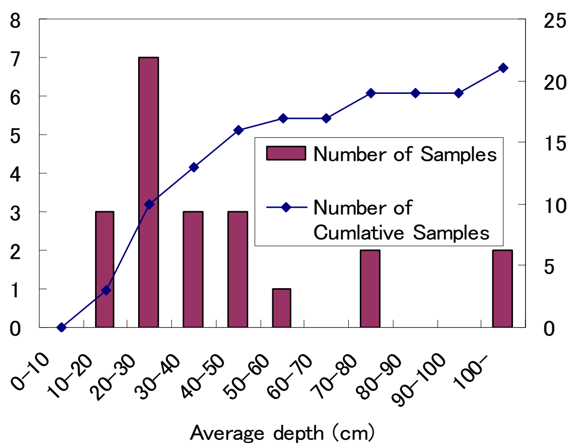

Fig. 1 Water depth of observed spawns

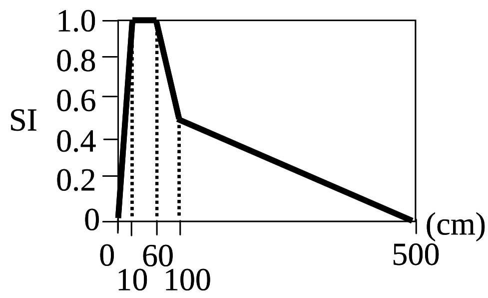

Fig. 2 SI model of water depth

SI Model of Water Quality

According to the data from the literatures and the data offered by Mr. Satomi (Fig. 3), a lot of spawns of Forest Green Treefrogs were monitored in the range of pH4.7 to pH7.6. So SI value was set to be 1.0 in this range. On the other hand, SI value was established as 0 in the range of less than pH3.0 and more than 9.0, because no Forest Green Treefrog was observed in its range. Therefore, it was fixed that SI value increased in the range of 3.0-4.7 and decreased in the range of 7.6-9.6 regularly (Fig. 4).

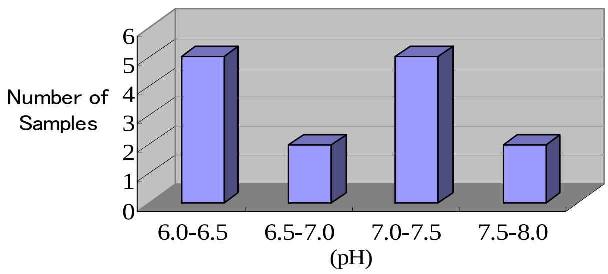

Fig. 3 Data of water quality offered by Mr. Satomi

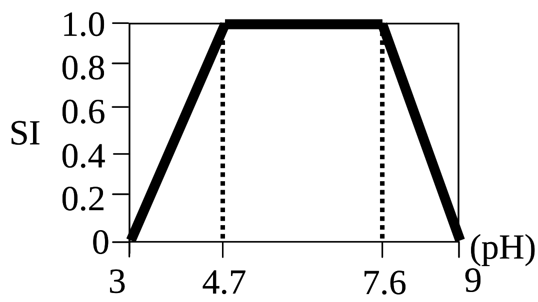

Fig. 4 SI model of water quality

SI Model of Water Temperature

Since it was reported by many literatures and researches that the larvae and adult Forest Green Treefrogs can swim and grow satisfactorily in the range of 19-28 degrees Celsius (Fig. 5), SI value was set to be 1.0 range. In the range of more than 43 degrees Celsius, and less than 6 degrees Celsius, SI value established to be 0 because many researchers reported Forest Green Treefrogs would be dead in that range. Therefore, it was established that SI value increased in the range of 6-18 degrees Celsius, and decreased in the range of 28-43 degrees Celsius (Fig. 6).

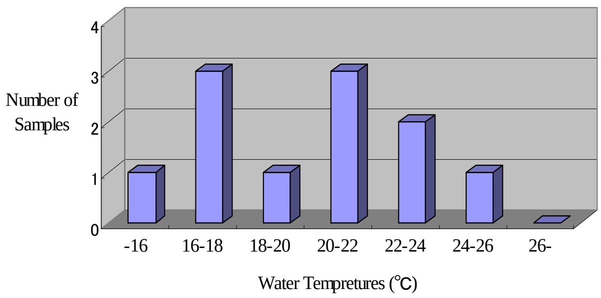

Fig. 5 Collected data of water temperature

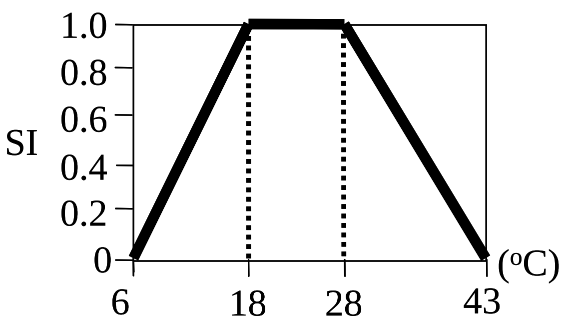

Fig. 6 SI model of water temperature

SI Model of Air Temperature

SI value of air temperature in the range of 13-25 degrees Celsius, was established to be 1.0 based on the data and information from literatures and researches (Fig. 7). They awake from hibernation about 7 degrees Celsius of the air temperature, and in the range of more than 35 degrees Celsius, no Forest Green Treefrogs were observed.

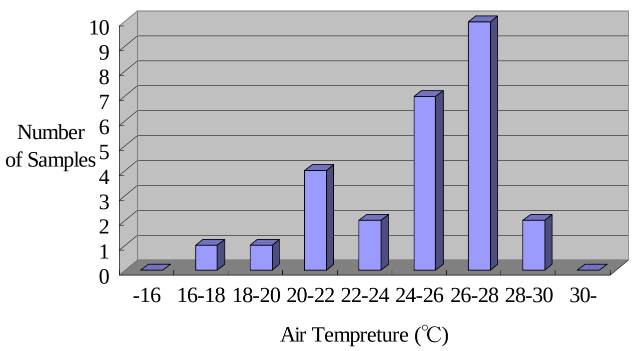

Fig. 7 Collected data of air temperature

So SI value was set to be 0 range. Therefore, SI value was fixed as it increased in the range of 7-13 degrees Celsius and decreased in the range of 25-35 degrees Celsius (Fig. 8).

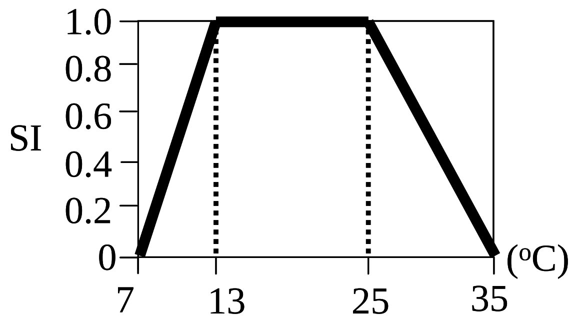

Fig. 8 SI model of air temperature

SI Model of Humidity

Many spawns were observed between ranges 75-90% by the literatures and data offered by Mr. Sato (Fig. 9). So SI value was set to be 1.0 range. According to the results of a interview survey to Mr. Murakami who is raising Forest Green Treefrogs, the spawns needed high humidity condition because they were sensitive to dry and would be dead in case of very low humidity. Therefore, SI value was established to be 1.0 even if the humidity was 100%, and 55% thus no spawns were observed when set to SI value as 0 (Fig. 10).

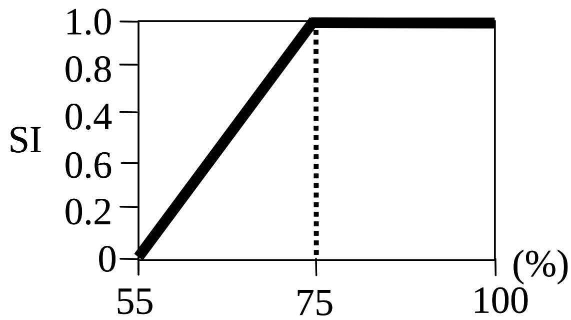

Fig. 10 SI model of humidity

SI Model of Ratio of Forest Coverage Area

The presence of trees for spawning around the pond is an important factor because death rate of Forest Green Treefrog is very high in case of spawning on the ground. Thus, the variable of SI value is established based on the cover ratio of the leaves that were overhanging within 30cm to centre of a waterside in height and range from 10cm to 8m (Fig. 11).

Values were decided based on the results of interview surveys to feeders and experts of Forest Green

Treefrog. If the ratio of forest coverage area is more than 50%, SI value was set 1.0, while SI value in case of 0% was established as 0. And SI value until 50% was set to increase regularly (Fig. 12).

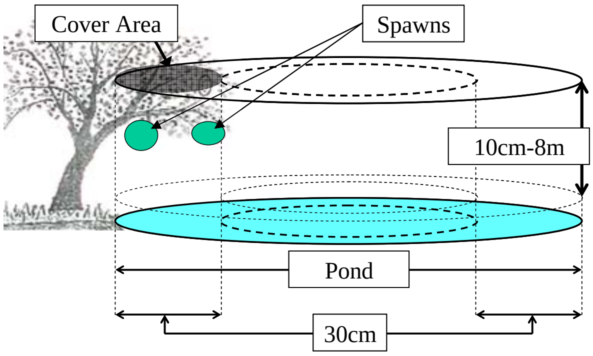

Fig. 11 Diagram of the ratio of forest coverage area

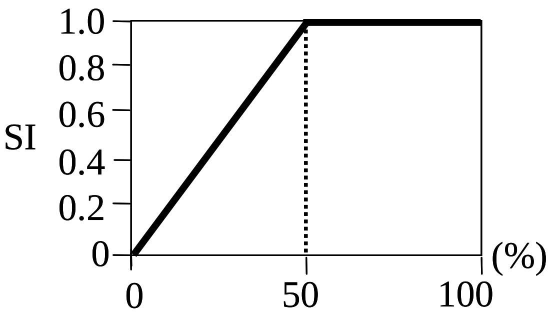

Fig. 12 SI model of ratio of forest coverage area

APPLYING DEVELOPED SI MODELS TO THE MITIGATION PROJECT ON NIKKO-UTSUNOMIYA ROAD

Summary Description of Nikko-Utsunomiya Road

Nikko-Utsunomiya is a road connecting between Utsunomiya I.C and Kiyotaki I.C. that was constructed for mitigating the traffic jam of Route 119 and Route 120 in Tochigi prefecture (Fig.13). The total length is 30.7km and it has been in operation since 1981.

Fig. 13 Location of Nikko-Utsunomiya road and artificial reproduction ponds of forest green treefrog

Environmental impact assessment was not conducted on this road, however, the former Japan Highway Public Corporation (JH) tried to decrease the amount of change of land and install some box culverts to secure the passage for animals in order to mitigate the impacts on ecosystem. So this road is called first Eco-Road (Ecological Road) in Japan for its consideration on conserving ecosystem very well (Shinoda 2003). JH found some Forest Green Treefrogs through a feasibility survey and estimated the disappearance of its reproduction area by the road project. So JH has created 4 simple holes to hold water as a compensatory mitigation measure along the roadside (Photo 2) (Mori et al. 1988). However, JH did not assess whether the mitigation project is appropriate to protect them or not because it was not obligated by a law and there was no environment assessment method. Its management had also been transferred from the JH to Tochigi prefecture road public corporation since 2005 (JH 1997).

Photo 2 Artificial reproduction ponds created by JH

Practice of Field Survey and Calculating SI Value

The field survey of each indispensable condition at 4 artificial reproduction ponds was carried out in the breeding season of July 2005.

Water depth was measured 5 times at each pond and average value was computed. Water temperature and humidity were measured by using each gauge, and water quality was measured by pH meter. Each ratio of forest coverage area was estimated by making the map. As a result of calculating SI value by applying each SI model, almost SI values were 1.0 that meant most suitable environmental quality. However, the SI value of humidity and ratio of cover area of crown were 0.54 and 0.36 respectively, because there were few trees around No.4 pond. Each HSI value representing the quality of reproduction environment was calculated by a geometric average of each SI value. As a result, almost HSI values were high (Table 3).

Assessment of Mitigation Project

There were no data to estimate the impacts on the environment for reproduction by constructing Nikko-Utsunomiya road because environmental impact assessment was not carried out by JH. So it was assumed that HSI is 1.0 (most suitable), and assessed the mitigation project by estimating the maximum possible missing area. Each area of 4 created ponds is 1.0 m^2, and Habitat Unit (HU) that represented the synthetic concept of environmental quality and quantity was evaluated by multiplying area and SI value. According to the then design, the area of each pond was 1.0 m^2. As a result, each HU per a year was 0.88 HU (pond No.1), 0.89 HU (pond No.2), 0.89 HU (pond No.3) and 0.75 HU (pond No.4) respectively. However, time differences for the construction of each pond must be noted. No.1 and 4 ponds where made at the same time when Nikko-Utsunomiya road was constructed. No.2 and 3 ponds were developed 10 and 27 years later respectively after the completion of Nikko-Utsunomiya road (Fig. 14).

Therefore the total HU of 4 created ponds was analyzed in case of project life 50 years under the premise that HU is regular baseline. As a result, total HU for 50 years was 138.3 HU. If the disappeared reproduction area was less than 2.77m^2, it is concluded that this mitigation project is satisfactory more than no-net-loss level (Table 4).

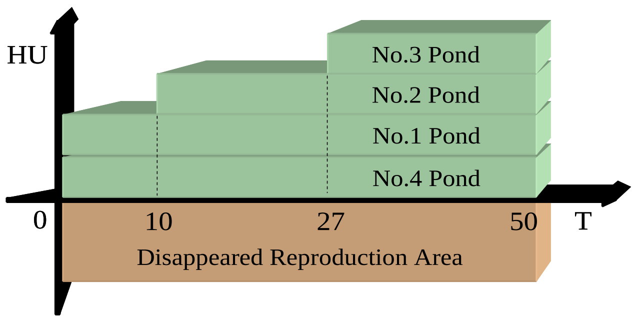

Fig. 14 Relationship of total HU between created ponds and disappeared reproduction area

Table 4 Results of each HU of created ponds

Pond	Year	HSI per a year	HU	Total HU
No.1	50	0.89	44.6	139.5
No.2	40	0.90	36.1	
No.3	23	0.90	20.8	
No.4	50	0.76	38.1	

CONCLUSION

In this study, the SI models of Forest Green Treefrog were developed and applied to the mitigation project along Nikko-Utsunomiya road.

The conclusions in this paper are as follows:

1. The environment for reproduction to conserve Forest Green Treefrog should be created additionally since the evaluated area that can possibly compensate the mitigation project was only 2.77 m^2.

2. There are indications that there are some improvements around ponds to acquire more HU such as afforesting around No.4 pond.

3. It was proved that the establishment of HEP in Japan is indispensable for assessing the development impacts on living things and for quantitatively planning mitigation project and to certify its validity.

For the further study, it is recommended that to raise the accuracy of each SI model more data concerning Forest Green Treefrog should be collected. It is also necessary to examine the possibility of establishing the SI models which depict other environmental concerns besides reproduction such as feed and forest coverage.

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Table 3 Results of field survey and estimated HSI

Pond	V1:Water Depth		V2: Water Quality		V3: Water Temperature		V4: Temperature		V5: Humidity		V6: Ratio of Cover Area of Crown		Area	HSI
	Value (cm)	SI	Value (pH)	SI	Value (Degree)	SI	Value (Degree)	SI	Value (%)	SI	Value (%)	SI		
No.1	20.0	1.0	7.7	0.93	17.3	1.0	17.4	1.0	65.8	0.54	59	1.0	1.0	0.89
No.2	13.7	1.0	7.4	1.0	16.5	1.0					52	1.0	1.0	0.90
No.3	29.9	1.0	7.4	1.0	17.4	1.0					100	1.0	1.0	0.90
No.4	22.0	1.0	7.1	1.0	17.1	1.0					18	0.36	1.0	0.76

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