

A Systematic Area Prioritization Process for Biodiversity Conservation in the DMZ and the CCZ

생물종 다양성 증진을 위한 보존지역 선정모델에 대한 연구
: 비무장지대와 민통선지역 사례 연구

김진오 Research Fellow, Metropolitan Design Center,
Kim Jinh College of Design, Univ. of Minnesota
(kjo612@yahoo.co.kr)

목 차

- I. Background
- II. Research Purpose and Methods
- III. A Conservation Planning Process
 - 1. Compilation and Assessment of Biodiversity Data
 - 2. Identification of Biodiversity Surrogates
 - 3. Data Process for Area Prioritization
- IV. Discussion
- V. Conclusion

I. Background

At the end of the three-year Korean War in 1953, the Demilitarized Zone (DMZ) was established between South Korea and North Korea, and has been left undeveloped as a result of heavy military. Along the 38th parallel, the DMZ corridor has become an important refuge for diverse wildlife, including several endangered species. The 4-kilometer-wide by 250-kilometer long zone was established along the Military Demarcation Line set by the Armistice Agreement. According to the Korean Ministry of Environment (MOE) (2004), the DMZ currently provides habitat for 146 endangered species and more than 2,800 different animals and plants. Thus, scientists and environmental groups in Korea and international organizations studying biodiversity conservation are concerned about the future of the DMZ because it may face environmental destruction when, and if, the two separated countries unify and the DMZ is opened to development.

In South Korea, one of the most densely populated countries in the world, urban growth and economic development have greatly influenced degradation of the natural environment, resulting in significant loss of biodiversity. Furthermore, Seoul metropolitan region, with a population of 11 million people, is located only sixty four kilometer away from the southern boundary of the DMZ, and could be a significant threat to the region's rich biodiversity if the status changes. In an effort to preserve the DMZ effectively, South Korea is laying the groundwork for the designation of the DMZ as a "Trans-boundary Biosphere Reserve" in conjunction with the United Nations Education, Scientific and Cultural Organization (UNESCO), in hopes of preserving this unique reserve regardless of future political changes. However, one of the important political impediments to establish this designation is the fact that the parties who agreed to create the DMZ in 1953 under the Military Armistice Agreement are the United Nations Command (with the United States speaking on its behalf), North Korea, and China. Thus, formally speaking, South Korea is not a party to the Agreement, but the government and the UNESCO are pursuing the designation in cooperation with North Korea in the hope that the other parties would agree with the project if the two Koreas were to agree on the environmental protection of the DMZ.

However, in spite of the general agreement to preserve the biodiversity of the DMZ, the environmental quality of the DMZ is significantly threatened by rapid urban development occurring in the Civilian Control Zone (CCZ), which is adjacent to southern boundary of the DMZ. The CCZ is the 5 to 20km wide buffer zone with initial occupation of 1,529km² in South Korea, and a similar civilian control zone is said to exist to the north of the DMZ. The CCZ in South Korea was partly occupied by 14 cities and districts and 2 provinces (Kim. 2001). Due to the matter of security, the land uses in the CCZ have been very restrictive and only limited agricultural

Figure 1 _ The Locations of DMZ and CCZ on the Border of North and South Korea

land uses and military trainings have been allowed. Landmines laid by the US Army and South Korean Army in the DMZ and CCZ during the war and later also have restricted human land use activities. According to the Ministry of National Defense of South Korea, the number of mines laid is estimated at 1.1 to 1.2 million, making the DMZ and CCZ one of the most heavily mined areas in the world. However, these restrictive conditions for human use have made the CCZ a haven for many plants and animals that were considered extirpated or endangered. The CCZ flora includes 1,170 vascular plants and the waterways support 83 fish species, and the entire ecosystems of DMZ and CCZ provide significant habitats and wintering grounds for a variety of endangered species, including two of the world's most endangered birds, the white-naped crane (*Grus vipio*) and the red-crowned crane (*G. japonensis*) (MOE. 2004).

The CCZ mammal fauna consists of 51 species, which represent 67% of Korean fauna, and nine rare species of mammals inhabit the CCZ, including the black bear (*Selenarctos thibetanus ussuricus*) and the musk deer (*Moschus moschiferus caudatus*) (MOE. 2004). However, serious threats to biodiversity in the CCZ are now on rising. Local cities in the CCZ are developing tourism economies, and major corporations are interested in developing the region for future projects. Even more serious is the damage that is being done in some valuable habitats, particularly wetlands in the CCZ. For example, the preliminary construction of a railroad and highway stretching across DMZ and CCZ has significantly threatened the Sachon River's ecosystem near the eastern CCZ (Soh. 2000).

II. Research Purpose and Methods

This study aims to propose an approach that systematically prioritize areas for biodiversity conservation of DMZ and CCZ areas in South Korea where area prioritization is one of significant issues for effective conservation. Instead of using intuitive approaches for area selection, the study incorporates ResNet and Maxent in conjunction with Geographic Information System(GIS) to systematically prioritize areas for conservation. The process of the conservation planning applied in this study is based on the systematic conservation planning process outlined by Sarkar (2005). This systematic conservation planning process is an extension and modification of the six-stage process proposed by Margules, et al.(2002). Sarkar's 11 steps include; ① identify stakeholders for the planning region, ② compile and assess biodiversity data for region, ③ identify biodiversity surrogates for region, ④ establish conservation targets and goals, ⑤ review existing conservation areas, ⑥ prioritize new sites for potential conservation action, ⑦ assess prognosis for biodiversity for each potential targeted place, ⑧ refine networks of places targeted for conservation action, ⑨ perform feasibility analysis using multiple criterion synchronization, ⑩ implement conservation plan, and ⑪ periodically reassess the network.

Recognizing that systematic application of these entire steps through iterative and heuristic process is essential for successful biodiversity conservation, this study focused on area prioritization process as a way to produce options for conservation area network. In particular, the study used ResNet to identify sets of complementary sites needed to achieve quantitative targets for biodiversity features. Maxent that maximizes the probable presence with limited number of species identified was also used as a prior step to ResNet. This combined set of process for area prioritization applied in this study is not a linear process. Rather, it is iterative process based on continuous data updates. This systematic area prioritization process using biodiversity content information will provide significant basis for applying multiple criteria to include social demands for future study as well.

III. A Conservation Planning Process

Conservation areas are defined as geographically specified terrestrial or marine regions managed for the persistence of biodiversity features (taxa, community, and habitat types, etc.) and processes (Sarkar, et al. 2006). Sarkar, et al.(2005) also defines conservation planning as the selection of conservation area networks (CANs) and the formulation of management plans for them, and suggests representation, persistence, and economy as the general goals of conservation

planning. Based on these concepts, this study uses coarse-grained environment data publicly available from World Wide Web and the data on species occurrences provided by Korean Ministry of Environment in 2004.

1. Compilation and Assessment of Biodiversity Data

Korean Ministry of Environment (MOE) (2004) found that, as of 2002, 18,052 animal and 8,271 plant species have been identified and recorded in Korea. Among the 1,440 species of vertebrates, 905 are fish, 41 amphibians and reptiles, 394 birds, 100 mammals, and 11,853 species are classified as insects (MOE, 2004). In South Korea, many remaining wetlands are still supporting over 1 million wintering ducks and geese and a significant percentage of the East Asian–Australasian Flyways migratory shorebirds.

It has been reported that at least 21 Threatened Migratory Waterbirds that are listed in the Asia–Pacific Migratory Waterbird Conservation Strategy were identified. However, with the loss of wetland the wide range of species are already facing imminent extinction. Due to rapid urban development and human disturbance, many animals and plants species have been threatened, thus, 43 endangered species and 151 threatened species of wildlife and plants are designated to be protected based on the Natural Environment Conservation Act. With forests covering 66 percent of its territory, Korea has a variety of tree species. However, these rich biodiversity had been seriously devastated under the Japanese colonialism in the first half of the 20th century and the Korean War in 1950~53. In 1962, the government initiated an ambitious nationwide forestation project to rehabilitate most of the affected forests. But, rich diversity was replaced chiefly with conifers, and habitats for many species gradually disappeared.

In DMZ and CCZ, a vascular plant is known to have 1,597 taxa; 1,163 taxa in the east coastal region and mid–east mountainous region, 954 in inland mid–west region, and 1,102 in the west coast and islands. The endangered plants found in DMZ are *Crypsinus hastatus*, *Lilium cernuum*, *Trillium tschonoskii*, *Iris dichotoma*, *Gastrodia elata*, *Ranunculus kazusensis*, *Paeonia japonica*, *Echinosophora koreensis*, *Trientalis europaea*, etc.. These are mainly distributed in Mt. Daeam, Yanggu–Gun, Cheolwon–Gun and Ganghwa Island. In particular, Mt. Daeam was noteworthy for the concentration of endangered plants in its highland marshes. Korean Ministry of Environment (2004) investigated biodiversity and concluded that 249 red–crowned cranes and 401 white–naped cranes were observed at Cheolwon in 2003 keeping relatively stable status. Both species mostly used dried paddies but the behavioral characteristics were different. Due to the human disturbance including road construction, the distribution pattern of red–crowned cranes in and around DMZ

reveals differently every year. In Odu-mountain and Imjin-gak area, various bird species wintering have been observed.

2. Identification of Biodiversity Surrogates

The use of surrogates to represent biodiversity in planning protocols is essential because the standard components of biodiversity cannot usually be surveyed adequately under the constraints of time and budget, and our knowledge about biodiversity is limited and records of geographical location are biased (Sarkar, et al. 2005). In this study biodiversity surrogates are classified into two categories: environmental surrogates and species surrogates.

1) Environmental Surrogates

In spite of limited resources, 22 environmental surrogates are identified as useful ones. The map of Korean terrestrial ecoregions of the world was obtained from the website of WWF (<http://www.worldwildlife.org/ecoregions/>; Olson, et al. 2001) to analyze the characteristics of entire ecoregion of Korea including the DMZ and CCZ. According to the map, the ecoregions of Korea represent four types: Central Korean deciduous forests, Changbai Mountain mixed forests, Manchurian mixed forests, and Southern Korea evergreen forests. The ecoregions within the DMZ and CCZ indicate Central Korean deciduous forests and Manchurian mixed forests.

The geology of the DMZ and CCZ is mostly composed of the Precambrian gneiss and Mesozoic granite. However, along the linear pattern from Wonsan through Cheolwon even up to Seoul, the great lineament is detected. Especially, the segment of Wonsan to Cheolwon is called as Chugaryung Rift Zone, which is composed of the Pleistocene lava flow and some of the Cretaceous tuffstone. The plain area around Cheolwon is the Pleistocene basalt with the layer thickness 50m to 100m. Hantan River flows along the boundary of basalt and granite or in the middle of basalt plain, and forms a narrow gorge (30m) with cliff height 25m to 35m. Korea has a temperate climate, with four distinct seasons. Winters are cold and windy, and snow falls in all but the southernmost regions. Summers are hot, humid, and rainy. The annual average precipitation of the DMZ and CCZ region is 1,100~1,600mm, and the annual average temperature is 8~11°C. Cheolwon is known for the coldest area in South Korea with around -25°C at mid-winter because of the cold air mass, funneled through the Rift valley from the North, fanning out into the Cheolwon plain area. The climate of Korea Peninsula including DMZ and CCZ was predicted to be changed with increased mean air temperature about 3~9°C and increased precipitation about

30~500mm. Climate data for Korea was obtained from the WORLDCLIM (<http://biogeo.berkeley.edu/worldclim/worldclim.htm>), a set of climate layers on a square kilometer grid, provided by the University of California at Berkeley. The BioClimatic variables are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables. The bioclimatic variables represent annual trends, seasonality, and extreme or limiting environmental factors. A quarter is a period of three months. The data layers were generated through interpolation of average monthly data from weather stations on a 30 arc-second resolution grid. These environmental surrogates include annual mean temperature, mean diurnal range, isothermality, temperature seasonality, maximum temperature of warmest month, minimum temperature of coldest month, temperature of annual range, mean temperature of wettest quarter, mean temperature of driest quarter, mean temperature of warmest quarter, mean temperature of coldest quarter, annual precipitation, precipitation of wettest month, precipitation of driest month, precipitation seasonality, precipitation of wettest quarter, precipitation of driest quarter, precipitation of warmest quarter, precipitation of coldest quarter.

Elevation data were obtained from the GTOPO30 DEM (Digital Elevation Model) at 1K scale available from the United States Geological Survey (USGS) (USGS, 1988, <http://edcdaac.usgs.gov/gtopo30.html>). The raster data of the areas of CCZ and DMZ were processed by using Surface Analyst extension in ArcGIS 9.0 to transform to 50 meters contour. The elevation was divided into 5 classes.

The Land Cover data for CCZ were obtained from the website of the Global 2000 Land cover (GLC, 2000) (<http://www-gvm.jrc.it/glc2000/products/fullproduct.asp>). The GLC2000, a new global 1 km land cover classification for the year 2000, was created by the European Commission's Joint Research Center (JRC) in collaboration with over 30 research teams from around the world to provide accurate baseline land cover information to the International Conventions on Climate Change, the Convention to Combat Desertification, the Ramsar Convention, and the Kyoto Protocol.

The GLC2000 land cover database has been chosen as a core dataset for the Millennium Ecosystems Assessment to define the boundaries between ecosystems such as forest, grassland, and cultivated systems. The GLC2000 dataset has total 96 classifications that indicate various kinds of forests, fields, grassland, woods, cropland, evergreen, wetland, and etc. In the area of South Korea 16 different land cover types were identified, indicating two most dominant land covers; needleleaf evergreen forest and cropland. Other land cover types include broadleaf evergreen forest, broadleaf deciduous forest, needleleaf deciduous forest, mixed forest, shrubs, herbaceous, herbaceous with sparse tree, sparse herbaceous, wetland, urban, water, bare rock,

bare soil, and rice paddy. In the area of the DMZ and the CCZ, broadleaf deciduous forest is the most dominant.

2) Species Surrogates

Due to the impossibility of complete identification of all wildlife species in the DMZ and CCZ, surrogates representing a small proportion of total biodiversity were applied to identify biodiversity priority areas. For species surrogates, this study relies on the data produced from the research conducted by Korean MOE in 2004. The species surrogate data include 2,960 occurrence points of 131 species in South Korea territory. Species surrogates include 11 mammals, 48 birds, 3 reptiles, 3 amphibians, 12 insects, 34 plants, 2 invertebrates and 18 fish. According to the report, MOE (2004) identified a number of endangered species including 20 species of birds, 3 species of mammals. These are; Black-faced Spoonbill (*Platalea minor*), Yellow Billed Spoonbill (*Platalea leucorodia*), White-tailed Sea Eagle (*Haliaeetus albicilla*), Steller's Sea Eagle (*Haliaeetus pelagicus*), Crane (*Grus japonensis*), Swan Goose (*Anser cygnoides*), Greater White-fronted Goose (*Anser albifrons*), Cinereous Vultures (*Aegypius monachus*), White-naped Crane (*Grus vipio*), Kestrel (*Falco tinnunculus*), Hooped Crane (*Grus monacha*), Tundra Bean Goose (*Anser fabalis*), Common Buzzard (*Buteo buteo*), Canada Goose (*Branta Canadensis*), Grey Heron (*Ardea cinerea*), Spot-billed Duck (*Anas poecilorhyncha*), Mallard (*Anas platyhynchos*), Green-winged Teal (*Anas crecca*), Ruddy Shelduck (*Tadorna ferruginea*), Pygmy Woodpecker (*Dendrocopos kizuki*), Chinese Water Deer (*Hydropotes inermis*), Antelope (*Naemorhedus caudatus*), Wild Boar (*Sus scrofa*).

In South Korea, Chinese Egret (*Egretta euophote*)'s ecology and distribution remain relatively poorly known, and the species still does not receive quite the same high level of conservation interest (MOE. 2004). Currently, it is known that Chinese Egret has a total breeding population of between 2,400~3,600 individuals and that it is declining. Chinese Egret has also been classified as "vulnerable" by Birdlife International. However, Chinese Egret is still threatened by massive reclamation of key tidal-flat areas and the increased degradation of hinterland all over the Korea. A Black-faced Spoonbill (*Platalea minor*) is a globally endangered species, only distributed along the east fringe of Asia. Its known world population is less than 1,000 individuals. The bird breeds in some islands in the West Sea of Korea and spends winters in surrounding countries such as China, Hong Kong, Taiwan, Japan, and the Philippines. According to Wetlands International, the nesting sites of the Black-faced spoonbill are in a safe situation in South Korea and maybe even in the North Korea, as they are mainly found in the DMZ (MOE. 2004). They found that the safety

of feeding and roosting sites outside the breeding season needs to be secured as several of the important mudflats have been lost to coastal development in recent years. Rice fields, their main feeding habitat, also need to be closely monitored as the chemical materials and fertilizers that the farmers using could be a potential threat to the birds. A major location where Black-faced Spoonbill has been observed is around Odu-mountain Unification Observatory in midwestern area of CCZ. A Yellow Billed Spoonbills (*Platalea leucorodia*) is common in south-east Australia, not unusual on the remainder of the continent. Its foods include aquatic life, and it nests in trees, marshes or reed-beds. In Korea, it has been rarely identified, and in 2004, the Korean MOE found only one individual during their CCZ field survey. The White-tailed Sea Eagle (*Haliaeetus albicilla*), the fourth largest eagle in the world, is found across Europe and also inhabits parts of Asia. The bird's preferred habitat is rocky coasts, but it may also inhabit areas such as remote lakes and marshes, further inland. The White-tailed Sea Eagle is listed as "lower risk" by the 2000 IUCN Red List. They have been threatened by loss habitat, persecution and pollution. Steller's Sea Eagle (*Haliaeetus pelagicus*) is globally rare. It is classified as "vulnerable", and a small number of records in total have been monitored in South Korea.

According to the BIRDSKOREA, a specialist conservation organization based in South Korea, in winter of 2002 and 2003 at least 12 and possibly closer to 20 were present nationwide, with 1 or 2 in the DMZ, at least 4 in the Nakdong estuary, and one or two in the west, including a regularly returning individual at Seosan. In 2004, the Korean MOE also identified a few of Steller's Sea Eagle around the Odu-mountain and the Imjin-gak, the west area of the CCZ.

Red-crowned Cranes (*Grus japonensis*) are the only crane species that have white primary feathers. Red-crowned Cranes breed in large wetlands in temperate East Asia and winter along rivers and coastal and freshwater marshes in Japan, China, and the Korean Peninsula. Red-crowned Crane, classified as Endangered under the revised IUCN Red List Categories, prefer to nest and feed in marshes with relatively deep water, and will nest only in areas with standing dead vegetation. They are generalist feeders and prefer wetter feeding sites, but also forage along dikes and in croplands. Red-crowned Cranes have been seriously threatened by loss of habitat caused by agricultural expansion, reed harvesting, river channelization, deforestation, and road building. In Korea, potential development in the CCZ and DMZ poses large-scale threats to breeding, migration, and wintering habitat. Other anthropocentric threats include disturbance, intentional setting of fires, and overharvesting of wetland resources in key breeding areas. The majority of these cranes migrated along the east side of North Korea and then inland to spend the winter in the Cheolwon Basin of the CCZ. Amongst the many winter birding highlights in South Korea are the concentrations of raptors. Classified as near-threatened, the Cinereous Vultures

(*Aegypius monachus*) within Eastern Asia breeds in mainland China and Mongolia, with significant numbers moving south into South Korea, from November onwards. The Cinereous Vultures have been wintering in South Korea, with the largest concentrations in the northwest; over 200 in the DMZ, in the outstandingly important Cheolwon Basin. The species is regular in smaller numbers throughout the country.

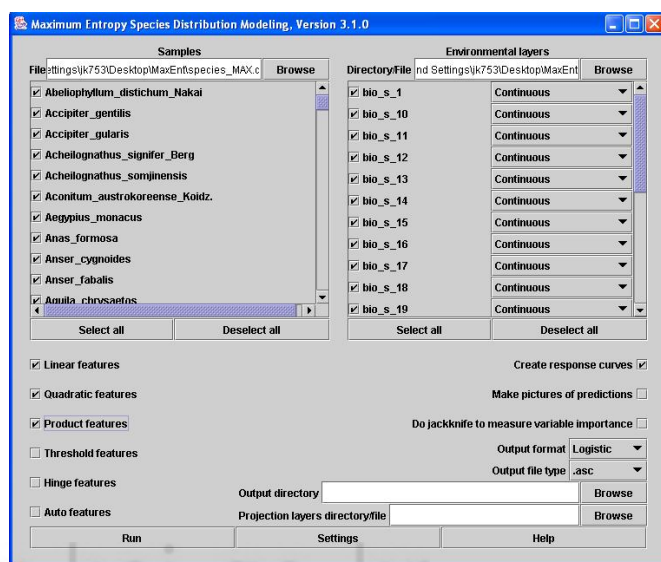
3. Data Process for Area Prioritization

1) Species Distribution Modeling

Based on the surrogates data identified above, the area of South Korea was divided into cells at the resolution of $0.01^{\circ} \times 0.01^{\circ}$ of longitude and latitude, resulting in 92,201 cells created. These cells enable to identify the spots where wildlife species were observed by Korean Ministry of Environment, as well as to input the information for each cells to create a database using ArcGIS. The surrogates database was produced by joining the tables of Grid shapefile and the Species point file. However, due to the limitation of the small number of datasets for species distribution, Maxent (Maximum Entropy Density Estimation) program was utilized. Maxent performs better than other types of ecological niche modeling such as the Genetic Algorithm for Rule-Set Prediction (GARP) in predicting species geographic distribution with presence-only data (Phillips, et al. 2006). Unlike other traditional methods, Maxent, according to Phillips, et al. (2006), better discriminate suitable versus unsuitable areas for the species. Maxent computes models of species geographic distributions using an algorithm based on the maximum-entropy principle from statistical mechanics (Pawar, et al. 2005)(see Appendix 1).

Given a set of species data and environmental variables, Maxent estimates the predicted spatial

Figure 2 _Data Input Process for the Maxent Application



distribution by finding the distribution of maximum entropy. The model for a species is determined from a set of environmental surrogates for a set of grid cells, including sample locations where the species has been observed. The model estimates the suitability of the grid of each species surrogate as a function of the environmental variables at that grid cell. A high value of the function at a particular grid cell represents that the grid cell is predicted to have suitable conditions for that species (Pawar, et al. 2005). The biological interpretation of the Maxent output is that it represents the “fundamental niche” of each species, which is defined as the complement of ecological factors that the species requires (Soberon and Peterson.

2005). The result of Maxent transformed after creating coordinates to maximize future probable species distributions, will be utilized to run the ResNet to analyze place prioritization for overall biodiversity conservation.

The Maxent software has processed an ASC file of 131 species surrogates and 23 environmental surrogates in a same extent of area with same cell size. As a result, Maxent constructed 96 species distribution models, while discarded 35 species for the unreliable number of species point data. Among the 96 species distribution models, 43 species models were finally selected as useful based on two measures of accuracy: the AUC on test data and the number of hypothesis tests. The AUC, known as the Area Under the Receiver Operating Characteristic Curve, is currently considered a standard method to assess the accuracy of predictive distribution models.

The AUC summarizes overall model performance over all possible thresholds to avoid the supposed subjectivity in the threshold selection process, when continuous probability scores

Figure 3 _A Spatial Distribution Model of the Red-crowned Crane in the CCZ and DMZ

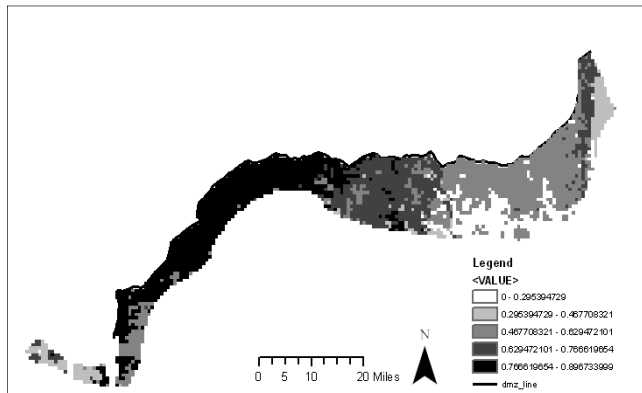
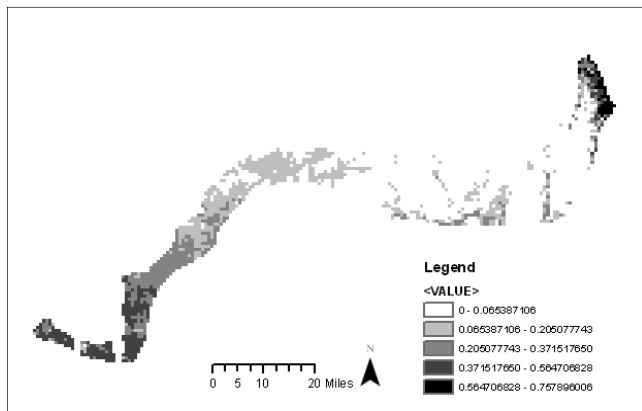


Figure 4 _A Spatial Distribution Model of the Whooper Swan in the CCZ and DMZ



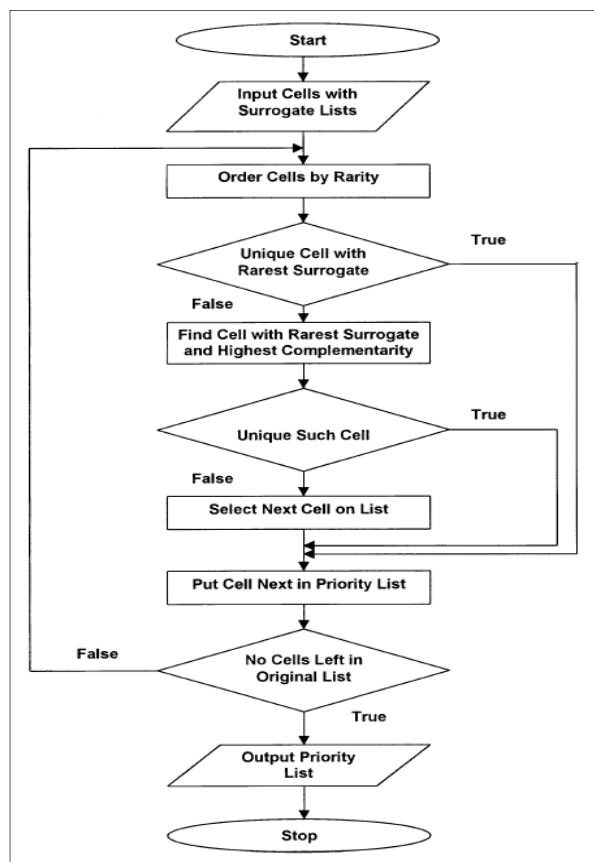
derived need to be converted to binary presence–absence variable (Phillips, et al. 2006). In this study, species distribution models with an AUC 0.75 were selected as well–constructed, as was supported by Elith (2002). AUC = 0.75 means that in places where a species is present, in 75 percent of cases the predicted value will be higher than where the species has not been recorded (Elith, 2002). However, due to the weaknesses of using exclusively one criterion of the AUC, as pointed out by Lobo et al. (2008), I applied an additional measurement criterion for model selection. I retained the species model if more than one hypothesis test was significant for the species. The number of hypotheses that are significant for each species was determined by counting the number of rows in the P–value column that are less than 0.05 in the table generated from Maxent analysis. Finally, the 43 species that meet the two criteria are selected (see Appendix 2).

2) ResNet Analysis to Prioritize Areas in the DMZ and CCZ

After modeling distributions of species surrogates using Maxent, ResNet program was applied to the systematic area prioritization process for biodiversity conservation. This software package implements a Conservation Area Networks (CAN) selection algorithm fully described by Sarkar, et al. (2002). ResNet provides a useful tool for systematic conservation planning, while an implicit area selection has been traditionally based on intuitive judgments of biodiversity value. These intuitive judgments also include concern for charismatic or useful species, and the use of criteria that are extraneous to biodiversity conservation such as scenic value and wilderness quality (Sarkar, 2005). The algorithms of the ResNet assume that a definite target has been set in the form of adequate representation of each surrogate. The goal of the algorithm is to achieve the set target efficiently by selecting as few places as possible that together reach the conservation goal. To run ResNet, the study uses the environmental surrogate data and the species distribution models produced from Maxent analysis. The place prioritization algorithm is that the first cell is selected by the presence of the rarest surrogate in the data set, and next the CAN is iteratively augmented by adding cells using rarity and complementarity (Figure 5).

In this study, 812 cells in the geographic territory of the CCZ and the DMZ were used as input file to run ResNet. In its first run, ResNet selected about 88 sites, which were treated as permanently excluded when finding the second ResNet solution. This ResNet process was repeated to find the third solution, by treating the first and the second ResNet solutions as a set of permanently excluded cells. However, when ResNet was run to find the fourth solution, 250 cells were treated as permanently excluded cells. This indicates that it was not possible for ResNet to find

Figure 5 _ResNet: The Basic Algorithm. The Flowchart Describes the Basic Algorithm Incorporated in ResNet



Source: Sarkar, et al. 2002.

process method proposed in this study is unique for the following two reasons. First, it provides a systematic way to assess biodiversity value using incomplete (probabilistic) data of species' occurrence and environment surrogates. In particular, Maxent enables to rapidly predict species' geographical distributions based on known occurrence data. In modeling species' distributions, Maxent mathematically computes the relationship between species occurrence data and environmental surrogates. Using well-constructed habitat distribution models, ResNet applies explicit area selection rules, such as complementarity and rarity to maximize biodiversity value. This combined application of algorithms is especially useful to establish conservation area networks in the CCZ and the DMZ, where access to data and resources is constrained significantly. Second, the concept of core areas has been supported by UNESCO's Biosphere Reserve Program to protect biodiversity and the range of different natural processes. Once core areas are identified, buffer zones and corridors can be easily established to design effective conservation area networks. This is especially significant for the CCZ

more solutions that satisfied the 15 percent target of representation for all of the species with 250 cells permanently excluded. Thus, from this ResNet analysis, the three solutions were identified as meaningful under 15 percent target, meeting the same level of biodiversity value. These targets, however, should not be interpreted as suggesting that the biodiversity is being adequately protected by satisfaction of the targets, because the targets may only reflect a limited scope of socio-political constraints (Soule and Sanjayan. 1998).

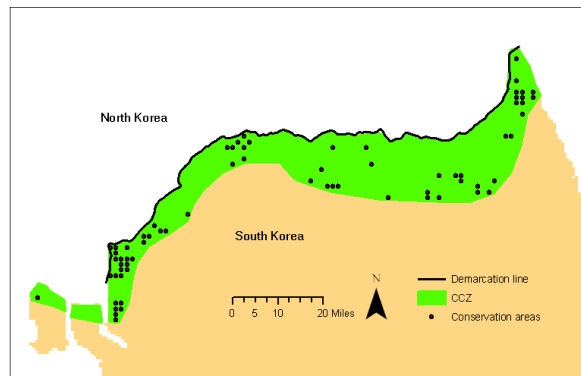
IV. Discussion

The method presented here attempts to account for the significant data restrictions associated with the modeling of biodiversity in the CCZ and the DMZ. In this respect, the area prioritization

because if conservation area networks were established based on the core areas, useful guidelines can be provided for planning in the adjacent areas along the southern boundary of the CCZ. Since local governments are currently in a rush for economic development in and around the CCZ, this systematic area prioritization method would help planners develop conservation plans.

While this systematic method applied in this study would provide a useful framework for biodiversity conservation, important limitations for application to the CCZ and DMZ are also identified. The most notable limitation is that the number of species distribution models can be significantly reduced by the Maxent run depending on their quality of data. Maxent requires more than four records of species' occurrence for modeling, and constructs a limited number of species' distribution models. In this study, out of 131 species, only 43 species' distribution models were well constructed, due to the internal rules applied by Maxent. For example, some internationally endangered species such as Black-faced Spoonbill were not considered in the area prioritization process due to the failure to construct accurate models with Maxent. Second, the unit of analysis used in this study is coarse, thus it may overestimate or underestimate the amount of land that is significant for conservation purposes. The areas selected using the integrative method need to be subdivided into smaller units for further analysis, using information on conservation targets, viability, ecological integrity, and other ancillary data sets. Especially when an area selected to be included in a conservation plan encompasses a significant amount of human use, more careful analyses at finer scales are critical. This is likely to be a perennial feature of conservation planning in the CCZ. For example, vulnerable species such as the Red-crowned Crane and the White-naped Crane routinely forage in the vicinity of agricultural lands. Proscribing agricultural activity in these foraging areas is unacceptable to local stakeholders. Thus, a more judicious approach may involve restricting the harvest of rice in some areas and in certain seasons, since the cranes prefer to forage in unplowed fields. In general, the formulation of conservation plans in the CCZ should be based on collaborative evaluation by a variety of experts, including community and regional planners, biologists, and landscape architects. Third, in the CCZ and the DMZ, the lack of information on the locations of landmines is one of the significant constraints in the area prioritization for biodiversity conservation. Some areas that are suspected to contain landmines may be included in conservation areas on the grounds that it is

Figure 6 _ 15 percent Target Area for Conservation in the CCZ and the DMZ



ostensibly unsuitable for human use. However, this may result in the designation of areas that are not necessary for biodiversity conservation in the CCZ and DMZ. Given that the land available for biodiversity conservation in the CCZ is limited by agriculture and military uses, it is essential that rationale for prioritization of a conservation area should be a site's biodiversity content, rather than its purported landmine content.

V. Conclusion

This study offers a spatial modeling that incorporates a habitat projection modeling tool and an area prioritization algorithm for effective biodiversity conservation in the CCZ and the DMZ where access to accurate data is highly limited for military security. These systematic tools have been widely applied in the field of conservation biology for their explicit attention to biodiversity in modeling processes as well as for efficiency that is critical for threatened biodiversity areas. However, due to its heavy reliance on the quality of data as well as limited nature of the algorithms, continuous efforts to improve the process are necessary. There is a no single way to decide which sites to protect, because there are several factors affecting conservation and land use decision (Costello and Polasky. 2004). Most of all, the areas of habitat under the most threat of development should be considered in defining high priority locations for conservation. Selecting surrogates is also one of the most important steps in conservation planning. Thus, building a theory to define the criteria of surrogates including not only species but also other crucial factors including cultural and aesthetic values is significant.

The systematic tools used in this study may help future DMZ and CCZ conservation in identifying ecologically valuable places. This will be especially useful to make eco-regional network plan for effective conservation. Understanding relationship between species distributions and a particular environmental condition (surrogate) is also an important issue for further research. One of the challengeable questions for future research is how these spatial analysis tools (Maxent and ResNet) can be effectively incorporated into the current practice of land use decision process. In particular, how these place prioritization tools for biodiversity conservation can be applied in developing future land development scenarios that minimize destruction of biodiversity can be an interesting topic for future research.

Reference

Costello, C. and S. Polasky. 2004. "Dynamic Reserve Site Selection". *Resource and Energy Economics* vol.26.

SanDiego : Elsevier. pp157-174.

Elith, J. 2002. "Quantitative Methods for Modeling Species Habitat: Comparative Performance and an Application to Australian Plants". In Ferson, S. and M. Burgman(eds.). *Quantitative Methods for*

- Conservation Biology*. New York : Springer. pp39-58.
- Kim, K. C. 1997. "Preserving Biodiversity in Korea's Demilitarization Zone". *Science* vol.278. Washington, D.C : American Association for the Advancement of Science. pp242-243.
- _____. 2007. "Preserving Korea's Demilitarized Corridor for Conservation: A Green Approach to Conflict Resolution". In Ali, S.(eds.). *Peace Parks : Conservation and Conflict Resolution*. Cambridge, Massachusetts : The MIT Press.
- Kim, K. G. 2001. *A study on the feasibility as well as an operational strategy to develop DMZ Transboundary Biosphere Reserve between DPR Korea and Republic of Korea*. Jakarta : UNESCO.
- Lobo, J., A. Jimenez-Valverde, A., and R. Real. 2008. "AUC: A Misleading Measure of the Performance of Predictive Distribution Models". *Global Ecology and Biogeography* vol.17. New Jersey: Wiley-Blackwell. pp145-151.
- Margules, C. R., R. Pressey, and P.H. Williams. 2002. "Representing Biodiversity: Data and Procedures for Identifying Priority Areas for Conservation". *Journal of Bioscience* vol.27, no.4. India : Indian Academy of Sciences. pp309-326.
- Ministry of Environment of Korea(MOE). 2004. *Ecosystem Approach for the Investigation, Analysis and Impact Assessment of De-militarized Zone of Korea*. Gwacheon : Republic of Korea.
- Olson D., Dinerstein, E., Wikramanayake, E., Burgess, N., Powell, G., Underwood, E., D'Amico, J., Itoua, I., Strand, H., Morrison, J., Loucks, C., Allnut, T., Ricketts, T., Kura Y., Lamoreux, J., Wettengel, W., Hedao, P., and Kassem, K. 2001. "Terrestrial Ecoregions of the World: A New Map of Life on Earth". *BioScience* vol.51. Washington, D.C : American Institute of Biological Sciences. pp933-938.
- Pawar, S., M. Koo, and D. Crawford. 2005. "Protocol for Installing and Running Maxent". *Biodiversity and Biocultural Conservation Laboratory*. Austin, TX : University of Texas at Austin Press.
- Phillips, S., R. Anderson, and R. Schapire. 2006. "Maximum Entropy Modeling of Species Geographic Distributions". *Ecological Modelling* vol.190. Amsterdam : Elsevier. pp231-259.
- Sarkar, S. 2005. *Systematic Conservation Planning: A Primer*. Austin, TX : University of Texas at Austin Press.
- _____. 2005. "Systematic Conservation Planning: A Primer". *Biodiversity and Biocultural Conservation Laboratory*. Austin, TX : Section of Integrative Biology, University of Texas at Austin.
- Sarkar, S., A. Aggarwal, J. Garson, C. Margules, and J. Zeidler. 2002. "Place Prioritization for Biodiversity Content". *Journal of Bioscience* vol.27, no.4. India : Indian Academy of Sciences. pp339-346.
- Sarkar, S., J. Justus, T. Fuller, C. Kelly, J. Garson, and M. Mayfield. 2005. "Effectiveness of Environmental Surrogates for the Selection of Conservation Area Networks". *Conservation Biology* vol.19, no.3. New Jersey : Wiley-Blackwell. pp815-825.
- Sarkar, S., Mayfield, M., Cameron, S., Fuller, T., and Garson, J. 2006. "Conservation Area Networks for the Indian Ecoregion: Systematic Methods and Future Prospects". *Biodiversity and Biocultural Conservation Laboratory*. Austin, TX : Section of Integrative Biology, University of Texas at Austin.
- Soberon, J. and A.T. Peterson 2005. "Interpretation of Models of Fundamental Ecological Niches and Species' Distributional Areas". *Biodiversity Informatics* vol.2. Lawrence, Kansas : University of Kansas. pp1-10.
- Soule, M. and M. Sanjayan 1998. "Conservation Targets: Do They Help?". *Science* vol.279. Washington, D.C : American Association for the Advancement of Science. pp2060-2061.
- Westing, A. 1998. "A Transfrontier Reserve for Peace and Nature on the Korean Peninsula". *International Environmental Affairs* vol.10, no.1.(publisher information is not identified). pp8-17.
- Won, B. O. 1996. *Bi Mujang Jidae: Yasaeng eu Bogo*(in Korean): Demilitarized Zone Wildlife Report. Sungchun-Munhwa-Jaedan, Seoul, Korea : Hyunamsa.
- Soh, J. "DMZ-Ecological Paradise in Jeopardy". The Korea Times. <http://www.mtholyoke.edu/~jeehan/ppage4p.html>. [2010.2.19]

- 논문 접수일: 2010. 4.21
- 심사 시작일: 2010. 4.26

- 심사 완료일: 2010. 5.11

ABSTRACT

**A Systematic Area Prioritization Process for Biodiversity Conservation
in the DMZ and the CCZ**

Key words: Biodiversity, Conservation, Area Prioritization

This study aims to propose an approach that systematically prioritize areas for biodiversity conservation in the DMZ and CCZ in Korea. Instead of using intuitive approaches for area prioritization, the study incorporates Maxent and ResNet in conjunction with Geographic Information System(GIS) to systematically select areas for biodiversity conservation. The study used Maxent to rapidly predict species' geographical distributions based on known occurrence data, as well as ResNet to identify sets of complementary sites needed to achieve quantitative targets for biodiversity features. In modeling species' distributions, Maxent mathematically computes the relationship between species occurrence data and environmental surrogates. Using well-constructed habitat distribution models, ResNet applies explicit area selection rules, such as complementarity and rarity to maximize biodiversity value. This combined application of algorithms is especially useful to establish conservation area networks in the CCZ and the DMZ, where access to data and resources is constrained significantly.

**생물종 다양성 증진을 위한 보존지역 선정모델에 대한 연구
: 비무장지대와 민통선지역 사례 연구**

주제어: 생물종 다양성, 보존계획, 비무장지대

본 연구는 한국 비무장지대(DMZ)와 민통선(CCZ) 지역의 생물다양성 보존을 위한 중요 지역 선별방법 모델 제안에 그 목적을 두고 있다. 이번 연구는 그동안 생태적으로 중요한 지역선별 시 주요 생물종 발견 지점 혹은 주변 서식처 위주로 해오던 방법 대신, Maxent와 ResNet라는 두 컴퓨터 프로그램을 GIS와 함께 사용, 이들의 적용 메커니즘과 적용 시의 장단점을 분석하고자 한다. Maxent는 각 생물종이 관찰된 지점의 제한적 공간정보와 이에 상응하는 각종 환경정보, 즉 토지피복, 고도, 경사도, 기후정보 등과의 통계적 상관성을 바탕으로 이들의 지형적 분포를 예측하는 데 이용된다. 또, ResNet는 Maxent로부터 생성된 각 생물종들의 지형적 분포모델을 종합적으로 분석, 보완성(Complementarity)과 희소성(rarity)이라는 두 가지 지역 선정 원칙(algorithm)을 바탕으로 생물종 다양성을 확보하는 데 중요한 지역들을 우선적으로 선정하게 된다. ResNet은 target 설정에 따라 보존지역 선정에 대한 다양한 안을 제안할 수 있는 장점이 있으며, 기존에 지정되어 있거나 이미 알려진 보존가치가 있는 지역들과의 연계성을 함께 고려, 생물종 다양성을 더욱 증진하는 방향으로 지역을 선정하는 데 중요한 툴로 활용될 수 있다. 이 두 가지를 함께 적용하는 방법은 직접적이고 광범위한 생물종 조사를 위한 데이터 측정과 확보가 매우 어려운 비무장지대와 민통선 지역의 생물종 다양성 보존에 매우 효과적으로 활용될 수 있는 가능성을 보여주고 있으며, Maxent의 제한적 생물종 지형분포 모델링과 데이터의 정밀도, 그리고 결과물에 대한 해석 등의 한계는 앞으로 적용 시 더욱 주의 깊게 연구하고 또 보완해야 할 문제로 판단된다.

[Appendix 1]

Probabilistic Formulation of the Maximum Representation Problem

To provide a context for the probabilistic Maximum Representation Problem, I first explain the deterministic Maximum Representation Problem. I imposed a constraint on the area prioritization to limit the amount of land that could be put under a conservation plan while satisfying the targets for as many species as possible. When the species' occurrence data are deterministic, this is known as the Maximum Representation Problem. I use the following notation to define the Maximum Representation Problem:

Sets/Indices

$i \in I$ species. i is a particular species. I is the set of all species. $|I| = m$

$j \in J$ sites. j is a particular site. J is the set of all sites. $|J| = n$

Data/Parameters

a_{ij} 1 if species i is in site j . 0 otherwise. $a \in \{0, 1\}^{m \times n}$

t_i target of coverage for species i , $t_i \in \left\{1, 2, \dots, \sum_{j=1}^n a_{ij}\right\}$

b budget. The number of sites that can be selected. $b \in \{1, 2, \dots, n\}$

Decision variables

x_j 1 if j is selected. 0 otherwise. $x \in \{0, 1\}^n$

y_i 1 if i is covered at the targeted level in the conservation areas. 0 otherwise.

$y \in \{0, 1\}^m$

Formulation

$$\max_{x, y} \sum_{i=1}^m y_i \quad (S2.1)$$

$$s.t. \sum_{j=1}^n a_{ij} x_j \geq t_i y_i, 1 \leq i \leq m \quad (S2.2)$$

$$\sum_{j=1}^n x_j \leq b \quad (S2.3)$$

$$x_j \in \{0, 1\}, 1 \leq j \leq n \quad (S2.4)$$

$$y_i \in \{0, 1\}, 1 \leq i \leq m \quad (S2.5)$$

The objective function (S2.1) selects as many species as possible to be represented in the conservation areas at or above their targets of coverage. Constraint (S2.2) states that if

a species i is selected to be covered in the conservation areas, then the representation of i in the selected sites must equal or exceed the target for i . However, there is a budgetary constraint on the number of sites that can be put under a conservation plan (S2.3). Due to the budget constraint, it may not be possible to represent all species in the conservation areas at the targeted levels. Constraint (S2.4) states that each site must either be selected or not selected to be put under a conservation plan. Constraint (S2.5) states that each species must be selected to be represented at the targeted level in the conservation areas or not so selected.

Including a constraint on the amount of land that can be put under a conservation plan in the CCZ and DMZ is appropriate for several reasons. First, the establishment of conservation areas in the CCZ and DMZ must compete with agricultural and commercial development and the use of land for security purposes by the military and state police. The South Korean Army, the DMZ Civil Police with 1024 officers and a small number of US forces maintain facilities in the vicinity of the DMZ. Limiting the total area of the conservation area network is intended to decrease conflicts with other land uses, such as military use. Another rationale for limiting the total size of the conservation area network is that sites in the CCZ and DMZ are among the most heavily mined areas in the world, with 1.1 to 1.2 million mines and 112.5km² of mined land. Imposing a constraint on the total area of the network indirectly limits the cost of mine cleanup and the danger of injury to humans and wildlife by land mines.

In addition to the notation of (S2.1)–(S2.5), the following is required:

Ω discrete outcome space. $\Omega = \{\omega: \omega \text{ is a } m \times n \text{ matrix with each entry } E_{ij} \in \{0, 1\}\}$

E_{ij} discrete event. $E_{ij} = \{ 1 \text{ if species } i \text{ does not have suitable habitat in } j \text{ } 0 \text{ otherwise} \}$

$P(\cdot)$ probability measure ($P: \Omega \rightarrow R$)

Data/Parameters

$$P_{ij} = 1 - P(E_{ij})$$

a_i probability of persistence for species

Decision variable

w_i the probability that species i is not covered in the sites selected to serve as conservation areas

Formulation

$$\max_{w, x} \sum_{i=1}^m (1 - w_i) \quad \text{In} \quad (S2.6)$$

$$\text{s.t. (S2.3) \& (S2.4)} \quad (S2.7)$$

$$W_i = \prod_{j=1}^n (1 - p_{ij})^{x_j}, \quad 1 \leq i \leq m \quad (S2.8)$$

$$(1 - w_i) \geq a_i, \quad 1 \leq i \leq m \quad (S2.9)$$

Like optimization model (S2.1)–(S2.5), Model (S2.6)–(S2.9) selects a subset of the sites in the study region to serve as conservation areas. In Model (S2.6)–(S2.9), the conservation decision-maker wants to select sites so that the probability that a species i is represented in the conservation areas is as large as possible. w_i is the probability that i is not covered in the conservation areas, so maximizing $(1 - w_i)$ maximizes the probability that i is covered (S2.6). In general, w_i can be calculated as follows:

$$1 - P\left(\bigcap_{j=1}^n E_{ij}\right) = 1 - P(E_{i1}) \cdot P(E_{i2} | E_{i1}) \cdot P\left(E_{i2} | E_{i2} \cap [E_{i1}]\right) \cdot P\left(E_{i3} | \bigcap_{j=1}^{n-1} E_{ij}\right) \quad (S2.10)$$

However, equation (S2.10) requires knowing the joint probabilities of the E_{ij} events. Since the data parameters of the optimization model (S2.6)–(S2.9) do not define these joint probabilities, solving the model requires making some assumption about the joint probabilities. The typical approach is to assume independence. The independence assumption states that:

$$\forall i, j, k, P(E_{ij} \cap E_{ik}) = P(E_{ij}) \cdot P(E_{ik}), \quad 1 \leq i \leq m, 1 \leq j \leq n, 1 \leq k \leq n \quad (S2.11)$$

As in the optimization model (S2.1)–(S2.5), in Model (S2.6)–(S2.9), there is a budgetary ceiling on the total number of sites that can be put under a conservation plan and each site must either be selected or not selected (S2.7). Constraint (S2.8) is interpreted as follows.

If site j is selected to serve as a conservation area, then $x_j = 1$ and $(1 - p_{ij})^{x_j} = (1 - p_{ij})$. Suppose the region of the analysis consists of two sites, j and k . Let p_{ij} be the probability that species i has suitable habitat in j and let p_{ik} be the probability that i has suitable habitat in k . Under the independence assumption (S2.11), $w_i = (1 - p_{ij}) \cdot (1 - p_{ik})$ if both j and k are selected to serve as conservation areas. Constraint (S2.8) is derived by generalizing this principle to an arbitrary number of sites. If the independence assumption (S2.11) is made, then (S2.8) can be linearized by logarithmic transformations:

$$\ln \in (w_i) = \sum_{j=1}^n \ln (1 - p_{ij}) x_j, \quad 1 \leq i \leq m \quad (S2.12)$$

Furthermore, the non-linear function $In(w_i) = \sum_{j=1}^n In[(1-p_{ij})x_j]$, $1 \leq i \leq m$ in (S2.12) can be approximated by a linear function using breakpoints. Constraint (S2.9) requires that species i is represented in the conservation areas with probability a_i . a_i is typically based on the conservation status of species i , such as the species' category in the IUCN Red List. If i is critically endangered, then conservation planners may set a_i at 0.99, whereas if i is a species of least concern, a_i may be set at $\frac{1}{2}$ or lower. Optimization model (S2.6)–(S2.9) assumes that $0 \leq p_{ij} < 1$.

[Appendix 2]

Table 1_ Species' Ecological Niche Models Produced by Maxent

Scientific name	Common name	No. records	AUC	No. signif. Tests
Birds (12 species)				
<i>Anser fabalis</i>	Bean Goose	23	0.773	11
<i>Bubo bubo kiautschensis</i>	Eurasian Eagle-owl	52	0.751	11
<i>Charadrius placidus</i>	Long-billed Plover	57	0.836	11
<i>Cygnus columbianus</i>	Tundra Swan	10	0.826	10
<i>Cygnus cygnus</i>	Whooper Swan	16	0.76	10
<i>Dryocopus martius</i>	Black Woodpecker	31	0.823	11
<i>Egretta eulophotes</i>	Chinese Egret	14	0.838	6
<i>Gallicrex cinerea</i>	Watercock	8	0.879	6
<i>Grus japonensis</i>	Red-crowned Crane	16	0.992	9
<i>Grus vipio</i>	White-naped Crane	5	0.909	10
<i>Haliaeetus albicilla</i>	White-tailed Eagle	8	0.789	1
<i>Strix aluco</i>	Tawny Owl	27	0.791	11
Butterflies (1 species)				
<i>Fabriciana nerippe</i> C.&R. <i>Felder</i>	none	13	0.822	11
Fish (15 species)				
<i>Acheilognathus signifer</i> Berg	Korean Bittering	85	0.901	11
<i>Acheilognathus somjinensis</i>	Seomjin Bittering	5	0.912	7
<i>Cottus hangiongensis</i> Mori	Tumen River Sculpin	16	0.986	11
<i>Cottus poecilopus</i>	Alpine Bullhead	85	0.84	11
<i>Gobiobotia brevibarba</i> <i>Mori</i>	Short-barbel Gudgeon	55	0.886	11
<i>Gobiobotia macrocephala</i> <i>Mori</i>	Big-headed Gudgeon	24	0.791	11
<i>Gobiobotia naktongensis</i> <i>Mori</i>	Nakdong Gudgeon	24	0.91	11
<i>Iksookimia choii</i>	Choi's Spiny Loach	5	0.972	10
<i>Lampetra reissneri</i> Dybowski	Far Eastern Brook Lamprey	31	0.783	6
<i>Microphysogobio koreensis</i> <i>Mori</i>	Gudgeon	14	0.944	11

note: *Listed as "endangered" by IUCN

**Listed as "vulnerable" by IUCN

Listed as "nationally endangered" by Ministry of Environment of the Republic of Korea

Table 1_ Species' Ecological Niche Models Produced by Maxent(Continued)

Scientific name	Common name	No. records	AUC	No. signif. tests
Fish (continued)				
<i>Pseudobagrus brevicorpus</i> Mori #	Korean Stumpy Bullhead	10	0.934	11
<i>Pseudopungtungia nigra</i> Mori #	Black Shiner	56	0.949	11
<i>Pseudopungtungia tenuicorpus</i> Jeon & Choi	Slender Shiner	77	0.904	11
<i>Pungitius kaibarae</i> Tanaka	Short Nine-spined Stickleback	39	0.988	11
<i>Pungitius sinensis</i> Guichenot	Chinese Nine-spined Stickleback	5	0.909	6
Mammals (5 species)				
<i>Martes flavigula</i>	Yellow-throated Marten	81	0.836	11
<i>Naemorhedus caudatus</i> **,#	Chinese Goral	29	0.981	11
<i>Prionailurus bengalensis</i>	Leopard Cat	480	0.817	11
<i>Pteromys volans</i>	Siberian Flying Squirrel	30	0.86	10
<i>Ursus thibetanus</i> **,#	Asiatic Black Bear	8	0.892	11
Plants (10 species)				
<i>Aconitum austrokoreense</i> Koidz.	none	12	0.957	11
<i>Berchemia berchemiaefolia</i> Koidzumi	none	29	0.985	7
<i>Corylopsis gotoana</i> var. coreana	none	25	0.968	11
<i>Hylotelephium ussuriense</i> D. Leem, sp. nov.	none	8	0.985	6
<i>Iris odaesanensis</i> Y. Lee	none	24	0.911	10
<i>Leontice microrhyncha</i> S. Moore	none	6	0.959	8
<i>Lilium cernuum</i> Komarov	Cernuous Lily	20	1	11
<i>Millettia japonica</i> A. Gray	none	4	0.985	6
<i>Paeonia obovata</i> Maxim.	Chinese Peony	22	0.999	11
<i>Smilacina bicolor</i> Nakai	none	16	0.892	9