| | |
|---|---|
| Title | Geospatial Approaches towards Biodiversity Conservation : case study in Fuji-Tanzawa regions in Japan |
| Sub Title | 生物多様性保全に向けた空間情報学的アプローチ : 富士丹沢地域を事例研究として |
| Author | 土光, 智子(Doko, Tomoko)<br>福井, 弘道(Fukui, Hiromichi) |
| Publisher | 慶應義塾大学湘南藤沢学会 |
| Publication year | 2009 |
| Jtitle | Keio SFC journal Vol.9, No.1 (2009. ) ,p.7- 20 |
| JaLC DOI | 10.14991/003.00090001-0007 |
| Abstract | In this paper, we introduce several geospatial approaches for biodiversity conservation, taking an example of our on-going project. Chapter 1 introduces the needs of ecological networks formation, and Fuji-Tanzawa regions as the study area. Chapter 2 presents the ecological modeling approach which can model species' geographic distribution and assess present needs for the ecological networks. Chapter 3 outlines fieldwork for Asiatic black bears' ecology, which focuses on the capture and collecting fieldsigns. Chapter 4 introduces few experimental results on an advanced satellite tracking system, namely GPS-AROGS, concerning animal movement. Chapter 5 presents a Web-based GIS development as a policy making support system for conserving biodiversity. Chapter 6 briefly described future works. |
| Notes | 特集 位置情報計測技術の応用<br>招待論文 |
| Genre | Journal Article |
| URL | https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=0402-0901-0100 |

◆特集＊招待論文◆

# Geospatial Approaches towards Biodiversity Conservation

## Case study in Fuji-Tanzawa regions in Japan

# 生物多様性保全に向けた空間情報学的アプローチ

## 富士丹沢地域を事例研究として

Tomoko Doko
Doctoral Program, Graduate School of Media and Governance, Keio University
Research Fellow of the Japan Society for the Promotion of Science
土光 智子
慶應義塾大学大学院政策・メディア研究科後期博士課程
日本学術振興会特別研究員 (DC)

Hiromichi Fukui
福井 弘道
Professor, Faculty of Policy Management, Keio University
慶應義塾大学総合政策学部教授

In this paper, we introduce several geospatial approaches for biodiversity conservation, taking an example of our on-going project. Chapter 1 introduces the needs of ecological networks formation, and Fuji-Tanzawa regions as the study area. Chapter 2 presents the ecological modeling approach which can model species' geographic distribution and assess present needs for the ecological networks. Chapter 3 outlines fieldwork for Asiatic black bears' ecology, which focuses on the capture and collecting fieldsigns. Chapter 4 introduces few experimental results on an advanced satellite tracking system, namely GPS-AROGS, concerning animal movement. Chapter 5 presents a Web-based GIS development as a policy making support system for conserving biodiversity. Chapter 6 briefly described future works.

本稿では、生物多様性保全に向けた空間情報アプローチを紹介する。第 1 章では、エコロジカルネットワークと研究対象地域の富士丹沢地域を概観した。第 2 章では、生息地域空間的分布モデリングを用いて、エコロジカルネットワークの必要性をアセスメントする定量的手法を提案した。第 3 章は、ツキノワグマの生態を調査するフィールドワーク方法を紹介した。第 4 章では、最新型の動物衛星追跡システムの精度実証実験を紹介した。第 5 章においては、政策決定支援システムとして、Web-GIS を開発した。第 6 章では、将来展望を述べた。

Keywords: Ecological networks, Asiatic black bear, ARGOS, Modeling, Web-GIS

# 1 Introduction

### 1.1 Biodiversity loss and ecological networks

International awareness of the need to protect biodiversity has been growing steadily as the 10th Conference of the Parties to the Convention on Biological Diversity (COP 10) is scheduled in 2010, Aichi-Nagoya, Japan. In 2007, Japanese government adopted the third National Biodiversity Strategy, which stipulates the seven major themes for implementing biodiversity conservation policies, including formation of "ecological networks". The development of the ecological networks can connect the fragmented habitats of wild animals, stem the biodiversity loss, and promote dispersal and genetic exchange of wild species.

### 1.2 Study area

The area of our interest is the 'Fuji region' in part of the Fuji-Hakone-Izu National Park and the 'Tanzawa region', Japan. The Fuji-Hakone-Izu National Park covers area of 121,851 ha, which is across four prefectures and consists of Mt. Fuji, Hakone, Izu Peninsula, and Izu Island chain. The various types of volcanoes can be seen, because the park is located from the Pacific Ocean to the central part of the Main Island crossing the Fuji volcanic belt. Vegetation is varied from the plants in the warm-temperature zone in Izu Island chain to the ones in the Alperstein zone of Mt. Fuji. Throughout the park, there are a number of habitats and breeding place for wild bird species. On the other hand, Tanzawa region is the mountainous area which consists of Hirugatake (1673 m), Mt. Tanzawa, Sagami oyama, Togadake. It across three prefectures: Kanagawa, Yamanashi, and Shizuoka. This region is designated as a Quasi-National Park in Japan.

Fuji region and Tanzawa region are geographically not far; however, because of the recent urbanization and new road construction, the exchange of genes between the metapopulation of big mammals, especially Asiatic black bear, in the two regions are reported to almost cease (Japanese Mammals Society 1997). In both of Mt. Fuji and Tanzawa region, there exist the big mammals such as Asiatic black bear (*Ursus thibetanus japonicus*) and Japanese serow (*Naemorhedus crispus*). The area 121,851 ha of the National Park is considered as an appropriate size for large mammal species. There exist a variety of endemic species in the park as well because of the specific biota caused by the 'Fossa Magna'. Landscape and biodiversity in this area is in a variety.

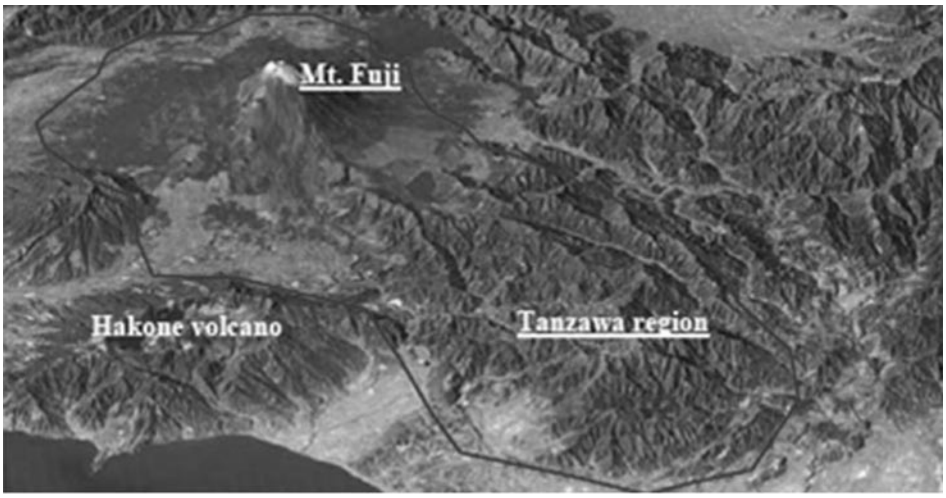


**Figure 1 Study area: Tanzawa and Fuji regions**

The study area, shown in Figure 1, was ranged from 3830925.47 to 3949185.47 N and 177284.971 to 390854.971 E in a datum of WGS 1984 and projection of UTM Zone North 54.

### 1.3 Outline of this paper

In this paper, we introduce several geospatial approaches towards biodiversity conservation, taking an example of our on-going project. Chapter 1 introduces the needs of ecological networks formation, and Fuji-Tanzawa regions as the study area. Chapter 2 presents the ecological modeling approach which can model species' geographic distribution and assess present needs for the ecological networks. Chapter 3 outlines fieldwork for Asiatic black bears' ecology, which focuses on the capture and collecting fieldsigns. Chapter 4 introduces few experimental results on an advanced satellite tracking system, namely GPS-AROGS, concerning animal movement. Chapter 5 presents a Web-based GIS development as a policy making support system for conserving biodiversity. Chapter 6 briefly described future works.

## 2 Modeling of Species' Gegraphic Distribution for Assessing Present Needs for the Ecological Networks

### 2.1 Introduction

#### 2.1.1 Background and research problem statement

The third National Biodiversity Strategy of Japan (2007) stipulates seven major themes for implementing biodiversity conservation policies. The first theme is conservation of priority areas and formation of ecological networks. Its basis is to reinforce the protected-area system. In addition to the perspective of conserving natural landscape of the Natural Parks, measures from the perspective of ecosystem conservation, especially of animal habitat conservation, should be institutionalized. The development of the ecological networks can connect the fragmented habitats of wild animals, stem the biodiversity loss, and promote dispersal and genetic exchange of wild species. Serious fragmentation of habitats has been caused by the industrialization of agriculture, restructuring of land use, the building of huge transport networks and metropolitan (Stanners and Bourdeau 1995). For fragmented habitats, the theory of island biogeography (MacArthur and Wilson 2001) can be applied, and connecting the 'islands' through the ecological networks can reduce the risk of extinction of species.

As for the Japanese mammals, the Ministry of Environment of Japan has conducted the national distributional survey of Japanese animals (Biodiversity Center of Japan 2004) in 1978 and in 2003 as a monitoring activity. The main objective was to acquire national distributional maps of ten main mammals, including key wildlife species in this study. Based on survey data from interviews and questionnaires on a sampling grid of 5 by 5km, these distribution maps were compiled at a national scale (1: 2,500,000).

Although these maps provide insight in species' distribution at a glance, they do not reflect distribution at local population level. An appropriate approach for preparing conservation and zoning plans requires spatially explicit information of species distribution at a local scale with more accurate resolution. With this information, the core area of a suitable habitat can be identified, and ecological networks can be designed if necessary. There are several studies that have integrated habitat models into GIS (for example, see Corsi *et al.* (1999). However, these have not assessed the need for ecological networks of large mammals. Also, to date, no studies were found on quantitative needs assessment of ecological networks.

In this paper, we present a quantitative methodology for the modeling of the geographic distribution of two key species of large mammals in order to assess the need for ecological networks.

#### 2.1.2 Research objectives

There are three main objectives of this study: 1) to acquire more accurate potential spatial distribution of habitats of 'key' wildlife species, 2) to identify the 'core areas' of these habitats, and 3) to assess the present needs for ecological networks.

At present, the most accurate distribution map of the target species has a resolution of 2 by 2.5km (Ohba 2002). This study aims to create distribution maps with a resolution of 90 by 90 m, or at best 30 by 30 m. The area of interest is the Fuji and Tanzawa regions located in the central part of Japan's main island. The administrative boundaries of Kanagawa Prefecture and Shizuoka Prefecture have been selected as the study area. The Asiatic black bear and the Japanese serow were identified as the target species.

### 2.2 Data management

#### 2.2.1 Species' records extraction

Species' presence data consist of localities of 1) 14 tracked Asiatic black bears in the South Alps region (715 points) and 56 observed field signs of Asiatic black bear in the Fuji region (Mochizuki *et al.* 2005) and 2) 160 observed Japanese serow in Tanzawa region (Yamaguchi *et al.* 1998). In total 49 paper maps of the above mentioned sources were scanned; four maps for bears of the Fuji local population, 44 maps for bears of the South Alps local population, and one map for Japanese serow in Tanzawa Mountains. Next, the scanned maps were geo-referenced respectively. The 1st order polynominal affine transformation was conducted to rectify the scanned images within 50 m of the total RMS error for the bear's maps. The maximum total RMS error was 251 m for the distribution maps of the Japanese serow. Thereafter, the rectified images were used to extract species observation points. 931 points were digitized manually. Geographic coordinates were calculated from point features by the ArcMap's VBA built-in function.

The national distributional map of Japanese mammals (Biodiversity Center of Japan 2004) was used to create points representing species' absence data. It was based on interviews and questionnaires in 1978 and in 2003 for grids of 5 by 5km. Following (Corsi *et al.* 1999), any area where no evidence of stable target species' presence had been gathered in the last 26 years has been defined as species' absent area. Each image was geo-referenced using the intersections of administrative boundaries, whereafter the species' known presence and absence areas was digitized as a polygon. Random points distributed within the absent range for each species were considered to represent each species' absence data. To ensure a balance in the number of species' presence and absence records, the same number of records was plotted for each species: 770 random points for the Asiatic black bear and 160 random points for the Japanese serow.

#### 2.2.2 Geo-database for predictors

Based on known Asiatic black bear's and Japanese serow's ecology, the selected environmental predictors can be categorized in five groups: 1) topographical variables, 2) water-related variables, 3) climatic variables (Guisan and Zimmermann 2000; Pearson and Dawson 2003), 4) variables related to roads (Okumura *et al.* 2003), and 5) variables related to vegetation (Hashimoto *et al.* 2003; Huygens *et al.* 2003). All variables were obtained digitally from various sources (See Appendix) and stored in a GIS environment. Considering the relatively small size of important landscape elements in the Japanese landscape and the high precision of the species' records, all predictor variables were compiled at a resolution of 30 by 30m. For calculating NDVI value, Erdas Imagine® 8.7 was used, and for other variables, ArcGIS® 9.0 was used.

#### 2.2.3 Preparation for test and train data

Plotting 1861 species records, 25 records fell outside the study area. These records were discarded so that the total number became 1836. From all layers of environmental predictor variables, pixel values were extracted for the geographic coordinates of species' presence and absence records by ArcMap 9.0 ®'s in-built function.

Subsequently the dataset, containing species presence-absence records, geographic coordinates, and each environmental predictor's value, was split into a train and a test dataset. The train dataset was used to make predictive models. Then, the test dataset was used to assess the accuracy of these models. An independent dataset is ideal for testing the models. Thus for Asiatic black bear, all records in the South Alps were used for training and all records in Fuji area were used for testing the models. By this method, also the model's transferability can be tested whether models developed on one local population, South Alps, can be applied to another neighboring local population in Fuji. To maintain proportion of presence and absence data, approximately the same number of records was taken from absence data for training and testing. Because no independent dataset for the Japanese serow was available, its records were randomly partitioned into two subsamples. One subsample was used as the train dataset and another subsample was kept for testing models. This method is known as "split-sample approach" (Guisan and Zimmermann 2000).

### 2.3 Modeling

Three modeling algorithms: GARP - Genetic Algorithm for Rule-set Production (Stockwell and Peters 1999), MaxEnt -Maximum Entropy (Phillips *et al.* 2006), and GLMs - Generalized Linear Models (logistic regression models) (Nelder and McCullagh 1989) were used in this research in order to predict the probability of species occurrences by the environmental variables as limiting factors for species' survival. The accuracy of the predictive models was measured using the test dataset by the Kappa statistics (Landis and Koch 1977).

### 2.4 Estimation of population size within habitat patches

Based on the comparison of the predictive models, the predictive maps by the best modeling algorithm for each species were chosen to estimate the population size. The population of the target species was estimated based on known population density and area in $km^2$, derived by a following equation.

$$N=A*PD$$

**(Equation 1)**

where $N$ is estimated population (head-count), $A$ is area ($km^2$), and $PD$ is population density (head-count/$km^2$).

### 2.5 Results and conclusion

For bear, MaxEnt performed best with the predictor variables: altitude, distance to paths and stone steps, distance to wide roads, and vegetation cover types (Figure 2: above). GARP failed to predict presence in Fuji. Its best GLM equation was $\log(p/(1-p))=(-1.486e+01)+(7.335e-04)*$*distance to paths and stone steps*$+(9.470e-03)*$*altitude*. For serow's distribution, GARP performed best with altitude, slope, distance to highways, distance to general roads, distance to paths and stone steps, distance to rivers, and NDVI (Figure 2: below). Its best GLM equation was $\log(p/(1-p))=$ $-5.91785430+0.04024136*$*slope*$+0.26478759*$*square root of altitude*. The estimated numbers of individuals for bear was 5~9 in Mt. Ashitaka, 51~102 in Fuji-Tanzawa, 160~320 in South Alps, 4~8 in Mt.

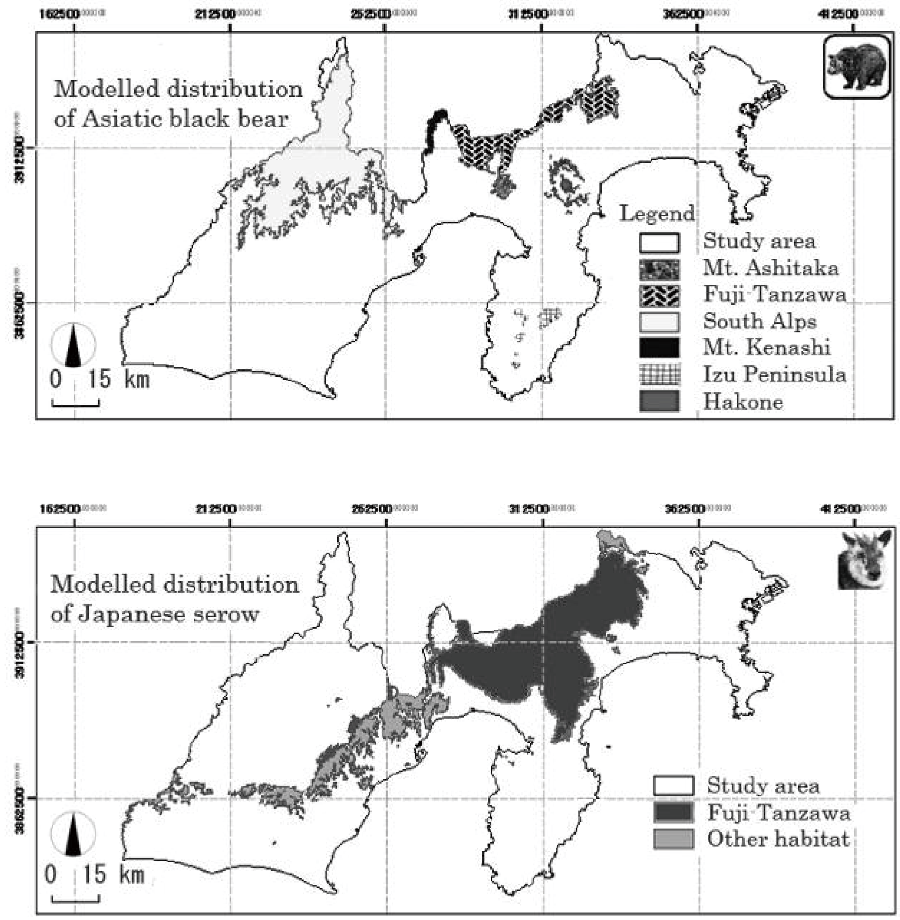


**Figure 2 Modelled distribution for Asiatic black bear (above) and Japanese serow (below)**

**Table 1 Estimated population size and needs assessment of ecological networks**

| | Location | Area (km$^2$) | Estimated population | Needs assessment of ecological networks |
|---|---|---|---|---|
| Asiatic black bear | Mt. Ashitaka | 30 | 5 ～ 9 | serious danger of extinction |
| | Fuji and Tanzawa regions | 340 | 51 ～ 102 | serious danger of extinction |
| | South Alps region | 1066 | 160 ～ 320 | endangered |
| | Mt. Kenashi | 28 | 4 ～ 8 | serious danger of extinction |
| | Izu Peninsula | 28 | 4 ～ 8 | serious danger of extinction |
| | Hakone | 37 | 6 ～ 11 | serious danger of extinction |
| Japanese serow | Fuji and Tanzawa regions | 1581 | < 1581 | healthy |
| | South Alps region | 537 | < 537 | healthy |

Kenashi, 4~8 in Izu Peninsula, and 6~11 in Hakone; for serow, < 1581 were estimated in Fuji-Tanzawa, and < 537 in other areas (Table 1). For bear MaxEnt and for serow GARP are the best algorithms, but GLM has good transferability. There is a need for ecological networks in Fuji-Tanzawa for bear, but not for serow.

## 3 Fieldwork for Asiatic Black Bear's Ecology

### 3.1 Introduction

Fieldwork for Asiatic black bear's ecological research requires tremendous efforts as they inhabit wide home range and steep mountainous area (Japanese Mammals Society 1997). The ecological research on the Asiatic black bear's Tanzawa local population has rarely been published; to date, only one article on food habit investigation of Asiatic black bear by scatting analysis in Tanzawa was reported by Koyama *et al.* (1994). Therefore, it is necessary to collect Asiatic black bear's observation point data as primary sources. We have collected these data by locating field signs (bear's net, scratch, droppings (Figure 3: right), footprints, or hair). Also, we attempted to capture few Asiatic black bears in order to track individual ones by satellite tracking system which is described in section 4. In preparation for tracking bears, the most substantially difficult work is to capture a bear alive and release with a collar. In this section, we introduce a methodology, which we succeeded to capture an Asiatic black bear alive and released in a Tanzawa local population where is well-known as low population density of Asiatic black bear.

### 3.2 Capturing strategy of the Asiatic black bear

The Asiatic black bear was captured by 2 traps of double-barreled drum cans (Figure 3: middle). The traps were set up in forests of surrounding Miyagase Lake in Kiyokawa-village, Kanagawa Prefecture, considering recently observed Asiatic black bear's localities and field signs. Whilst Tanaka-Way trap, a kind of a box trap, has a risk to make bears' teeth or mandible damage by biting barred door (Maida 1998), the double-barreled drum can is suitable for the capture because that trap cannot be bitten. After "a certificate to capture beasts and birds" was issued by Kanagawa Prefecture, traps were located on 13 July 2008. We aimed to capture one bear before 15 November 2008, the starting date of hunting. Inside of traps, 0.5 little of honey was located as inducing food. Animal capture reporting systems were installed with the traps. When the reporting system was activated, we went straight to the scene immediately. If not, we went to field at least once a week regularly for visual confirmation.

### 3.3 Immobilization and Release

An Asiatic black bear was found captured in a trap on 7 October 2008. We carried out immobilization and release of that bear on 8 October 2008 (Figure 3: left). Firstly, for chemical immobilization, domitor-ketamine mixture was dosed by a blowpipe. Secondly the body of the Asiatic black bear was measured and we recorded location, date, and sex. The captured bear was female, 1.5 years old; the body length was 86cm; and the body weight was 14.5kg (The bear was named "MOMO"). Hair of bear and blood were sampled for DNA analysis. We implanted a microchip in an ear for identification (ID is 968000005393497). We were planning to collar the bear with GPS-ARGOS (920g), but because the body weight of the

**Figure 3 Captured bear (left), trap of double -barreled drum cans (middle), and bear's droppings (right)**

captured bear was not sufficient compared to the weight of the collar, we could not implement the tracking system. After we administered intravenous fluids, the bear was released naturally at the same place it was captured.

## 4 Testing Accuracy of GPS Using Satellite-Tracking System for Collared Animals

### 4.1 Background

For wildlife researchers, location data and movement pattern of target animals is the most essential information. Recently GPS telemetry has become an important wildlife research technique (Jiang *et al.* 2008), because of its automatic and objective method to collect location data and its high accuracy. For example, Garneau *et al.* (2008) examined habitat use of GPS-collared black bears. More recently, however, new ARGOS system, namely GPS collar with ARGOS uplink (hereinafter referred to as “GPS-ARGOS”), was developed; this can collect highly accurate location data by GPS and transmit collected data to satellites, such as NOAA or METOP (Figure 4). After data processing, data will be delivered to users through the ARGOS server, e-mails, or CD-Roms.

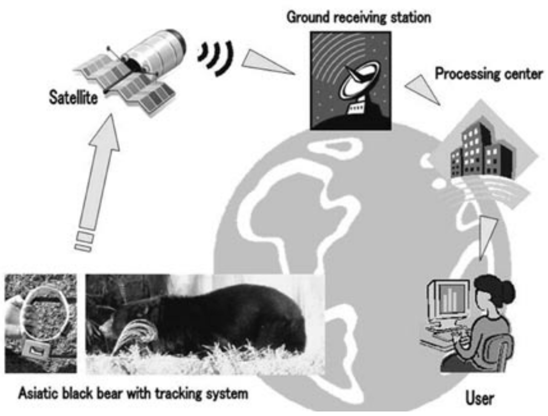


**Figure 4 GPS-ARGOS mechanisms**

### 4.2 Objectives

However, cases using GPS-ARGOS has been rarely published. Till now very few cases have been reported; For instance Ito *et al.* (2006) reported Mongolian gazelle’s habitat use by using ARGOS tracking system, but gazelle’s habitat is characterized by open grassland, which differs drastically from Japanese mountainous habitat. Mountains in Japan are characterized by steep terrain and high canopy closure density. More investigation is needed to test whether GPS-ARGOS can be useful for highly dense canopy closure in forest with comparison in other type of locations. The objective of this study is to test accuracy of GPS using satellite-tracking system (ARGOS; (CLS (Collecte Localisation Satellites) 2007)) in three perspectives of a) GPS fix, b) ARGOS uplink, and c) activity sensor, in different habitat and location features. Considering the weight of GPS-ARGOS currently available (for instance, model TGW-4580, Telonics Inc is 1100-1200g (Telonics Inc. 2008)), medium or large mammals which inhabit in forest are target species in this study. Thus, the ultimate objective of this study is to seek the potential applications for tracking terrestrial mammals, such as Asiatic black bear, Japanese serow, Sika Deer, or Japanese Macaque.

### 4.3 Fieldwork designs

We carried out an experiment using ARGOS with GPS during 19 July to 15 August, 2008 in Japan. The performance of a satellite transmitter (platform terminal transmitter or PTT; model TGW-4580, Telonics Inc.) with an Argos uplink was tested. The PTTs were programmed (1) to collect location data (latitude and longitude) recorded by its internal GPS, temperature, altitude, and activity data, for every 4-hour per day and (2) to transmit above data through radio signals to satellites every 3-day for 6 hours. For a comparison purpose, the location data was also recorded with the combination of a digital camera

**Table 2 GPS fix rate and Test location features**

| Average \ Test location | A | B | C | D1 | D2 |
|---|---|---|---|---|---|
| Canopy closure (% ) | 86.91 | 62.61 | 10.85 | 0 | 0 |
| Altitude (m) | 502.8 | 80.4 | 120.2 | 134.8 | 105.88 |
| Temperature (degrees Celsius) | 32 | 27 | 26 | 28 | 33 |
| GPS fix rate (% ) | 88.9 | 97.7 | 92.0 | 88.9 | 44.4 |
| GPS horizontal error (m) | 60.38 | 45.36 | 55.33 | 53.97 | 34.79 |
| GPS positional dilution | 7.125 | 4.309 | 5.74 | 6.950 | 3.112 |

A: Mountain surrounding Miyagase Lake, Tanzawa,
B: Experiment forest, Shonan Fujisawa Campus, Keio University,
C: Urban area at low altitude, Seya-ward, Yokohama City,
D: Open area; in front of railway station (D1) or on roof of building (D2)

(model CAPLIO 500SE WL JPN L736-20, Ricoh Co. Ltd.) and a bluetooth GPS receiver (model HI-408BT, Haicom Electronics CORP). Forest canopy density and sky openness were estimated by photographs taken by a digital camera. Handy GPS (model eTrex Legend HCx,GARMIN Ltd.) was used to count the available satellite number for each GPS fix.

#### 4.4 Results

#### 4.4.1 GPS fix rate

GPS fix success rate and location feature are summarized (Table 2). Except location D2 (Open area on roof of building) which scored 44%, GPS fix rate was high, which has always been over 88%. In general, GPS fix rate can be expected high in forests of mountain with dense canopy closure though GPS horizontal error and GPS positional dilution increase compared to the other location.

#### 4.4.2 ARGOS uplink performance

When GPS-ARGOS was positionally-fixed on a roof of an apartment in an open area, the average ARGOS successful uplink number per hour was 1.16. When a GPS-ARGOS collar was fixed vertically on a front window of a car and moved by the car at speed of 40km/h, average successful uplink number was 1.16 as well. On the other hand, in another open place on a roof of a building (4th floor), SFC, Keio University, the ARGOS uplink number per hour was 1.00. Most importantly for considering target animal's habitat, the test in a forest of Chamaecyparis obtuse showed fairly reasonable result, whose uplink number per hour was 0.5.

As for the ARGOS uplink performance, generally from the open area on a high building ARGOS transmitting messages can be received successfully by satellites, such as NOAA or METOP. Negative movement effects for ARGOS uplink performance can be neglected; because movement by a car does not decrease ARGOS uplink hit number. On the other hand, even in a forest of Chamaecyparis obtuse, which is characterized as a place with dense forest canopy closure, ARGOS uplink hit number does not decrease drastically. Of course, the success rate in a forest becomes lower compared to the one in open area. From the average uplink number per hour, 3 times of ARGOS uplink messages during 6 hours per day (every 3-day) can be expected to be received by satellites.

#### 4.4.3 Activity value and activity type

Distribution of activity values averaged per minute is categorized according to activity types recorded in field. Distribution for each activity was clearly distinguished. Mean of the activity value when GPS-AROGS was moving by car at speed of 40km/h was 0.3667(Min. 0 to Max. 1.1000); while the one for walking at speed of 57m/min was 16.18 (Min. 2.75 to Max. 28.20) and the one for climbing mountain was 36.93 (Min. 36.14 to Max. 37.71). When GPS-ARGOS was not moved at all, value was always 0.

Activity value can be classified into its activity type: moving by car at speed of 40km/h, walking at speed of 57m/min, climbing mountain, or no movement. During field survey, the author expected that activity value of "moving by car at speed of 40km/h" could represent high speed of movement, such as running. However, the GPS-ARGOS was fixed static on the automobile thus acceleration and angle had kept almost always same. As a result, this activity value was very low (mean was 0.3667) compared to walking or climbing activity values. Considering method how the activity sensor functions, it is concluded that "moving by car at speed of 40km/h" cannot represent high speed of movement of animals. On the other hand, this experiment showed that other activities: walking, climbing in mountain, no movement, can be successfully classified with activity value. Also, the distribution of activity value is very distinguishable; therefore this result can be used as classification method of activity type.

### 4.5 Conclusions

As conclusion, performance of GPS collar using satellite-tracking system (GPS-ARGOS) can be expected to be a useful tracking system for terrestrial mammals, such as Asiatic black bear, Japanese serow, Sika Deer, or Japanese Macaque.

## 5 Web-Based GIS Development as a Policy Making Support System for Conserving Biodiversity: Case Study in Fuji-Tanzawa Region, Japan

### 5.1 Introduction

In Japan, the third National Biodiversity Strategy was adopted in 2007. Hence, measures from the perspective of ecosystem conservation, especially of animal habitat conservation, should be institutionalized. Nevertheless, knowledge on spatial distribution of animal habitat is obviously lack. In order to address this problem, Doko *et al.* (2008) developed spatial distribution models for Asiatic black bear and Japanese serow to estimate core areas of habitats, and assessed the present needs for ecological networks as a case study in Fuji-Tanzawa region, Japan. This result suggests that the Asiatic black bear needs newly created ecological networks (Doko *et al.* 2008).

For an effective policy making, a spatially explicit inter-operational platform is crucial. Recently with fast advancement of the Internet and rapidly growing interests lead a number of applications on a web-based decision support system (DSS) (for example, see Repoussis *et al.* (2009)). The combination of DSS and GIS (Geographic Information Systems) functions can provide the ordinary Internet users with a strong spatial communication tool for biodiversity conservation. Therefore we developed an integrated Web-based GIS system, which can facilitate communication among local habitants, experts, ministries, and local governments, in order to support a policy making for conserving biodiversity.

### 5.2 Web-based GIS system

#### 5.2.1 System structure

The Web-based GIS system for conserving biodiversity system was operated by Google Earth (GE) and ArcIMS®.

Google Earth (GE) is an application which enables the Internet users to view global geo-spatial information by combining satellite imageries, aerial photos, maps, geography, or 3D models. It is an excellent GIS data viewer to enable spatial search, multi-layer display, and seamless data view.

On the other hand, ArcIMS ® is the software developed by ESRI ®, which can structure maps, data, and tools, and then can publish and deliver spatial data through the Internet. Thus, local and global users can share information and data efficiently. ArcIMS components and architecture consist of web servers and client applications.

#### 5.2.2 Data management

This paper takes Fuji-Tanzawa regions as a case study, which is contained in Kanagawa and Shizuoka Prefecture, Japan. In order to facilitate an inter-operational platform through Web-based GIS system, various GIS data were needed to be stored in the system. According to characteristics of data, we categorized spatial data into a) base-map, b) environmental layers, and c) animal localities (See Appendix for sources). For instance, as a) base-maps, we prepared roads, administrative boundaries, National Parks, Quasi-national Parks, buildings, satellite imageries, location name; for b) environmental layers, altitude, slope, precipitation, temperature, river streams, lakes, NDVI, vegetation cover types; for c) animal localities, geo-tagged photographs of fieldsigns, as well as core areas of animal habitat, point data of animal field signs, and tracked animal movement data. Full description on image-processing for spatial data was given in our previous work (Doko *et al.* 2008).

In this study, because GE supports KML (Keyhole markup language) file format, shape files were converted to KML by ArcMap® 9.3. For data management in ArcIMS®, shape file and Erdas Imagine file formats are compatible with ArcIMS®, thus no conversion of data format were necessary.

#### 5.2.3 Basic functions

Basic functions of the system mainly contain view, zoom, pan, distance measuring, thematic mapping, overlay multi-layers, query spatial search, visualize 3D view (GE only), and display seamless imageries (GE only). Users can view attribute table (such as name, object ID, temporal data, latitude and longitude) by pointing out object spatially. Figure 6 and Figure 7 present the top page of a Web-based GIS system for conserving biodiversity using ArcIMS ® and Google Earth, respectively. This Web-based GIS system is distributed freely via the Internet.

#### 5.2.4 Utility and application

Using this system, we can update, query, and analyze the situation of animal movement and habitat.

Figure 5 shows an example of Asiatic black

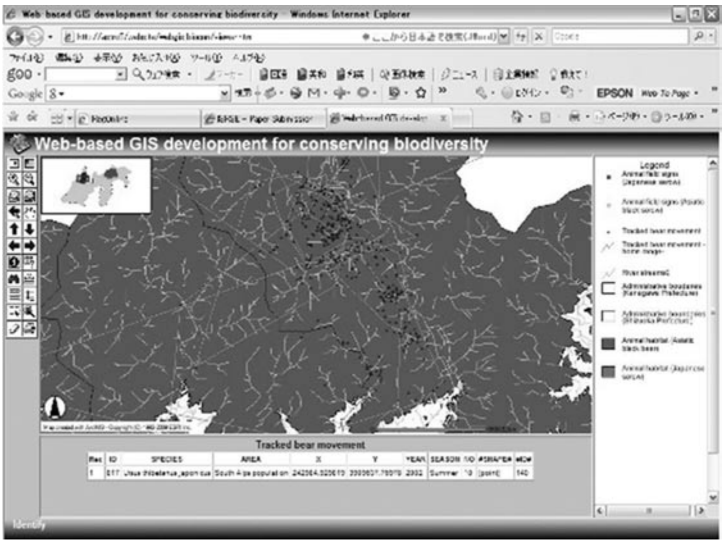


**Figure 5 An example of Asiatic black bear's movement**

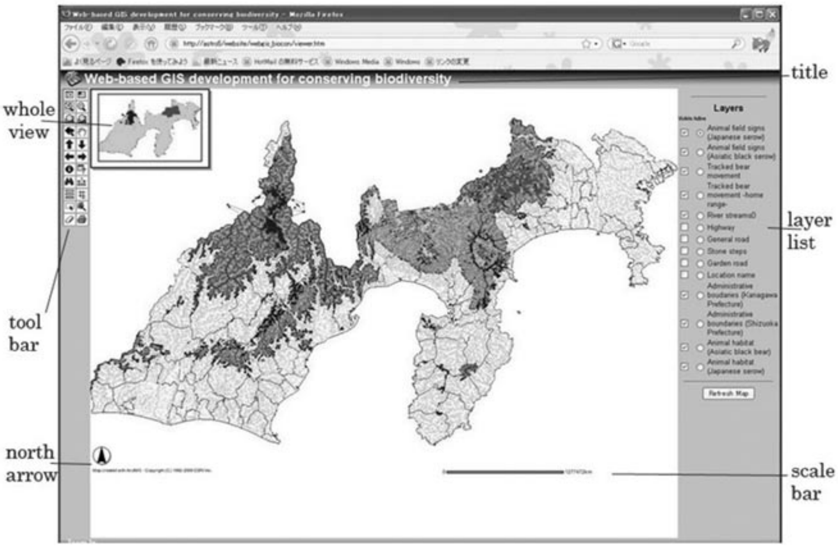


**Figure 6 Top page of a Web-GIS system [ArcIMS version]**

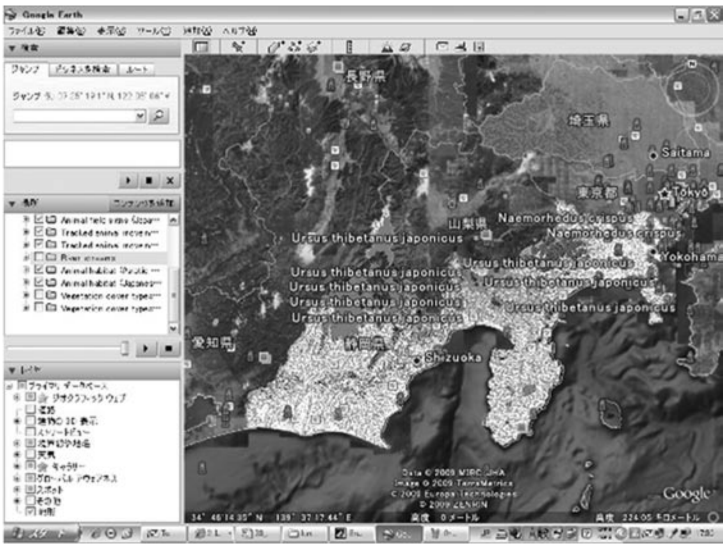


**Figure 7 Top page of a Web-GIS system [Google Earth version]**

bear's movement tracks and predicted habitat range using ArcIMS. We can overlay multi-layers such as tracked bear's point localities, predicted bear's habitat, and tracked bear's maximum home range, as well as river streams. We can also identify each point attribute table information, such as coordinates and species Scientific names, etc.

For instance, localities of Japanese serow's fieldsigns using Google Earth can be visualized. We can overlay many layers with satellite imageries as background maps. Species information can be extracted by pointing out by mouse.

**5.3 Conclusions**

The Web-based GIS policy making support system for conserving biodiversity was developed using Google Earth and ArcIMS®. This system can be expected to be useful to facilitate spatial informationsharing with other Internet users, such as local habitants, experts, ministries, and local governments, in order to support a policy making for conserving biodiversity.

Future research and development of the system will focus on 1) Participatory Geographic Information System (PGIS) so that authorized system users can input and edit data by themselves, and 2) display near real-time movement of tracked Asiatic black bear(s).

## 6 Future Work

The following topics are expected to carry out in our project:

* Implement a censoring system to monitor the traps in field of Asiatic black bears with remote-controllable camera
* Carry out near-real time tracking on Asiatic black bear(s) by GPS-ARGOS in order to collect primary data as presence data in Tanzawa area
* Design ecological networks and evaluate them based on several realistic scenarios in Fuji-Tanzawa regions
* Improve a Web-based GIS system to facilitate 1) Participatory Geographic Information System (PGIS) so that authorized system users can input and edit data by themselves, and 2) display near real-time movement of tracked Asiatic black bear(s).

## Acknowledgements

This research was financed by the Grant-in-Aid for Project by SFC Research Institute in 2007, Keio University, Research promotion fund in remembrance of Mori Taikichiro in 2007 and 2008, Graduate School Doctoral Students Grand-in-Aid Program 2008, and Research Fellowships of the Japan Society for the Promotion of Science for Young Scientists in 2009. The authors would like to thank Dr. Satoshi Osawa, Nihon University for financial assistance, Ms. Wenbo Chen, Keio University for assistance of fieldwork, image-processing and technical assistance for development of Web-based GIS system, Mr. Masayuki Nagasaka and Mr. Hidefumi Yatomi of Cubic i Co., Ltd., and Ms. Fumiko Kasahara of Nippon Kaiyo Co., Ltd for technical assistance for testing ARGOS system.

**References**

Biodiversity Center of Japan, *The National Survey on the Natural Environment Report on the distributional survey of Japanese animals (Mammals)*, Biodiversity Center of Japan, the Ministry of Environment, 232, 2004. (In Japanese)

CLS (Collecte Localisation Satellites)., "Argos User's Manual On Line", 2007, Retrieved 25 Oct., 2008, from http://www.argos-system.org/manual/.

Corsi, F., E. Dupre and L. Boitani, "A Large-Scale Model of Wolf Distribution in Italy for Conservation Planning", *Conservation Biology* 13(1), 1999, pp.150-159.

Doko, T., A. Kooiman and A. G. Toxopeus, "Modeling of Species Geographic Distribution for Assessing Present Needs for the Ecological Networks. ISPRS 2008", In *Proceedings of the XXIth ISPRS Congress, Beijing, China*, *ISPRS*, 2008.

Garneau, D. E., T. Boudreau, M. Keech and E. Post, "Habitat use by black bears in relation to conspecifics and competitors", *Mammalian Biology - Zeitschrift fur Saugetierkunde*, 73(1), 2008, pp.48-57.

Guisan, A. and N. E. Zimmermann, "Predictive habitat distribution models in ecology", *Ecological Modelling*, 135, 2000, pp. 147-186.

Hashimoto, Y., M. Kaji, H. Sawada and S. Takatsuki, "Five-year study on the autumn food habits of the Asiatic black bear in relation to nut production", *Ecological Research*, 18(5), 2003, pp.485-492.

Huygens, O. C., T. Miyashita, B. Dahle, M. Carr, S. Izumiyama, T. Sugawara and H. Hayashi, "Diet and feeding habits of Asiatic black bears in the Northern Japanese Alps", *Ursus*, 14(2), 2003, pp.236-245.

Ito, T. Y., N. Miura, B. Lhagvasuren, D. Enkhbileg, S. Takatsuki, A. Tsunekawa and Z. Jiang, "Satellite tracking of Mongolian gazelles (*Procapra gutturosa*) and habitat shifts in their seasonal ranges", *Journal of Zoology*, 269(3), 2006, pp.291-298.

Japanese Mammals Society, *Red Data: Japanese Mammals*, Bun-ichi Co., Ltd, 1997. (In Japanese)

Jiang, Z., M. Sugita, M. Kitahara, S. Takatsuki, T. Goto and Y. Yoshida, "Effects of habitat feature, antenna position, movement, and fix interval on GPS radio collar performance in Mount Fuji, central Japan", *Ecological Research*, 23(3), 2008, pp. 581-588.

Koyama, M. and K. Naganawa, "Food habits of Japanese black bear in Tanzawa mountain area", *Journal of Japanese Forest Research* 105, 1994, pp. 538-542. (In Japanese)

Landis, R. and G. Koch, "The measurement of observer agreement for categorical data", *Biometrics*, 33, 1977, pp. 159-174.

MacArthur, R. H. and E. O. Wilson, *The Theory of Island Biogeography*, Princeton University Press, 2001.

Maida, K., *Prevent bears' nuisance by keeping them alive*, Tokyo,

Rural Culture Association, 1998. (In Japanese)
Mochizuki, N., K. Sawai and T. Ohba, *Report on investigation of the habitat of Asiatic black bear in Shizuoka Prefecture (1998~2002)*, Shizuoka Prefecture Forestry and Forest Products Research Institute, 2005. (In Japanese)
Nelder, J. A. and P. McCullagh, *Generalized Linear Models*, Chapman & Hall/CRC, 1989.
Ohba, T., "Questionnaire Investigation about the Distribution of Sike Deer and Japanese Serow, and about the Population Condition, the Crops and Vegetation Damage, the Hunting, etc. of the Sika Deer in Shizuoka Prefecture", In *Research Report by Shizuoka Prefecture Forestry and Forest Products Research Institute (translated by author)*, 30, 2002, pp.1-16. (In Japanese)
Okumura, T., Takii, Koike and Hazumi, "Asiatic black bear's distribution and an issue of roadkill surrounding Mt. Fuji", *Wildlife Conservation Society,* 8(3), 2003, pp.74-75. (In Japanese)
Pearson, R. G. and T. P. Dawson, "Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful? ", *Global Ecology & Biogeography*, (12), 2003, pp.361-371.
Phillips, S. J., R. P. Anderson and R. E. Schapire, "Maximum entropy modeling of species geographic distributions", *Ecological Modelling*, 190, 2006, pp.231-259.
Repoussis, P. P., D. C. Paraskevopoulos, G. Zobolas, C. D. Tarantilis and G. Ioannou, "A web-based decision support system for waste lube oils collection and recycling", *European Journal of Operational Research*, 195(3), 2009, pp.676-700.
Stanners, D. and P. Bourdeau, *Europe's Environment. The Dobrís Assessment*. Copenhagen, European Environment Agency, 1995.
Stockwell, D. R. B. and D. Peters, "The GARP modelling system: problems and solutions to automated spatial prediction", *Int. J. Geographical Information Science*, 13(2), 1999, pp.143-158.
Telonics Inc., "GEN 4 GPS Subsystems", 2008, Retrieved 27 Oct. 2008, from http://www.telonics.com/products/gps4/.
Yamaguchi, Y., M. Nakamura and N. Watanabe, "Distribution of Japanese serow *Capricornis crispus* in Tanzawa Mountains, Kanagawa Prefecture", BINOS, 5, 1998, pp.23-30. (In Japanese)

## Appendix

Following is spatial data sources used for modelling and Web-based GIS:

The CGIAR Consortium for Spatial Information. "SRTM (Shuttle Rader Topography Mission)", http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp (accessed April 2008).

Geographical Survey Institute of Japan, 2006. "Download of the Global Map Japan Version 1", http://www1.gsi.go.jp/geowww/globalmap-gsi/download/index.html (accessed April 2008).

WorldClim, "WorldClim Version 1.4", http://www.worldclim.org/ (accessed April 2008).

The National Land Agency, 2003. Digital Map 25000 (Spatial Data Framework) KANAGAWA/ SHIZUOKA (CD-Rom).

Earth Science Data Interface, "GLCF: Earth Science Data Interface", http://glcf.umiacs.umd.edu/data/ (accessed April 2008).

Nature Conservation Bureau in Ministry of the Environment, 1997. 14 KANAGAWA/22 SHIZUOKA The dataset for GIS on the Natural Environment, Japan. Nature Conservation Bureau in Ministry of the Environment (CD-Rom).