

Selecting Protected Area Using Species Richness^{1a}

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ABSTRACT

We created species richness maps of mammals, birds and plants using "National Ecosystem Survey" data and identified correlations between species richness maps of each taxa. We examine the distribution of species richness of each taxa and calculated conservation priority rank through plotting species-area curves using an additive benefit function in Zonation. The conclusions of this study are as follows. First, plant showed high species richness in Gangwon province and Baekdudaegan, and mammals showed high species richness at eastern slope of Baekdudaegan in Gangwon province unusually and the species richness of mammals distributed equally except Gyeonggi and Chungnam province. However, birds showed high species richness in the west costal because the area is the major route of winter migratory birds. Second, correlation of each taxa's distribution is not significant. Correlation between mammals and birds is positive but correlations between birds and others are negative. Because mammals inhabit in forest but birds mostly live in coastal wetlands and rivers. Therefore, bird's habitats are not shared with other habitats. Third, the probability of mammals occurrence is very low under 25% in species-area curve, others increase proportionally to area. Birds increase dramatically richness at 10% because bird's habitat is concentrated in coastal wetlands and rivers. Plants increased gently species richness due to large forest in Gangwon province. We can calculate the predicted number of species in curves and plan various conservation strategies using the marginal number of species. Finally, high priority ranks for conservation distributed mainly in Gangwon province and Baekdudaegan. When we compared with priority map and terrestrial national parks, the parks were evaluated as high priority ranks. However, the rank of parks away from Baekdudaegan was low. This study has the meaning of selecting conservation priority area using National Ecosystem Survey. In spite of the omission of survey data in national parks and Baekdudaegan, the results were good. Therefore, the priority rank method using species distribution models is useful to selecting protected areas and improving conservation plans. However, it is needed to select protected areas considering various evaluation factors, such as rarity, connectivity, representativeness, focal species and so on because there is a limit to select protected area only using species richness.

KEY WORDS: SPECIES DISTRIBUTION MODELS, SYSTEMATIC CONSERVATION PLANNING, SPECIES-AREA CURVE, PRIORITY, ZONATION

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INTRODUCTION

At the 10th meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD COP 10), which was held in Nagoya, Japan in 2010, the Strategic Plan for Biodiversity 2010-2020 was adopted and it was decided that as part of Target 11, at least 17 percent of terrestrial and inland water areas, and 10 percent of coastal and marine areas should be conserved by 2020 (CBD, 2010; Kim, 2012). Accordingly, the Ministry of Environment (MOE) has been steadily striving to discover protected areas to meet such targets. In 2008, the National Institute of Environmental Research (NIER) has initiated an investigation to find areas with outstanding ecosystems and scenery, and it has been conducting in-depth surveys on forests and inhabited islands to excavate distinguished ecosystems, while at the National Wetlands Center (NWC), general surveys on national inland wetlands has been performed to discover new outstanding wetlands, and those areas that were designated as protected areas (NIER, 2012; NIER, 2013). Nevertheless, the portion of conserved areas is lower than that of global levels, as terrestrial protected areas, except dual-designated preserved areas, account for about 10.1 percent of the total land area of South Korea, and 6.2 percent for marine protected areas in territorial waters (Kim, 2012). The MOE established a plan to expand terrestrial protected areas to 15 percent, and 13 percent for marine protected areas by 2015, but it seems difficult for the ministry to accomplish its targets (MOE, 2006). The reasons behind the failure of past policy on protected area expansion are that (1) the MOE focused more on increasing the number of preserved areas rather than expanding the land area; and (2) a nation-level strategy was necessary to identify the current status of conservation areas, but due to the unclear criteria for the designation of protection, it was difficult to quantify and designate those areas. Moreover, when considering the fact that the government prioritizes development plans over conservation plans, an economic value assessment on natural resources is also likely to be needed (Lee, 2006; Sung *et al.*, 2011; Kim, 2012). Another obstacle for the policy on protected area expansion is the conflicts with residents. Almost 40 percent of national parks, the core of internal protected areas which makes up a mere 3.9

percent of the total land area, is private property or temple forests, making it difficult to promote the policy. It would be difficult to manage natural resources efficiently and induce residents' spontaneous participation unless issues related to private lands are resolved (Kim *et al.*, 2005; Lee, 2006; Sung *et al.*, 2011). In the United States and Canada, scenario planning; forecasting models; and spatial decision support systems (SDSS) are used to resolve such conflicts and pursue their policies (Kennedy *et al.*, 2008).

To resolve such complicated and multilayered issues and conflicts, Margules and Pressy (2000) suggested systematic conservation planning (Figure 1). Systematic conservation planning is a planning process to maximize preservation effect with minimum costs to enhance biodiversity or preserve valuable objects in nature (Rondinini and Boitani, 2006; Regan *et al.*, 2007; Micheli *et al.*, 2013; Meller *et al.*, 2014). Systematic conservation planning applies a simple and clear process through spatial information and quantification, and continuously evolves through monitoring and adaptive management (Margules and Pressy, 2000; Langford *et al.*, 2011). However, there is a gap between the plan and reality. In fact, the system has often displayed limitations due to the uncertain forecasting owing to limiting factors such as social, economic and political issues. Despite such limits, this approach is used to designate and manage various preserved areas. Also, much effort has been made in establishing more quantitative and accurate data to overcome such limits. Furthermore, for efficient planning, biologists and ecologists are invited to participate in an actual planning process to judge whether a new approach

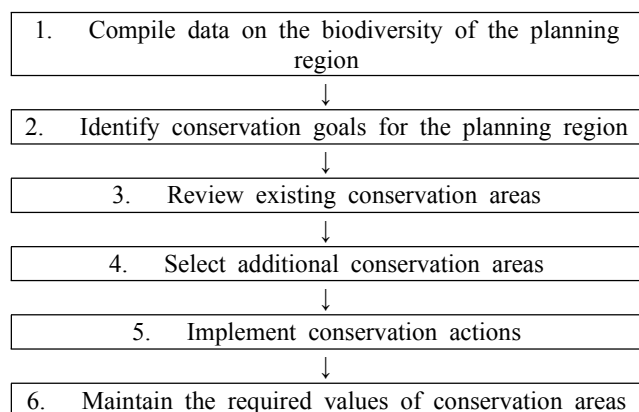


Figure 1. Stages in systematic conservation planning (Margules and Pressey, 2000)

is necessary for a plan and how to manage sociopolitical limiting factors (Margules and Pressey, 2000; Langford *et al.*, 2011; Micheli *et al.*, 2013).

MATERIALS AND METHODS

This study examined the national species richness patterns of mammals, birds and plants based on the Second National Ecosystem Survey (1997-2003) and some data from the Third National Ecosystem Survey (data from 2006-2009 for mammals and plants, 2006-2011 for birds). A study was conducted on 187 second-class and above floristic regional indicator plant species, which include the endangered species stated in National Ecosystem Survey data; 92 coordinates-specified bird species; and 15 mammal species (Kim *et al.*, 2012b).

A Maxent model used in the study, which is a species distribution model optimized for present-only data, has relatively high model fitness compared to other models. The results of individual distribution models calculated according to the Maxent model were added up, and the national species richness was mapped (Kwon *et al.*, 2012a; 2012b; Kim *et al.*, 2012a).

Regression analysis was conducted to examine the correlation among the species richness of biological taxa using grid values. Also, a species-area curve was created

through standardization; the distribution patterns of plant taxa was examined; a conservation priority order map was made based on the species richness of each taxon; and an assessment was made after comparing the map with existing terrestrial national parks. A conservation priority list could be determined on the basis of core-area zonation; additive benefit functions; and targets, and for this study, additive benefit functions were used (Moilanen, 2007).

ArcGIS 9.3 was used to make a map; DIVA-GIS 7.5 for analysis on the correlation among biological taxa; and Zonation software for determining a conservation priority list. Zonation is an algorithm to design protected areas using a species distribution model. It is used to determine the conservation priorities for natural resources. For instance, just as the top five percent of the priority list are selected within the top 10 percent, the determination of the ranks of protected areas is conducted repetitively, eliminating areas with lower conservation value from the entire area (Moilanen, 2007). Study

RESULTS AND DISCUSSION

1. Mapping Species Richness by Using Special Distribution Models

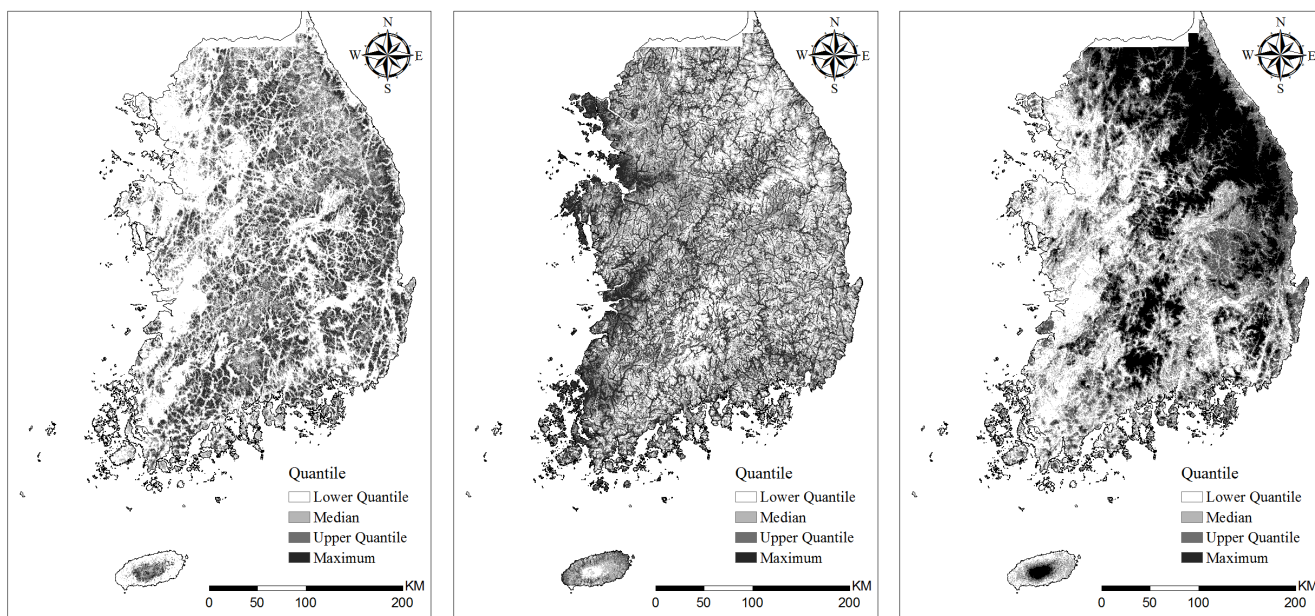


Figure 2. Species richness map for three different taxa (left-mammals, center-birds, right-plants). The maps are classified by quantile

Individual species distribution models were added up and made into a map (Figure 2; Kwon, 2011). There were areas where no mammals were witnessed to where 15 species were found. There were areas where a maximum of 62 out of 92 bird species and a maximum 122 out of 187 plant species were observed. With plants, the highest species richness was found in Gangwon Province: Mt. Deokyusan National Park and Mt. Jirisan National Park in the Baekdudaegan Mountain Range recorded highest species richness. In case of mammals, a few were observed where there are many cities or farmland areas in Gangwon Province and Chungcheongnam Province, where there are many cities or farmland areas, and a lot were found at the slope of the eastern Baekdudaegan Mountain Range, but overall, the population was dispersed over a wide geographical area. This is because they have a relatively a small number of species compared to other biological taxa, and many of their habitats are divided into inside and outside forest (Kim *et al.*, 2012a). As for birds, the highest species richness was found in Ganghwa Island and its neighboring islands; Asan Bay; Anmyeon Island; and Shinan County (Lee, 2001; Fly and Sarlov-Herlin, 1997). This is surmised to be due to their locations, the major flight paths of migratory birds, and the abundant sources of food in coastal wetlands (Moores, 1999; Amano *et al.*, 2010).

2. Correlation among Biological Taxa

This study examined the correlation of the species richness distribution among biological taxa. Overall, it showed low correlation coefficients, and the species richness distribution of biological taxa do not intersect with each other (Araújo and Thuiller, 2005). Nevertheless, while the flora and mammals showed a positive correlation, birds and mammals have a negative correlation

(Figure 3; Walters *et al.*, 2006). This seems to be because forests of high flora species richness provide various habitats and sources of food to mammals, but areas of high bird species richness are mostly located at the seashore, rivers and the edges of forests, where there are relatively low populations of plants and mammals. Also, more coordinates-specified recorded species, which are used in the model, inhabit the seashore and rivers more than forests (Fly and Sarlov-Herlin, 1997; Moores, 1999; Lee, 2001; Amano *et al.*, 2010).

$$Plants_{rich} = 7.66 + 3.37Mammals_{rich} (R^2 = 0.243)$$

$$Birds_{rich} = 25.66 - 1.19Mammals_{rich} (R^2 = 0.382)$$

$$Birds_{rich} = 23.82 - 0.15Plants_{rich} (R^2 = 0.278)$$

3. Species–Area Curve by Biological Taxon

If we take a look at Figure 2, as was mentioned earlier, regarding mammals, the mammals have a low distribution of about 25% of the total area due to distribution in large farming areas in the Metropolitan area and Chungnam Province which was not forecasted. Besides those areas, areas from low species richness to high species richness is increasing in a fan shape. In case of birds, unlike mammals, the curve is gentle until the occupied area goes beyond 0.9 where a steep increase can be observed. This shows that the areas of high species richness have limited space, and as can be seen in Figure 2, such areas are concentrated in the mud flats of the west coast and river estuaries. The flora graph depicts an exponential curve and is on an upward trend. This is because the areas of high species richness are widely distributed in the forests of Gangwon Province.

According to Figure 4, 9.3 mammal species, 21.4 bird species and 35.4 plant species are forecasted to inhabit

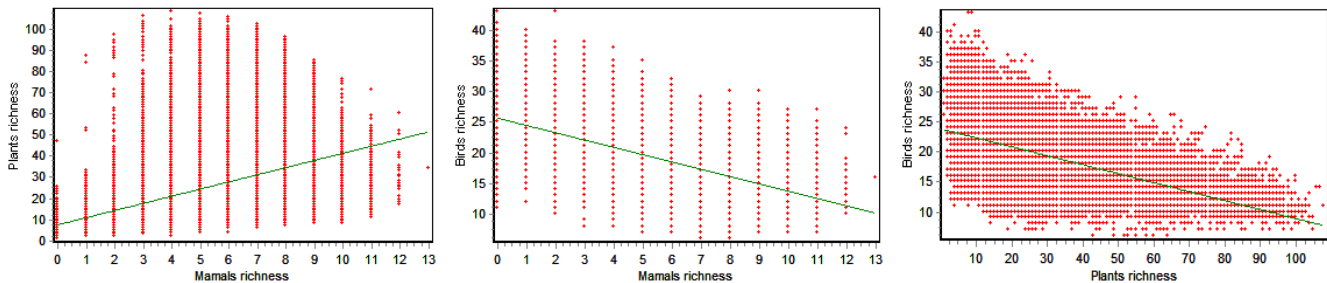


Figure 3. Comparison of species richness for three different taxa

protected areas at present. As for the protected areas of "at least 17 percent of the terrestrial and inland water areas of Korea," the target by 2020, 8.3 mammal species, 19.4 bird species and 26.2 plant species are expected to inhabit there. As the criteria of recommendations made in the past were based on outstanding protected areas, it was difficult to make a decision from a narrow selection of options. However, if the limited number of species of 17 percent or other targets are calculated through such method, it would be possible to expect a greater selection of choices, and establish various strategies to achieve the targets.

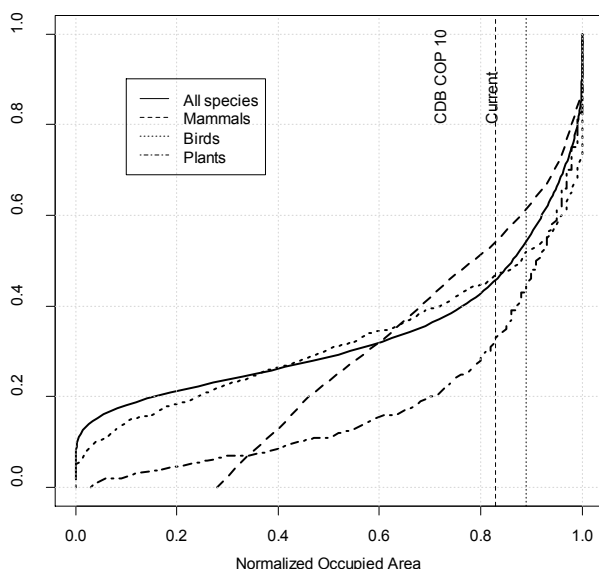


Figure 4. A species-area curve using an additive benefit function in Zonation. The target area of CBD COP10 is 17 % and the Current area is about 11 %

4. The Determination of Conservation Priority List

After applying the algorithm of the conservation priority list, due to the effect of flora which has a great number of species, Figure 5 shows similar results to that of plant species richness. To find out how much the derived results correlate to the past protected areas, this study overlapped those areas with terrestrial national parks. In case of national parks, they are not only the oldest protected areas, but they also have higher value than other protected areas. As the result of analysis, as can be seen in Figure 5, they match up well.

The total ranking of terrestrial national parks is about 0.83. If we take a look at priority order by national park, parks in Mt. Chiaksan, Mt. Odaesan, Mt. Seoraksan and Mt. Sobaeksan were highly placed. Moreover, areas closer to Gangwon Province and the Baekdudaegan Mountain Range ranked especially high on the priority list (Figure 6). Meanwhile, Byeonsan-bando, Gyeongju, Mt. Mudungsan and Mt. Wolchulsan, which are far away from the Baekdudaegan Mountain Range, ranked relatively low on the list. However, the average of the total is above 0.6, and in case of national parks, they meet the designation criteria in terms of biological species richness. Not only the natural environment, but the scenery and cultural aspects are taken under consideration when designating a national park. Therefore, when considering this, the results are favorable. Such results indicate the high-utility potential of the data of the National Ecosystem Surveys, as the forecast was made without information on biological species in national parks and the Baekdudaegan Mountain Range.

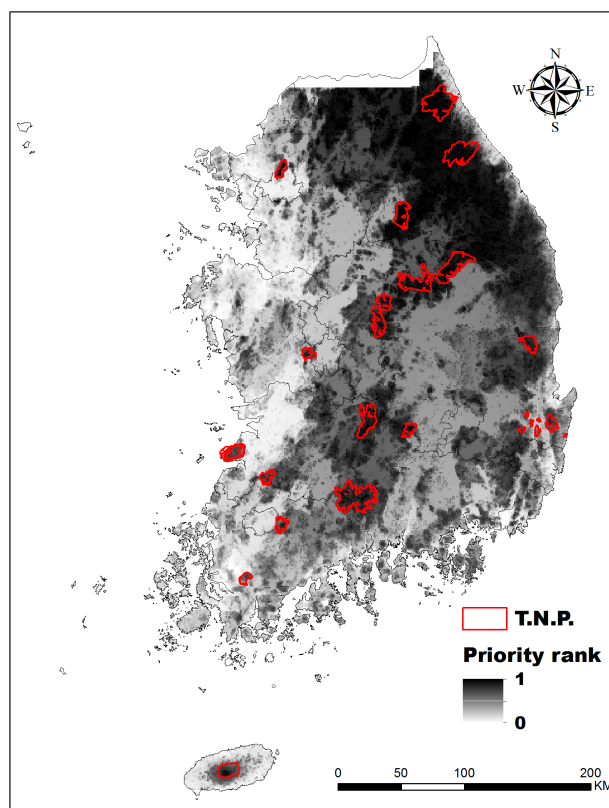


Figure 5. Conservation priority map using species richness maps. Terrestrial national parks display a higher priority rank

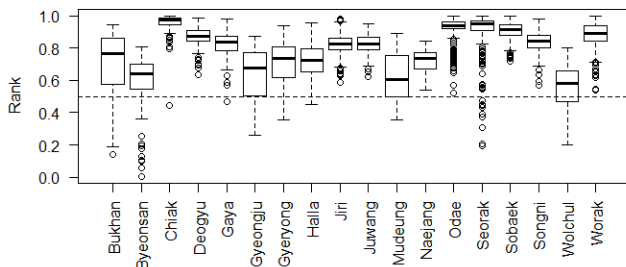


Figure 6. Priority ranking in each national park. This plot shows how the priority rank of parks near Baekdudaegan is higher than others

This study is significant as it implemented the method to determine a conservation priority list by using data from the National Ecosystem Surveys. The species distribution model could be substantially useful when selecting protected areas in the future, as the results showed a high correlation although data on national parks and the Baekdudaegan Mountain Range was left out. Also, besides existing protected areas, areas with high conservation value have been discovered and they could be used in case of selecting protected areas and establishing conservation plans in the future. However, there are limits when designating preserved areas based only on species richness. Accordingly, it would be necessary to decide the priority order of protected areas after considering various assessment factors such as rarity, connectivity, representativeness and importance of species.

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