F-4 Analysis and Evaluation of Migration Routes and Habitats of Migratory Birds using Advanced Information and Communication Technology (Abstract of the Final Report)

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Total Budget for FY2001-FY2003: 132,933,000Yen **(FY2003:** 43,137,000Yen)

Key Words: Satellite Tracking, GPS, storks, cranes, buzzard

1. Introduction

Recently the numbers of long-distance migratory birds are rapidly decreasing all over the world. The main reasons are considered to be environmental demolitions in breeding, stopover, and wintering sites of migratory birds due to human activities such as agricultural, residential, and industrial development. The rapid decrease of migratory birds means not only the extinction crisis of migratory birds themselves, but also the deterioration of ecosystems on a global scale. The extinction of migratory birds leads to malfunctioning of biological mutual connections supported by migratory birds and causes bad effects on the wholesomeness of ecosystems. The conservation of migratory birds is deeply related to the protection of the natural environment all aver the world that are connected by migratory birds and has a close connection with our human lives.

To promote the research on the conservation of migratory birds, satellite-based techniques such as satellite tracking, global positioning system (GPS), and satellite remote sensing are very effective because migratory birds move around over large areas. This research will contribute to the conservation of migratory birds and their habitats by using these advanced information and communication techniques.

2. Objectives and Methods

This research investigates migration routes and habitats of migratory birds by combining satellite tracking, GPS, and remote sensing techniques. Then the route selection mechanism of migratory birds is analyzed by quantitatively evaluating the relationship between selected migration routes and the environmental characteristics of stopover points. In addition a new tracking system using GPS is developed to improve the accuracy and efficiency of the bird tracking technique. This research consists of the following three subjects.

2.1 Environmental analysis and change prediction of migratory-bird habitats using satellite remote sensing and GIS techniques

First a method for measuring environmental conditions of migratory-bird habitats is developed using satellite imagery. Secondly the relationship between behavioral patters of migratory birds and environmental conditions of their habitats is investigated. Thirdly the effects of environmental changes due to large-scale modifications of land use and water resource developments on the living conditions of migratory birds are predicted and evaluated.

2.2 Mechanisms of migration route selection by birds, investigated by satellite-tracking

We analyzed satellite locations of five White-naped Cranes *Grus vipio*, four Grey-faced Buzzards *Butastar indicus*, and three Honey Buzzards *Pernis apivorus* to show their migration routes, migration patterns through time, and migration route selection. In White-naped Cranes, we used satellite locations obtained from earlier satellite tracking studies in Russia and China, and compared the area of wetland and grassland along the real migration routes and the supposed shortest migration routes. We used NOAA satellite images to calculate the area within a radius of 10km and 20km along the migration routes, respectively. Grey-faced and Honey Buzzards were captured and deployed with satellite transmitters in Japan, and were tracked in both seasons of fall and spring. We compared the migration between seasons, between years, and between species. Satellite locations were overlaid on maps and satellite images to show the characteristics of migration routes and habitats used.

2.3 Development of GPS-based migration birds tracking system

We develop a GPS-based long-term automatic tracking system that can collect position data of wild animals including migratory birds that move around over large areas. This new tracking system can obtain location data in better accuracy and cheaper cost than the existing ARGOS tracking system.

3. Results and Discussions

3.1 Environmental analysis and change prediction of migratory-bird habitats using satellite remote sensing and GIS techniques

(1) Resutls

New analytical method for identifying important stopover sites by assessing the connectivity of migration route network was developed using satellite tracking data. The method was applied to a data set for Oriental White Storks *Ciconia boyciana* tracked via satellite on their autumnal migrations from the Russian Far East breeding ground to the wintering ground in southeastern China in 1998 through 2000. The results suggested that if the seashore stopover sites facing Bohai Bay in eastern China were lost, the storks' wintering sites along the Yangtze River in southeastern China would be isolated. Among the seashore stopover sites, Jiantuozhi Gley Mire (39.185°N, 118.627°E), located on the northern seashore of Bohai Bay, was considered particularly important for migrating storks, because it was used every year by the storks we tracked. If conservation needs of this critically located site fail to be addressed, the stay site network of storks may become weak links in the chain of migration and, if 'broken', storks will have great difficulties in completing their autumnal migration.

The habitat use by Oriental White Storks at several stopover sites (Bohai Bay, Zhalong National Nature Reserve, Momoge Nature Reserve and Xianghai Nature Reserve) was investigated by overlaying the satellite tracking data on land-cover/land-use maps derived from Landsat-7 ETM+ imagery. Furthermore, the habitat use by Red-crowned cranes at the important wintering site, Cheorwon in the Korean Peninsula, was also investigated by the same means taking into account the location error of satellite tracking data. The results indicated that: the open water feature was an important environmental component for the storks; and the paddy fields were important for the cranes as their foraging fields and roosting places.

The spatial distribution of the area having the similar environmental characteristics with the storks' important stopover sites, Jiantuozhi Gley Mire, located on the northern seashore of Bohai Bay, was mapped by applying Constrained Energy Minimization (CEM) to high temporal resolution NDWI data set derived from SPOT VEGETATION S10 products.

New method for land cover change detection was developed, based on correlograms obtained by plotting auto-correlation and cross-correlation coefficients of NDVI time-series data as a function of lags. The performance test between the correlograms-based method and conventional CVA method showed that the correlograms-based method had significantly higher performance in detecting landcover changes throughout a broad spatial scale.

(2) Discussion

Migratory birds must contend with fluctuations in food availability, predation, and competition for food at each stopover site. These challenges will be exaggerated when available stopover sites occur only at discrete locations. Hence, stopover sites should be protected to form a well-connected network between breeding and wintering sites, so that migrants can replenish energy for continued travel while reducing the risk of exhaustion during migration journey.

Conservation priorities of stopover sites have been rated, based mainly on the demographic data in each site, but not on the contribution to preserving links between breeding and wintering sites. Furthermore, the operability of population-based approach can be hampered by logistical difficulties, especially when targeting long-distance migrants that make multiple stopovers at remote sites. The network model approach that we have developed here can complement the population-based approach, by providing a spatial context for interpreting the importance of stopover sites.

Wetland habitats for migratory water birds are rapidly disappearing in China, due to natural or human-induced factors. Identification and protection of wetlands available as stopovers sites are urgent matters to conserve the migrants. In light of a broad spatial scale, the network model approach demonstrates the importance of seashore stopover sites facing Bohai Bay in eastern China for preserving links from breeding sites to wintering sites of Oriental White Storks. It is highly recommended that the coastal area be protected to provide migrating storks with numerous alternative stopover sites for energy replenishment.

The GIS analyses with satellite tracking data and land-cover/land-use maps derived from satellite imagery provided us information about the environmental components important for migrating populations of Oriental White Storks and wintering populations of Red-crowned cranes. To provide an adequate design of protected sites, we must continue further studies of their distribution and habitat use at each site from the aspect of a finer spatial scale. We hope that the results of our study can serve as baseline information to promote the conservation of migratory water birds.

3.2 Study on migration route selection by birds, based on satellite-tracking

(1) Results

White-naped Cranes migrated from the breeding ground of south-eastern Russia through the mouth of the Yellow River to the wintering ground of Lake Poyang along the Yangsu River, southern China. The area of wetland and grassland was significantly larger along the real migration routes than along the supposed shortest migration routes. Grey-faced Buzzards migrated through the South-West Islands, Kyushu and Shikoku to Niigata or Fukushima in spring. The spring migration route was similar to the fall migration route but was different in some areas such as Gifu and Shiga Prefectures and Shikoku Island (Fig. 1). Fall migration was slower in speed than spring migration. In Inland areas, Grey-faced Buzzards tended to migrate over big rivers along high mountains. The spring migration route of the same individual was very similar for two consecutive years. The starting and ending dates were also almost identical.

Three Honey Buzzards migrated in fall from Nagano through Kyushu, eastern China and Malay Peninsula down to Sumatra and Java. One migrated further up to Borneo and the Philippines (Fig. 2). In spring, the buzzard that wintered in Java went north along a similar way to the fall migration, and reached the upper part of the Korean

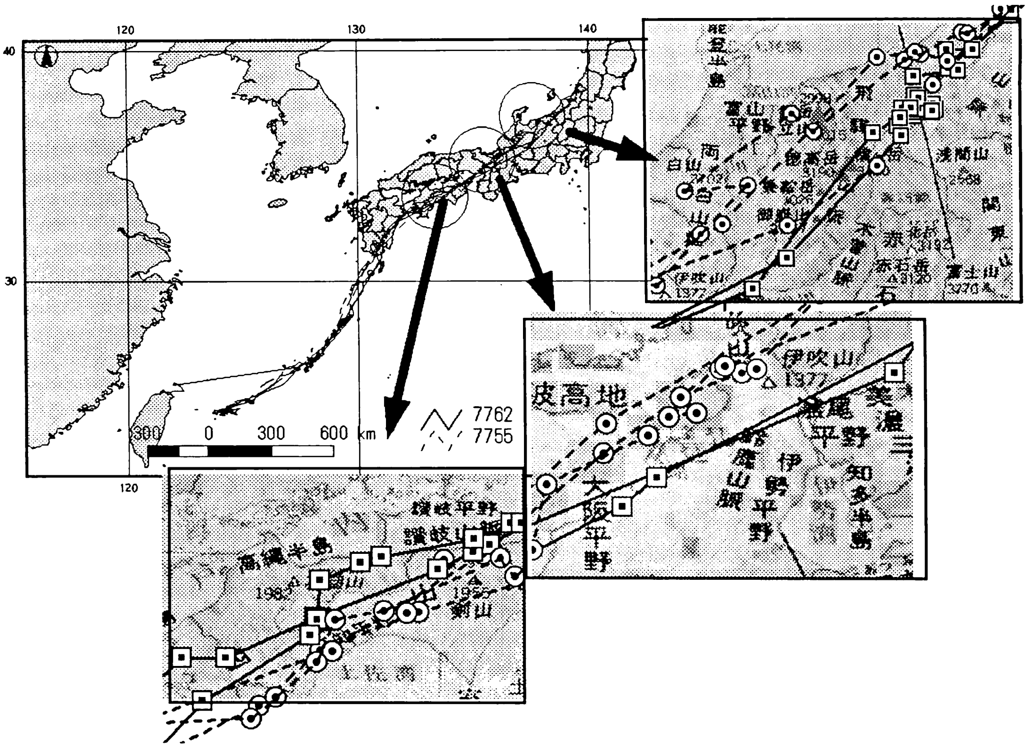

Fig. 1. Spring (⊙) and fall (▫) migration routes in two Grey-faced Buzzards.

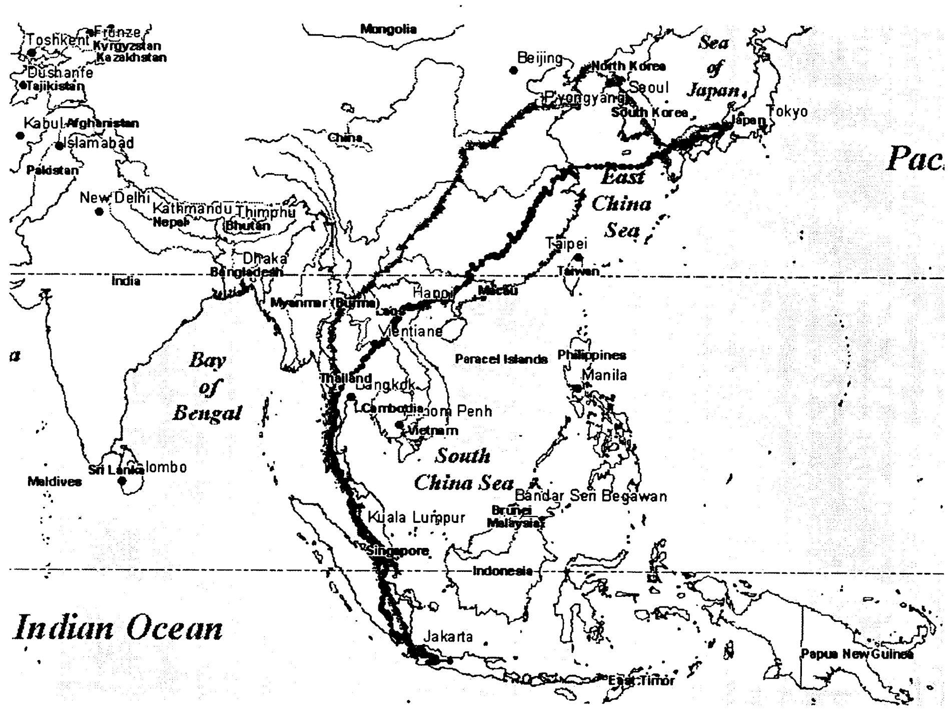

Fig. 2. Fall (●) and spring (△) migration of a Honey Buzzard satellite tracked from Nagano, central Japan.

Peninsula. She then came down the Korean Peninsula to Kyushu, and moved eastward through Hiroshima and Kyoto to Nagano. This is totally an unknown route in spring migration of birds. Another buzzard that wintered in the Philippines got back through the same way as fall migration to upper Malay Peninsula. Then, he moved eastward to Cambodia, where it's satellite transmitter stopped functioning. The other young buzzard has stayed in the middle part of the Malay Peninsula. It will not return to Japan in the first spring.

(2) Discussion

Analysis of migration route selection suggests that White-naped Cranes take the migration routes with larger area of good habitat even if they are roundabout routes that require more energy and time. It is likely that more food and better safety are available along the real migration routes. Grey-faced Buzzards commuted nearly straightforward between the breeding and wintering grounds. Their migration routes were similar in fall and spring. Honey Buzzards, on the other hand, took large roundabout routes both in fall and spring, and their migration routes differed between the two seasons. It is not known why Honey Buzzards take such different large roundabout routes in different seasons. Honey Buzzards feed on the pupae, larvae, and adults of wasps. There may be more plenty of wasps along different roundabout routes in different seasons.

It is still difficult, however, to understand why Honey Buzzards make big direction changes during their migration. For example, why do they have to migrate down the Korean Peninsula to reach Japan? It should be much easier for them to cross the East China Sea form eastern China to reach Kyushu, as did they in fall. It will be interesting to study the distribution and abundance of the buzzard food resources in East Asia. The reason why Honey Buzzards do not migrate through the South-West Islands of Japan may be that wasp resources are less available there. It will also be important to study wind directions along their migration routes. Honey Buzzards may have some difficulty to cross the East China Sea in spring.

All these crane and hawk species are threatened. We do not know the reason for their population decline. They face many difficult situations during the course of their migration. They include habitat loss, habitat deterioration, chemical pollution, and poaching. Satellite tracking is essential to show the migration route, the relative importance of each rest site, and conservation issues occurring along the migration route. We succeeded in satellite tracking the migration of the cranes and hawks, but the number of birds tracked is limited. We need to study more individuals to contribute to the conservation of these birds.

3.3 Development of GPS-based migration birds tracking system

Satellite tracking systems such as ARGOS are increasingly widely used in the study of bird migration. These systems are very powerful and have revolutionized the means of tracking migrating birds. However they do have some drawbacks. In an attempt to overcome some of the weak points in the satellite tracking systems, we have developed a new data logger called BGDL-II^{+} based on GPS. In our system, the equipment is several times cheaper than that of ARGOS. It needs not transmit a signal enabling us to reduce costs as we do not need to buy a license or pay for links. The position measurement is also much more accurate than the satellite system with a possible error of up to only 10 meters. In our system a daily schedule of measurements can be set beforehand using a personal computer temporarily connected to the unit. Due to the low cost of the equipment, which consists of a GPS receiver, a timer, memory, and a lithium battery that has the ability to fix 600 positions in total, we can get accurate position data from many birds simultaneously for longer periods, for example enabling us to track a bird over six months fixing positions three times a day. All at a more reasonable cost than the satellite system. Our unit is contained within 30m of water proofing, sufficient for albatrosses. The whole unit weighs 67 grams including battery. However the small size and light weight of BGDL-II is realized at the cost of real time delivery of position data, as users must re-capture the birds to obtain the information stored in memory of the equipments.

Due to the weight of the units and the necessity of re-capture, we selected certain kinds of albatross for the first application of our units. We conducted 1) Waved Albatross tracking around the Galapagos Islands, 2) Royal Albatross tracking around Taialoa Head, New Zealand, and 3) Chathum mollymawk tracking around the Chathum islands, 4) Grey-Headed and Wandering Albatross tracking around the South Georgia Islands. In these experiments, the failure rate in the fixing of positions during the birds flight is, on average, about 20% but in many cases it is lower than10% (See Table 1). From this we believe the performance of our unit to be satisfactory. Fig.3 shows the points fixed in the 12 experiments for Wandering albatrosses around the South Georgia Islands .

Table 1 List of field experiments using BGDL-II^{+}

Time	Place	Object	No. of files	Failure rate(%)[Max-Ave-Min]
2002-10	South Georgia Is.	Albatross	3	13.1 - 10.1 - 4.7
2002-12	Otago peninsula	Albatross	17	84.4 - 23.6 - 3.1
2002-03	South Georgia Is.	Albatross	30	27.7 - 8.1 - 0.3
2003-02	Sea of Okhotsk	Sea ice	2	0.0 - 0.0 - 0.0
2003-06～	Toi peninsula	Wild horse	3	13.9 - 9.7 - 5.6
2003-07	Galapagos Is.	Albatross	21	17.0 - 3.6 - 0.0
2003-08～	Alaska	Glacier	3	in progress
2003-08	Tibet plateau	Yaku	32	20.6 - 1.7 - 0.0
2003-12	Chathum Is.	Albatross	2	50.8 - 41.5 - 33.0
2004-01	Tibet plateau	Yaku	9	49.3 - 12.0 - 0.0

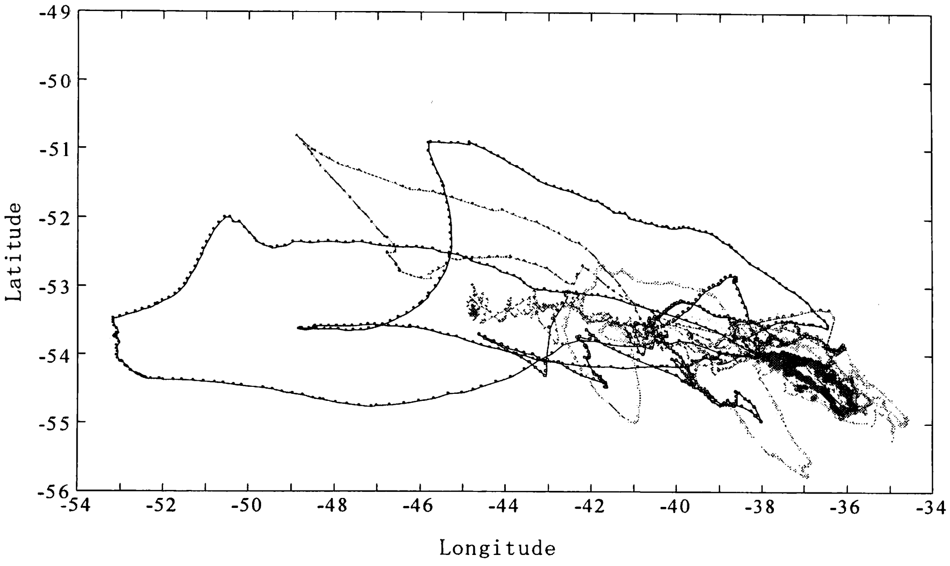

Fig. 1 Wandering albatross tracking around South Georgia Island.