F-1 Studies on the habitat assessment models and evaluation procedure for biodiversity conservation

Contact person Hisashi Nagata
Biodiversity Research Project Group
National Institute for Environmental Studies
Onogawa 16-2,Tsukuba,Ibaraki,305-8506 Japan
Tel:+81-29-850-2493 Fax:+81-29-850-2493
E-mail:hnagata@nies.go.jp

Total Budget for FY2003-FY2005 89,084,000Yen (**FY2005**; 27,029,000Yen)

Key Words Habitat suitability model, Analyses scale, Species occurrence, Geographical Information System (GIS), Habitat Evaluation Procedure

1. Introduction

One of major causes of biological extinction is habitat loss due to human activities[1). "Habitat loss" typically refers to the disappearance of a natural ecosystem like a forest, a wetland or a lake, however it does not imply a disappearance of an ecosystem, but an alteration of an ecosystem from one type to another. When an animal species does not select the place to live anymore, we perceive the habitat loss that may lead the population extinct. Then, habitat fragmentation by human activities reduces biological diversity and causes the extinction of many plant and animal species. The difficulty lies in the fact that there is no single fundamental scale at which ecological phenomena should be studied[2)]. Ecosystems and their associated populations vary over a range of spatial, temporal and organization scales, and mechanisms driving patterns may be operating at different revels. In the absence of a complete inventory of the distribution and abundance of species, the use of descriptive statistics is a starting point for understanding pattern[3)]. The success of biological conservation is measured in terms of the amount, quality and health of the biological diversity maintained. To make timely policy and management decisions, we now rely on geographical information system (GIS) and spatial statistics to qualify patterns at broad scales.

2.Research Objective

Due to recent developments of conservation biology, we are gradually preparing tools to predict how species go extinct, however, we still have only poor measures to predict which (or where) populations are likely to go extinct in real landscapes. This is mainly because our spatial information of biodiversity is far from complete. There are so many species and they are too widely distributed to deal with. Therefore, it will be much better knowing the rules of habitat selection with which animals employ than making efforts to collect complete information of spatial distribution. Conservation of biodiversity is the scale dependent in the planning process. At first, priority areas are screened extensively on the national or regional scale by using a simple habitat model. The second step is to design a conservation area in the landscape scale. We developed habitat models for animals in these two scales. If we can predict species occurrence of conservation target, we can protect them effectively without wasting resources. To address the question regarding population phenomena, we need to find ways to quantify these patterns in time and space, to understand how pattern may change with scale, and to understand the causes and the consequences of patterns. Therefore, we need to develop GIS-based habitat assessment models for wildlife. Conservation area selection then depends on using coarse, but not inaccurate, data that are available on relatively well known species (or species assemblages) such as birds, butterflies and dragonflies. Therefore, surrogate data are often used for making informed conservation decisions.

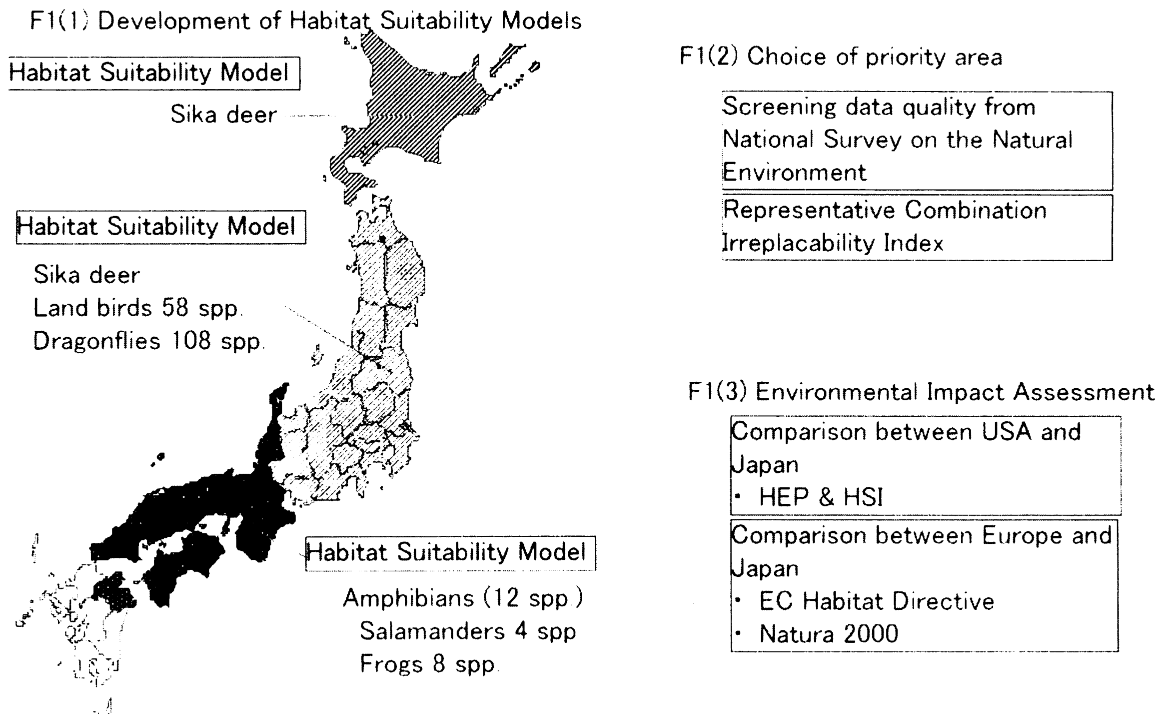

Fig.1 Outline of Research Project

It is also necessary to quantitatively assess impacts stemming from development projects on natural ecosystems in order to keep balance between development and conservation. For protecting biodiversity, both quantitative ecological impact assessment methods that can be used in environmental impact assessment and legislation that implies these assessment methods. A diverse of quantitative ecological impact assessment methods including Habitat Evaluation Procedure (HEP) have been developed in the U.S. and EU countries but not in East Asian countries including Japan. This study also aimed to review HEP and other Environment Impact Assessment (EIA) methods, and then to propose a quantitative ecological impact assessment method that can be applied to ecological impact assessments in Japan or East Asian countries.

3. Development of GIS-based habitat suitability models for wildlife

a. Methods

We used habitat, meteorological and topographical variables data providing from Biodiversity Center of Japan, Japan Meteorological Agency and Geographical Survey Institute. All these parameters have a resolution of about 1 km^2. We developed the suitable habitat models for dragonflies, 12 species of amphibians including both salamanders and frogs, 79 species of breeding birds, and Sika deer (*Cervus nippon*) at variable spatial scales by using GIS data, such as 50 m DEM, 1:50,000 vegetation map. Two different types of parameters: (1) climate condition (annual average temperature), elevation, and topography, which are semi-permanent parameters, and (2) land-cover types (forests, rice fields, wetlands, etc.) were used for those habitat models.

We used presence/absence data for clouded salamander and frogs derived from field census survey in Osaka and Shiga, and those for dragonflies and breeding birds derived from Report of the distributional survey of Japanese animals, National Survey on the Natural Environment. We generated current deer abundance maps for large scale in eastern Hokkaido based on number of harvested deer during 1997-2001. Fine scale model for deer abundance in wintering grounds (Akan, Shiranuka, and Onbetsu region) were based on the number of total sighting of deer by helicopter census during 1997-2002. Generalized linear models, especially logistic regression models, were used to estimate the potential habitat for the species in which both absence and presence data are available. Habitat suitability was estimated using Ecological-Niche Factor Analysis[4)] for species in which only presence data are available.

b. Results and Discussion

We developed habitat suitability models for 79 species of land birds within Kanto and Koshinetsu districts. Accuracy of each model was highly variable though given models were statistically significant. Performances of models, which are measured as the area under the receiver operating characteristic (ROC) curve, were acceptable for 58 species. Occurrences of summer visitor and forest species have explained by elevation and vegetation type within 1km^2 mesh better than resident/nomadic species and those for open habitat species. Performance of habitat model was negatively correlated with body mass, because home range size is increasing with it. Performance of models was actually improved when developing them based on large scale (25 or 100 km^2 mesh) in birds of prey and herons which have larger home range than small passerines. Therefore, performance of models is influenced by analyzing scale through home range size of target species.

We constructed dragonfly distributional models based on occurrence records collected in the national recording scheme of Japan. Temperature limits of species distribution were estimated using climate mesh data and occurrence records for most of dragonflies (108 species) inhabit main four islands. "Commonness" was defined as the proportion of the grids with occurrence records among grids with reliable data sets within the temperature range. Then we tried to find out landcover-occurrence relationships within the temperature range, based on logistic regression models. Performances of models were acceptable for 68 out of 108 species. Area of broad-leaved forests within a $100km^2$ mesh grid had positive effects on the occurrence of 55 species, indicating that about 50% of dragonflies depend on forests. It was suggested that common species require small forest area, while uncommon species require large forest area, suggesting a continuum from eurytopic to stenotopic species.

We applied habitat model for the clouded salamander *Hynobius nebulosus,* which was developed from data set of Osaka and Shiga, to extended area in western Japan. We found that the salamanders are distributed in areas where the density of local-suitable habitat is high. The model could predict the occurrence of the salamander at several sites where not shown in the National Record. Four regional population units were detected within the species by sequencing 420 bps of mitochondrion control region of 57 individuals from 14 populations. These results can help to determine the priority of important areas for the conservation of species. A habitat model in landscape scale (1 km x 2 km range) was also built for the clouded salamander by using a result of ecological survey and a fine scale map and 10 m DEM, and it was used to estimate extinction risk of the salamander in several scenarios of land change. Distributions of eight frog species were estimated by physical factors and vegetation in Osaka. For example, the forest green tree frog, *Rhacophorus arboreus* is distributed within range of 160-550 m above sea level, 220 mm of precipitation in July and more than 39 % of tree cover.

Early study on sika deer (*Cervus nippon*) distribution in Hokkaido suggested that snow depth and sasa bamboo variety were important variables limiting the distribution. Deer distribution survey in 2002, however, showed that deer expanded their range to western Hokkaido with heavy snow. In all habitat models for distribution in Hokkaido, snow coverage, sasa bamboo, and conifer forest were significant factors. In three habitat models in 1984 and afterwards, variable on population pressure was the most important, while the relative influence of snow coverage was weaker. It is suggested that the deer expanded the distribution greatly in recent years under reduction of the snow coverage and the influence of population pressure of deer. On the other hand, the habitat model for the deer abundance in eastern Hokkaido was indicated that variable about conifer forest was the most important, and sasa and snow depth also influence strongly. These results suggested that the abundance of sika deer is limited by snow depth and sasa, while sika deer expand the distribution into the western Hokkaido because of increase in the number of sika deer and change of climate. All habitat models for abundance in three winter habitats showed poor accuracy. There results suggested that 5-km resolution where data is collected in the large range is appropriate to the analysis of spatial patterns for sika deer distribution and abundance in broad scale. The habitat model for sika deer in eastern Honshu area was also developed. The limiting factor of the deer distribution is differed between eastern Japan and Hokkaido, which might be reflected the difference of body size and human impact to land use. On the other hand, the biological factor, such as population pressure strongly influenced the distribution both in eastern Japan and Hokkaido.

4.Choice of priority area based on habitat model

In the national recording scheme, records reported by the network of volunteer recorders provided, to some extent, comprehensive coverage of the country. These are immensely valuable for determining how well or not species are doing over time, as well as the extent of the geographical ranges of species. The outcome has been the production of an atlas (Japan Integrated Biodiversity Information System), which provides an immediate visual overview of present geographical ranges. However, there are shortcomings with these "record point maps". We have developed a method for data quality validation, to overcome some of these shortcomings inherent to the national recording schemes. We have selected only high quality data from the original data set, for the use in the analysis of relational spatial database. As the results, we could detect a continuous array from an extreme generalist to a specialist in odonate fauna, which reflects species' forest independency or dependency. In order to choose protected area to ensure achievement of a complete set of species, we also developed more improved algorithms for calculating the irreplaceability[5)] of areas within a region than the former method[6)]. We can derive a surrogate in a few second by using new algorithm. So far, we tried to conserve all species by protecting only one site (at least once). To ensure biodiversity conservation we need to choose at least two or more than two sites (multi-representative combination). If we can choose multi-representative combinations, those combinations are also useful for maintaining metapopulation. There may be various requirements depending on planners: they want to conserve a vulnerable site in first, a site with critically endangered species in first, and so on. And, we are afraid of a reliability of the original presence/absence data. We propose the practical algorithm in which we get quickly quasi-optimal multi-representative combinations and select the optimal one satisfying several conditions.

5. Comparison of Environmental Impact Assessment Procedure and its problems

Ecological impact assessment procedures of European Union (EU) were studied from the legislation aspect. The strategic environmental impact assessment[7)] would become main scheme with the usual EIA in EU countries. Natura 2000 intends to enforce unified and closed ecological network in EU countries. For the construction of the biodiversity evaluation systems, the existing network systems that relate to the assessment and management systems were also surveyed. In United Kingdom many habitats have been evaluated with overall land feature in a view of regional planning. Habitat is fairly evaluated by the cooperation of developer, local governor and conservation organization, as all necessary data are open to the public. Protected area had been strictly protected, and that area would be carefully developed under "no net loss" policy. It is difficult to access digital biodiversity database in Japan compared to Europe. In order to establish open biodiversity evaluation system digital information should be integrated and maintained by positive feedback system. We developed the prototype system for presenting and collecting biodiversity information.

Habitat Evaluation Procedure (HEP) has been developed and is widely used in the United States[8]. HEP is a species-habitat approach to ecosystem assessment and habitat quality for selected evaluation species is documented with an index, Habitat Unit (HU). HU derived from quality of habitat, which is defined by Habitat Suitability Index (HSI) and the total area of available habitat as the index of quantity. Habitat suitability index (HSI) models published in both the United States and Japan were collected, and each model was analyzed in terms of target species, number of SI models, cover types, applicable timing/duration, and year of publish. A hundred and fifty one HSI models currently exhibited on website of U.S. Geological Survey. On the other hand, 72 HSI models for 41 species have been built and published in Japan, so far. In total, 45 HSI models have been applied to ecological impact assessments in the United States. Among 45 cases, 38 cases were evaluated by using HSI models, only a case was evaluated by using Habitat Units, and 6 cases were evaluated by using cumulative Habitat Units. Totally, 72 HSI models for 41 species have been developed since HEP was firstly introduced into Japan 7 year ago. This fact shows the steady development of HEP or quantitative (i.e. spatial and periodical) ecological impact assessment in Japan. It is necessary to standardize HSI modeling and publishing, and HEP procedure. Consequently HEP and HSI modeling manuals are also essential in Japan. We developed a HSI model for Japanese littleneck *(Ruditapes philippinarum)* and evaluate man-made tidal mud flat in Hiroshima as a case study of Japanese style HEP application. We suggested 16 patterns of HEP analyses for EIAs in Japan, including analyses done by SI, HSI, HU or cumulative HU, and alternatives defined by "quality"(that is HSI), "space," and/or "time." This case study was also designed for "adaptive management" which is same as "feedback system" and now very popular concept for ecological restoration projects in Japan. We suggest HEP capabilities by showing a case study analyses in adaptive management scheme.

So far Japan's ecosystem assessments did not have aspects of time and space of ecosystems/habitats. As a result, natural environments/habitats were disappeared by proposed development projects through EIA procedures! One of the most contributions of HEP in Japan is to introduce concepts of both "time and space" that are indispensable in Japan's ecosystem assessments. HU analyses in HEP bring concepts of space. Cumulative HU analyses in HEP bring concepts of space and time. However, most of HSI models developed so far in Japan meant SI model. Most of HEP implemented so far in Japan meant SI modeling. Even this phenomenon is similar to the U.S., this situation that there is no Japanese language manual for HEP in Japan, will not contribute anything to the improvement of Japan's EIA systems. It is essential to make Japanese HEP manual and spread it. The other thing is about HSI models. So far there is no mechanism to open HSI models to public as the U.S. Geographic Service does on its website. It is critical to do same type of enlightenment of HSI models by Ministry of Environment or Japan Society for Impact Assessment.

Reference

1) Meffe, G.K. & Carroll, R., Principle of Conservation Biology. Sinauer Associates, Sunderland, (1994)
2) Levin, S.A., The problem of pattern and scale in ecology. Ecology, 73, (1943-1967, 1992)
3) Raven, P.H., Forward, Predicting species occurrences, xiii, Island Press, Washington, (2001)
4) Hirzel A.,Hausser J., Chessel D., & Perrin N., Ecological –niche factor analysis: How to compute habitat-suitability maps without absence data?, Ecology, 83, (2027-2036, 2002)
5) Ferrier, S., Pressey, R.L., & Barret, T.W., A new predictor of the irreplaceability of areas for achieving a conservation goal, its application to real-world planning, and a research agenda for further refinement. Biol. Conserv., 93, (303-325, 2000)
6) Tsuji N., Tsubaki Y., Three new algorithms to calculate the irreplaceability index for presence/absence data., Biol. Conserv., 119, (487-494, 2004)
7) European Commission, Environmental Integration Manual：Good Practice in EIA/SEA —Biodiversity, October, 2000, (2000)
8) U.S. Fish and Wildlife Service, Habitat Evaluation Procedures: For use by the Division of Ecological Services in evaluation of water and related land resources development projects. U.S. Dept. of Interior, Fish and Wildlife Service Mimeo. Report.30pp, (1976)