Chin. Geogra. Sci. 2014 Vol. 24 No. 1 pp. 113–125
doi: 10.1007/s11769-014-0660-y

Springer Science Press
www.springerlink.com/content/1002-0063

Combination of Ecoprofile and Least-cost Model for Eco-network Planning

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Abstract: The protecting requirements and functional connectivity of species in isolated habitat patches are crucial factors of eco-network planning. This study aimed to improve the method of eco-network planning for species conservation. Ecoprofiling was used to group the species by similar behavior types, namely, choice of ecosystem, area requirement, and short distance dispersal abilities. A least-cost model was used to simulate the optimal corridor location to maintain functional connectivity. A combination of ecoprofile and least-cost model was hired to develop an eco-network that promoted species conservation. A case study was also conducted in Beijing, China. In addition to the required ecosystem, habitat area is an important parameter for habitat extraction. Habitat area can remove noise habitat patches because of lacking area. Short-distance dispersal can be used to identify corridor requirements and avoid unnecessary building requirements. Species with various dispersal abilities exhibit significant differences in terms of corridor length and location requirement. Habitat isolation is the main threat for weakly mobile species, and habitat loss is the major risk of mobile species protection. Different species groups also exhibit distinct landscape pattern demands for an eco-network, and the eco-network planning based on specific species can not protect other species. We proposed that a combination of ecoprofile and least-cost model improved the efficiency of species conservation by eco-network planning.

Keywords: eco-network; ecoprofile; least-cost model; biodiversity conservation; Beijing; China

Citation: Xiao He, Liu Yunhui, Yu Zhenrong, Zhang Qian, Zhang Xin, 2014. Combination of ecoprofile and least-cost model for eco-network planning. *Chinese Geographical Science*, 24(1): 113–125. doi: 10.1007/s11769-014-0660-y

1 Introduction

Urbanization in Beijing Municipality has accelerated for the past few decades, in which the proportion of urban residents increased from 78% in 2000 to 86% in 2010 (Beijing Municipal Bureau of Statistics, 2011). This trend is predicted to continue in the succeeding decades. Urbanization is one of the common causes of habitat fragmentation (Shrestha *et al.*, 2012) and loss of biodiversity (Solé *et al.*, 2004; Conceição and de Oliveira, 2010); furthermore, urbanization has made biodiversity conservation a challenge to high-speed development of a sustainable environment. Although urban green-space planning is implemented in Beijing (Li *et al.*, 2005), biodiversity protection in rural areas remains unsuccessful. Thus, landscape pattern planning of the whole countryside is essential for a sustainable environment.

Opdam *et al.* (2006) defined an eco-network as a set of ecosystems of one type, linked into a spatially coherent system through flows of organisms, and interacting with the landscape matrix in which it is embedded. An eco-network has been demonstrated to mitigate habitat fragmentation from urbanization and promotes biodiversity conservation (Zhang and Wang, 2006; Hepcan *et al.*, 2009; Barreto *et al.*, 2010). In general, an eco-network contains two important parts: 1) core habitat, which function as main species habitats, and 2) corridors, which facilitate the dispersers movement across

Received date: 2013-04-18; accepted date: 2013-08-16
Foundation item: Under the auspices of National Natural Science Foundation of China (No. 41271198)
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habitat patches. The accurate extraction of the spatial locations of habitat patches and corridors is the key to ensure a successful eco-network planning.

1.1 Core habitat planning

Clearing habitat patches is the foundation of core habitat planning. These patches support various species living in an ecosystem. A sound biodiversity conservation plan should protect as many species as possible, with equal consideration for all species in an eco-network; however, only a few species are considered because of the lack of knowledge and financial support. Focal species (Battisti and Luiselli, 2011) and umbrella species (Bifolchi and Lode, 2005) are factors that determine the type of core habitat because the sensitivity of these species to environmental changes or their important functions in an ecosystem should satisfy the habitat requirements of other species. Conservation decisions based on these particular species indirectly protect many other species that make up the ecological community. Despite this strategy, many other important species in an ecosystem are neglected in eco-network planning (Chase *et al*., 2000). As such, an ecoprofile has been developed to solve this problem, in which the possible maximum number of species is considered (Vos *et al*., 2001; Sanderson *et al*., 2002).

Land use type is one of the most important factors of ecosystem types used to determine the distribution of animal species and evaluate their habitats. Land use patches with a habitat ecosystem that satisfies the requirements of a particular protected species are commonly used as direct habitats (Gurrutxaga *et al*., 2010; Pino and Marull, 2012). However, land use type is only one of the factors used by species when a patch is selected for a habitat; patch area, which provides sensitivity for species survival, is another criterion (Uezu *et al*., 2005). A particular threshold of a patch area corresponds to the species that responds to the same patch (Yamaura *et al*., 2009). Habitats with specific ecosystems and areas beyond the thresholds are distinguished from potential habitats, which contain the required ecosystem regardless of the patch area. Patches with medium and small areas influence biodiversity conservation (Wiktander et al., 2001; Fischer and Lindenmayer, 2002; Yamaura et al., 2009). Various species also have different habitat threshold requirements (Charles and Garten, 1995; Tweed *et al*., 2003). Thus, the area should be considered carefully in habitat planning and treated respectively among different species.

1.2 Corridor planning

Corridor is an important landscape element used to facilitate species movement. A corridor can increase the connectivity among isolated habitats. Regional landscape corridor planning should focus on the dispersal movement from one habitat where an offspring is born to another habitat where parents reproduce without considering a return movement (Jongman *et al*., 2004). Dispersal movement includes short- and long-distance dispersals, in which short-distance dispersals exhibit a closer relationship with regional corridor planning compared with long-distance dispersals (Baker *et al*., 2001; Nathan, 2005; Petit *et al*., 2008). Short distance dispersal is the maximum distance that a species exhibiting mobility can travel away from a habitat. Habitat patches connected via a short-distance dispersal range of a species comprise a meta-habitat that does not have a functional isolation. For meta-habitats, new corridors are not necessary because individuals can move freely. Species should also perform long-distance dispersals from their home meta-habitats to new areas in between meta-habitats. This process requires corridor planning to sustain living species and prevent fragmentation effect. However, corridor planning widely prefers functional connectivity rather than structural connectivity, and the quantitative evaluation of corridor distribution is usually based on a least-cost model (Belisle, 2005; Vogt *et al*., 2009). In a corridor design, factors other than a single species should be considered because distance varies among different species (Fasola et al., 2002; Roedenbeck and Voser, 2008).

1.3 Ecoprofile and least-cost model

An ecoprofile is a group of species with similar survival requirements in an ecosystem at a regional scale (Opdam *et al*., 2008); the species in this group also exhibit similar behaviors in landscape patterns and processes. These species represent a series of species groups, priority habitats, and key ecological processes. Species behavior profiles are used as criteria to determine whether or not different species are 'similar'. This evaluation is important for ecoprofile division. For example, Hong *et al*. (2007) defined three species profiles based on dispersal capabilities and then analyzed the connectivity of these profiles in a linear habitat network. Vos (2001) used individual area requirements and three kinds of mobility to group species. Opdam (2008) divided ecoprofiles according to ecosystem type, area requirements, and dispersal ability of species in terms of networks. The species included in a specific profile possibly elicit the same response to a landscape pattern because of a high similarity in terms of behaviors among these species. Moreover, conservation planning for species with different requirements can be effective if several ecoprofiles are implemented. This conservation planning has been applied in eco-network evaluation and planning (McHugh and Thompson, 2011).

Least-cost model has been developed to simulate the functional connectivity route quantitatively (Vuilleumier and Prelaz-Droux, 2002; Adriaensen *et al.*, 2003). This model is used to calculate cost surface by using Euclidian distance and the resistance of each land use type for species movement (Knaapen *et al.*, 1992). Each cell is provided the cost of a particular species to cross this cell; a higher cost value corresponds to a higher cost requirement of species. A minimum cost route refers to the traveling route from a source to a destination with the least accumulative cost and is considered as the optimal spatial distribution of a corridor (Vogt *et al.*, 2009). This route is prioritized because it requires the minimum energy cost for individuals to cross a land matrix. Empirically, least-cost routes have significantly greater cross rates than other routes in a landscape (Driezena *et al.*, 2007). Although the results from this model incompletely match the actual route that a particular species uses, least-cost route modeling approach provides a good solution for quantitative spatial corridor planning.

The current study investigated a planning method that combines least-cost modeling and ecoprofile to satisfy the different protecting requirements of species on landscape pattern and implement a more efficient eco-network. The ecoprofile is used to cover the species conservation requirements in planning. A least-cost model is used to clarify the optimal spatial distribution of corridors. This study also determined a method to improve conservation, in which the required species behavior types of habitat areas and short-distance dispersal were considered in an eco-network plan. These behavior patterns were statistically analyzed to determine the quantitative parameters of planning.

2 Materials and Methods

2.1 Study area

Beijing, which is the capital of China, covers an area of 16 410.54 km^2 (Fig. 1). The mountains in Beijing are mainly located in the western and northern parts, accounting for 62% of the total area; several rivers also

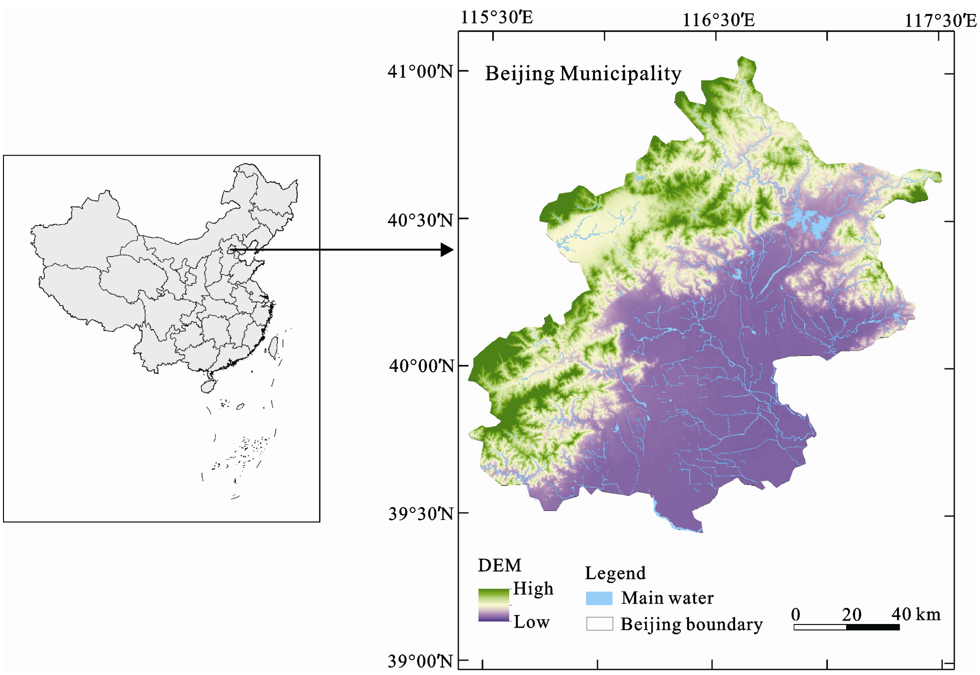

Fig. 1 Location of study area

flow near these mountain areas. Numerous large animals, such as wolves and elks, have disappeared because of continuous urban area expansion; for this reason, common fauna species dominating the area include migratory birds, small forest birds, and small mammals (Zhang *et al*., 2003; Yu *et al*., 2009; Zhang *et al*., 2009). A field survey in Beijing has shown that forests exhibit low species diversity (Liu, 2010). In the current study, land use mas in 2008 were used, with scales of 1∶2000 and 1∶10000 for plain and mountain areas, respectively; the same scales were respectively used for habitat extraction and least-cost corridor evaluation. We then separated eight general land use types, i.e., arable land, orchard, forest land, grassland, building, roads, waters, and others. Figure 2 shows the method framework used in this study. Three species behavior types, namely, the choice of ecosystem, area requirement, and short-distance dispersal, were considered for the quantitative planning of habitats and corridors. A least-cost model was used to verify the optimal spatial distribution of corridors. In planning the eco-networks of the ecoprofiles, different protecting requirements of the species were considered.

2.2 Ecoprofile

A plant ecoprofile was initially identified because plants are the primary producers and determinants of diversity in an ecosystem. The plant ecoprofile was based on a digitized map of tree species diversity from the geographic information system (GIS) database (Liu, 2010). The dispersal ability of plants is difficult to quantify, such that only the areas with high diversity were considered as core habitats in network planning. Three basic species behavior characteristics, namely, choice of ecosystem, area requirement, and short distance dispersal, were used as criteria to group the animal ecoprofiles. These characteristics are closely associated with the response of a species to a landscape pattern. We then categorized three animal ecoprofiles based on the most common surviving species in Beijing and large differences in species behavior profiles: migratory birds; small forest birds; and small forest mammals. Migratory birds, such as *Egretta garzetta*, are large birds that seasonally live in Beijing. Small forest birds are distributed widely in farms and forests. Small forest mammals are terrestrial species, such as *Sigmodon hispidus*.

2.3 Species behavior parameters

Species behavior was considered to identify the minimum habitat area and the requirements of corridor planning. Each ecoprofile contains several species, and species behavior comprised various parameters; each parameter exhibits a corresponding maximum and minimum value. In general, the maximum habitat area provides better biodiversity conservation; however, the extraction of habitat patches based on the maximum value of this parameter overlooks several patches with habitat function for other species. If the extraction parameter is set at the minimum value, low land-use efficiency is observed because many habitat patches can not support other living species. The same challenges are encountered in corridor planning based on short-distance dispersal. Therefore, we used the mean value as the species behavior threshold of area requirements and short-distance dispersal to maintain balance between biodiversity conservation and land resource utilization. Only few studies on species behavior patterns have been conducted. *Egretta garzetta*, which is a common species in Beijing, was selected to represent the ecoprofile of migratory birds. However, data on the required habitat area of migratory birds are unavailable; instead, a value of 10 ha was set for the required habitat area based on relevant experience data (Brooker, 2002; Opdam *et al*., 2008). The other behavior parameters of the selected ecoprofiles are listed in Table 1.

2.4 Least-cost model

The least-cost model was used to define the land use resistant value. Land use, which represents the optimal habitat for species, was assigned the least resistance value, whereas other less suitable land uses were assigned different values based on their resistance to species. Higher costs are incurred when organisms move across different areas as land use resistant value increase. For each land use, the landscape resistance value was based on previous studies (Table 2) (Adriaensen *et al*., 2003; Gurrutxaga *et al*., 2010; Rabinowitz and Zeller, 2010; Zetterberg *et al*., 2010).

The resistance value of land use represents the degree of difficulty that an ecoprofile encounters during movement. This degree of difficulty is not a comparison of the resistance value among ecoprofiles. A resistance value of 1 indicates that the land use type is the required ecosystem that is habitable for the ecoprofile, and a value of 100 represents the highest level of difficulty of species movement. For water land use type, waters refer to bodies of water and wetlands. The dried body of water land use type was excluded from the habitat patches of migratory birds because this type exhibits poor quality as a habitat function. Potential habitat area refers to the area of patches that are consistent with the required ecosystem of the species; habitat area refers to the area of patches with required ecosystem and area over the threshold.

2.5 Eco-network planning

Eco-network planning has two principles. First, regions

Table 1 Behavior parameters of selected ecoprofiles

Ecoprofile	Species	Area requirement (ha)	Short-distance dispersal (m)	Reference
Migratory birds	*Egretta garzetta*		10000.00	Fasola *et al*., 2002
Small forest birds	*Pomatostomus superciliosus*		1000.00	Cale, 2003
	Chthonicola sagittata		921.00	Gardner *et al*., 2003
	Hirundo rustica		800.00	Charles and Garten, 1995
	Petrochelidon pyrrhonota		1200.00	
	Myadestes palmeri	1.20	1000.00	Tweed *et al*., 2003
	Picoides arcticus		750.00	Merckx *et al*., 2009
	Myotis lucifugus		500.00	Lookingbill *et al*., 2010
	Sitta europaea	1.00	2500.00	van Langevelde, 2000
	Parus montanus	1.60		Yamaura *et al*., 2009
	Japanese white-eye Zosterops japonica	2.20		
Mean		1.50	1084.00	
Small mammals	*Lepus europaeus*		300.00	Roedenbeck and Voser, 2008
	Lepus europaeus		588.00	Avril *et al*., 2011
	Oryctolagus cuniculus		540.00	Calvete and Estrada, 2004
	Tamias striatus		400.00	Silva *et al*., 2005
	Fukomys damarensis		423.00	Young *et al*., 2010
	Marmota olympus		500.00	Griffin *et al*., 2008
	Sigmodon hispidus	1.00		Charles and Garten, 1995
	Dendrobates variabilis	0.04		Brown *et al*., 2009
	Oryctolagus cuniculus	0.22		Devillard *et al*., 2008
Mean		0.42	459.00	

Table 2 Ecoprofile parameters

Ecoprofile	Resistance value of land use							
	Arable land	Orchard	Forest land	Grassland	Building	Roads	Waters	Others
Migratory bird	10	60	60	10	100	30	1	10
Small forest bird	20	20	1	1	100	60	20	10
Small forest mammal	30	40	1	1	100	80	100	20

Ecoprofile	Potential habitat area (ha)			Habitat area (ha)			Ratio to potential habitat (%)
	Maximum	Mean	Total	Maximum	Mean	Total	
Migratory bird	9768.47	0.98	64936.22	9768.47	75.15	37199.96	57.29
Small forest bird	267242	8.75	838437.37	267242	74.55	816159.85	97.34
Small forest mammal	267242	8.75	838437.37	267242	31.69	828831.78	98.85

Notes: Resistance value represents the relative cost that species had to pay for crossing a special land use, and higher value means harder to cross; ratio to potential habitat is the percentage that habitats take in potential habitats, which had same ecosystem but area under the threshold with higher habitat density and dispersal frequency are prioritized for protection because of the main eco-processes involved in their ecosystems. Second, the habitats and corridors with greater species are prioritized for conservation because they are important for species diversity preservation.

We divided the habitats into core and normal habitats based on their density, which was calculated by using the GIS density tool. The area percentage of the habitats was initially calculated in a circular range with a radius of 1000 m. A map of the core and normal habitats was derived by applying the default separation of the GIS reclassify method, which can optimally group similar values and maximize differences between classes. Short-distance dispersal was used to determine whether or not a corridor plan is necessary, i.e., the only area considered for corridor planning exhibited a greater distance between two disjointed patches than that of the short-distance dispersal of a target ecoprofile. However, core corridors are frequently used by species and should always be planned for conservation to ensure an essential shelter function. Corridors at both north-to-south and bottom-to-mountain top directions were also considered to prevent climate change in the future (Bernstein *et al.*, 2007). To complement the least-cost model, this study considered the vegetation patches and the edges of rivers and valleys as the site corridors in corridor planning. Artificial disturbance areas were interpreted negatively for corridor planning.

To conserve each ecoprofile, we delineated an eco-network based on the geographical characteristics and the effects of anthropological activities on the ecoprofile. Ridges and valleys were defined using a digital elevation model (DEM) map (DEM data have a revolution of 30 m and are provided by the International Scientific Data Service Platform, Computer Network Information Center, Chinese Academy of Sciences, available at: http://datamirror.csdb.cn), whereas the effects of human activities were evaluated by using the map of the constructions. The final eco-network was generated by overlaying the eco-network of each ecoprofile. Only the core habitats and corridors were extracted to conserve the main eco-process in Beijing.

3 Results

3.1 Habitat distribution

Table 2 shows that many of the existing patches cover areas less than the threshold of habitat area requirement. This result was obtained when the three selected animal

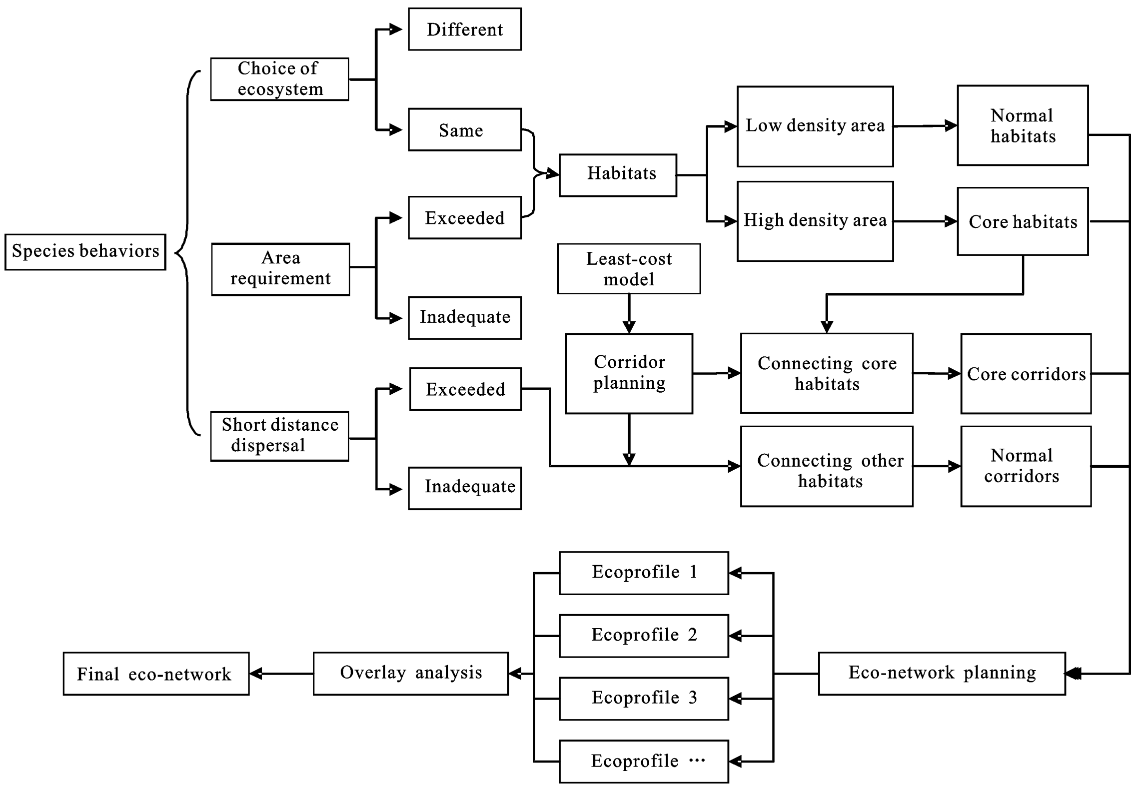

Fig. 2 Study framework

ecoprofiles in the habitat area were analyzed. For example, the habitats of the migratory birds accounted for only 57.29% of the potential habitats, and the remaining 42.91% potential habitats can not be considered as habitats because the areas were less than the threshold. On the other hand, the habitats of the small forest birds and small forest mammals with areas larger than the threshold accounted for large percentages of the potential habitats, reaching 97.34% and 98.85%, respectively. The following significant growths from potential habitats to habitats were observed in terms of mean area: from 0.98 ha to 75.15 ha for the migratory birds; from 8.75 ha to74.55 ha for the small forest birds; and from 8.75 ha to 31.69 ha for the small forest mammals. These results indicated that extracting habitats only based on ecosystem without consideration of area threshold caused errors.

Figures 3a, 3b and 3c show the spatial distribution of

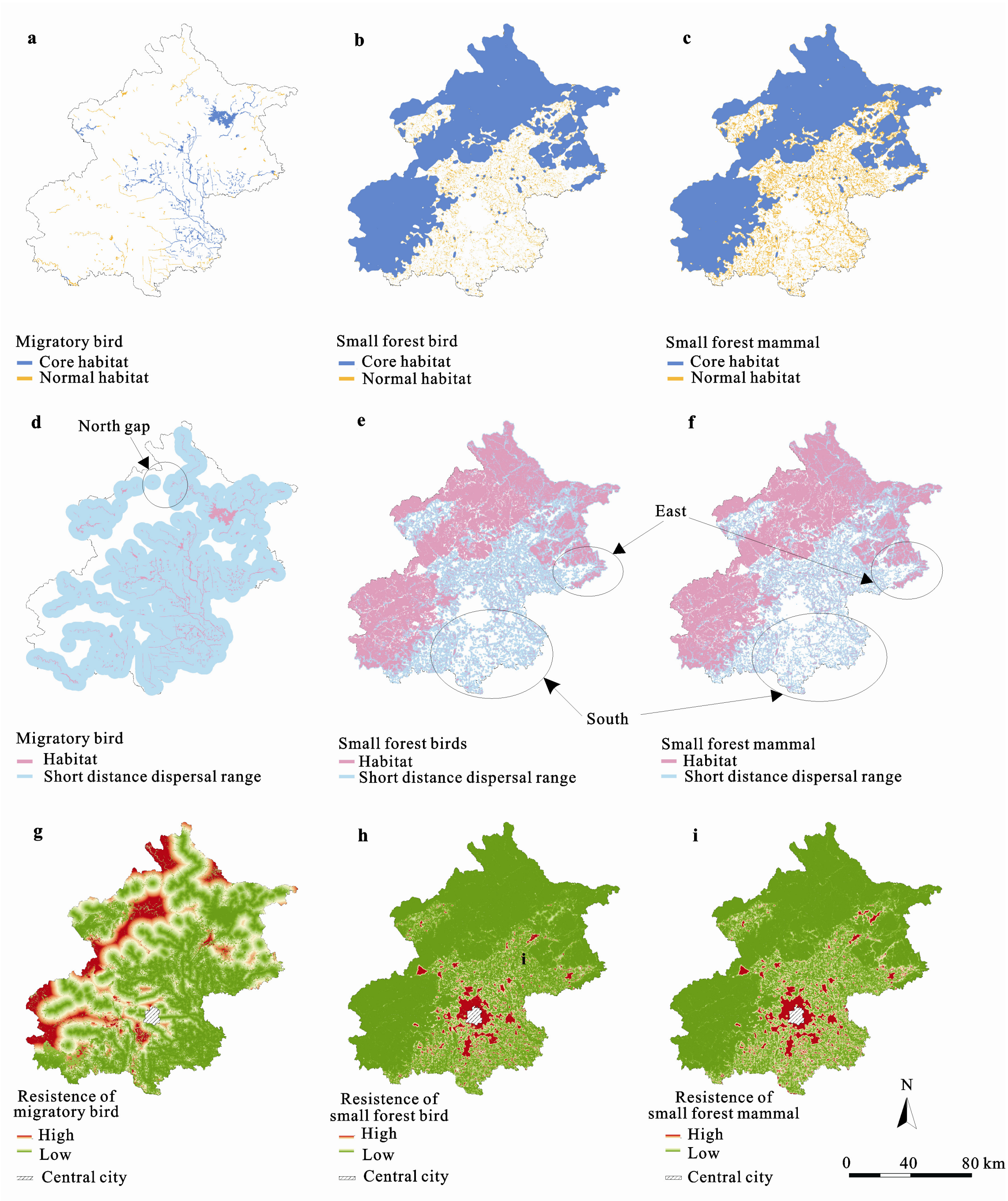

Fig. 3 Habitat distribution and short distance dispersal of three animal ecoprofiles in Beijing

core and normal animal habitats. The core habitats of the migratory birds include the Miyun Reservoir, which is the largest body of water in Beijing, and other bodies of water in the central area of Beijing city. The core habitats of small forest birds and small forest mammals were very similar; most of these habitats were located in the mountain region, whereas only few small habitats clustered in the plain area. In general, the core habitats of small forest birds and small forest mammals were more discretely distributed all over Beijing compared with those of the migratory birds, which were mainly aggregated in certain regions.

3.2 Evaluation of short distance dispersal

The habitat patches and short distance dispersal range were delineated (Figs. 3d, 3e and 3f), and the landscape resistance to the ecoprofiles was evaluated using the least-cost model (Figs. 3g, 3h and 3i). Considering the strong dispersal ability of the migratory birds, we found that only a few patches in the northern part were isolated from their main meta-habitat. The northern gap (Fig. 3d) between the two separated meta-habitats should be connected by corridor planning to decrease landscape resistance. Small forest birds and small forest mammals also exhibited similar habitat distribution and short dispersal range (Figs. 3e and 3f) in the southern and eastern parts. The distance gaps over the threshold between the habitat patches formed a migration barrier that threatened the survival of small forest birds and small forest mammals. Small forest mammals particularly faced a more serious threat than small forest birds because of the former exhibit weaker mobility than the latter. Fortunately, a lower landscape resistance in such regions allowed the construction of a facilitated corridor for dispersal. However, the habitats located in the western and most of the northern regions were well-connected and conferred a low isolation risk of fragmentation. In summary, the newly constructed corridors for the small forest birds and small forest mammals should be mainly located in the eastern and southern parts. The migratory birds also have a low requirement for corridors.

3.3 Eco-network planning

Constructions spread from the city center to rural areas (Fig. 4a) and threatened species dispersal. The normal corridors crossing aggregated constructions areas were not considered in eco-network planning since the high artificial disturbance. Protected plant patches (Fig. 4b) (Liu, 2010) played as core habitats for plant diversity conservation despite the low habitat density of the animals, and mainly distributed in mountain area. Considering the land use pattern, plant biodiversity, and species dispersal, we proposed eco-network planning strategies for the selected ecoprofiles (Figs. 5a, 5b and 5c). Migratory birds suffered from habitat loss because of their strong mobility; small forest birds and mammals were threatened by isolation. Small forest birds and mammals required more complicated corridor planning to connect their habitats, which were widely spread across the whole region, compared with migratory birds. A corridor was established to allow the migratory birds to travel across the two isolated meta-habitats in the northern east-to-west region. We planned to build two corridors to maintain the aggregated habitat in the central part and another two corridors in the southwestern area to promote crossing border dispersal. Small forest birds

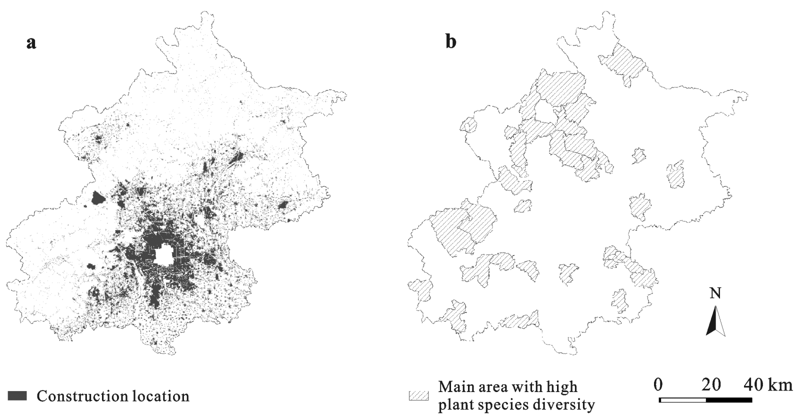

Fig. 4 Distribution of construction and high plant species diversity area

and small forest mammals exhibited the same core habitats and core corridor location plans because these organisms have quite similar habitats and dispersal abilities. Corridors were initially designed to connect isolated habitats, but this idea is unsuccessful because of the density surrounding the buildings. In general, small forest mammals had more normal corridors compared with small forest birds, particularly in a plain area where landscape fragmentation was high.

The finalized eco-network plan contained core habitats and core corridors (Fig. 5d). The core habitat patches were mainly located in the mountain area and certain plain areas. The core corridors, which had alternatives nearby, were also not included in the plan to save valuable land resources. The eco-network for the small forest birds and small forest mammals needed a detailed design because these organisms exhibited weak dispersal abilities and small habitat area requirements. A simple eco-network was developed for migratory birds whose mobility allowed them to overcome many barriers. The entire eco-network of the migratory birds and only the core ones of the small forest birds and small forest mammals were included in the final plan. The normal corridors were not included because these corridors elicited negligible effect on the sustenance of important ecological processes. The final plan balanced the conservation demands of the ecoprofiles and focused on protecting the key eco-processes.

The core habitats and corridors covered various distribution areas; for instance, 81.96% of the habitats were located in the mountain area and 80.81% of the corridors were located in the plain area. The small separated habitat patches with low densities situated along the corridors can be reserved for corridor conservation measures. The varied corridor lengths for ecoprofile conservation (Table 3) indicated that the species with

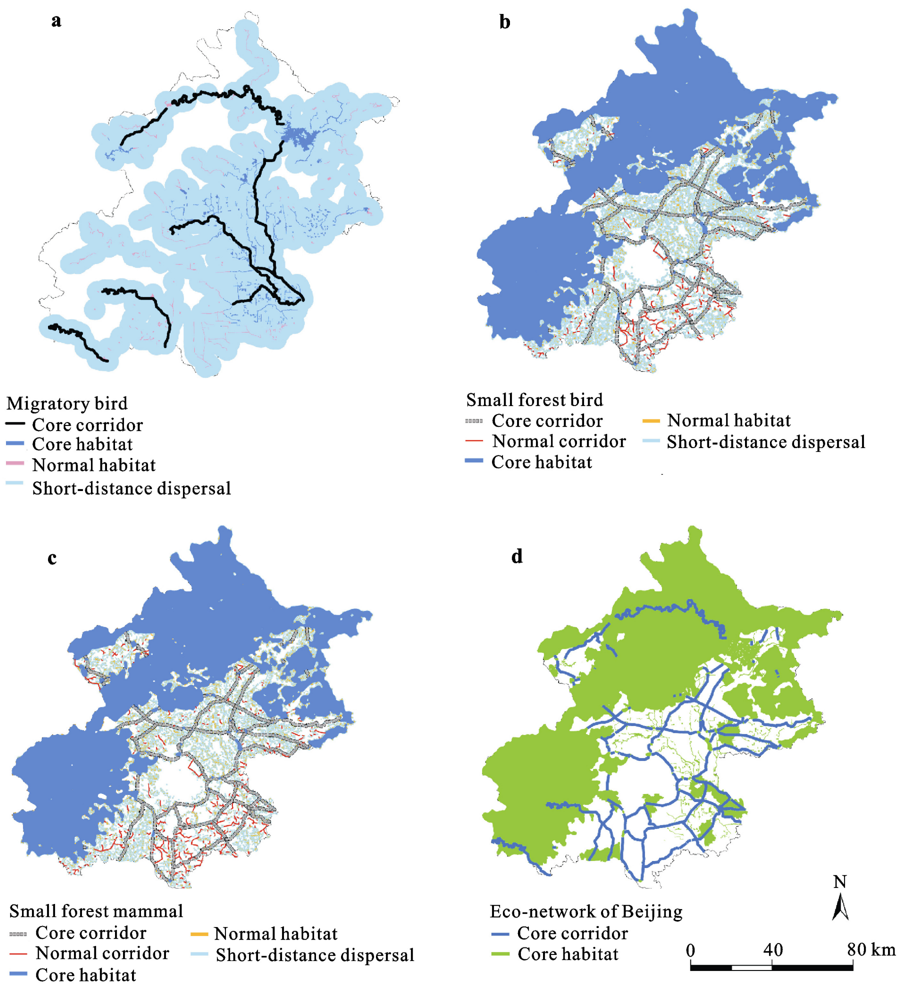

Fig. 5 Eco-network planning

Table 3 Corridor lengths for ecoprofile conservation

Corridor type		Corridor length (km)			
		Sum	Mean	Min.	Max.
Migratory birds		529.0	66.1	11.8	126.7
Small forest birds		1199.7	4.8	0.6	59.8
	Core	858.1	10.3	0.6	59.8
	Normal	341.6	2.1	0.7	13.9
Small forest mammals		1417.8	3.7	0.4	59.8
	Core	858.1	10.3	0.6	59.8
	Normal	559.7	1.9	0.4	18.1
Final eco-network		1138.3	13.1	0.6	126.7

stronger mobility required less corridor planning. For example, migratory birds, which exhibited the strongest mobility, had the shortest planned conservative corridor (total of 529 km); by contrast, small forest mammals, which exhibited the weakest mobility, had the longest planned conservative corridor (total of 1417.8 km). In general, the mean and minimum corridor lengths decreased and the maximum length increased as species mobility decreased. Small forest mammals and small forest birds had approximately equal corridor lengths because of highly similar habitat distributions of the two organisms. In the eco-network, migratory birds had the maximum corridor; small forest mammals and small forest birds had the minimum corridor. Large differences among the three animal eco-networks showed that conservation planning of a particular species partially support the protection of other species. Such differences also showed that a final eco-network is necessary for a balanced plan.

4 Discussion

4.1 Distinguishing targets by ecoprofile

In our case study on the Beijing region, different species were distributed in three ecoprofile groups, namely, migratory birds, small forest birds, and small forest mammals. The species behavior types of these profiles differed from one another. Significant differences were obtained between small forest birds and small forest mammals in terms of habitat area and short-distance dispersal (statistical mean comparison analysis using SPSS 16 (ANOVA: $F = 9.241$, $P = 0.023$ and $F = 6.078$, $P = 0.03$). The migratory birds were not analyzed because only one sample was collected, although the values of this group were significantly higher than those of the other two groups. In an ecoprofile, the species also exhibited specific behavioral characteristics, such as the change in the short-distance dispersal of small forest birds from 500 m to 2500 m. The statistical analysis provided a useful method to obtain the behavior parameters to calculate the means.

Significant differences among the ecoprofiles proved that eco-network planning based on one specific species was not sufficient to protect most species. The use of ecoprofiles to distinguish the targets in eco-network planning provides an opportunity to protect most species with different conservation requirements. This process improves the protecting efficiency of eco-network and stimulates biodiversity conservation. Ecoprofile also ensures the practicability of eco-network planning because it focuses on grouping species with similar behavior and does not attempt to consider the requirements of each species (Vos *et al.*, 2001; Sanderson *et al.*, 2002). Thus, an ecoprofile can be considered in urban green space planning, such as eco-network planning, to promote biodiversity conservation, particularly when this ecoprofile is combined with a least-cost model for corridor planning.

4.2 Considering species behaviors in eco-network plan

We selected three behavior types that are strongly associated with landscape pattern, quantitatively extracted habitat patches, and evaluated the need for corridor planning. The behavior types were listed as follows: choice of ecosystem type; area requirement; and short distance dispersal. Ecoprofiles faced different threats to conservation in terms of habitat distribution and short dispersal range. Despite the abundant habitats surrounding the plain region in Beijing, isolation remained the main threat to the weak-mobility group (e.g., small forest birds and small forest mammals). Habitat loss was the main threat to the strong dispersal group, such as migratory birds. The quantitative analysis of species behavior patterns can also be considered as a tool for local construction plans. For example, the minimum habitat area and the maximum distance between the separated habitats can be determined by such analysis. Through this process, species behavior types can be effectively integrated into the eco-network plan, thereby improving quantitative planning.

An eco-network builds a special landscape pattern that a species can use to maintain eco-processes for their survival in a fragmentation matrix. These processes include preying, dispersal, and nesting. The landscape pattern preferred by such behavior types can enable more effective biodiversity conservation (Jokimäki *et al*., 2011). The least-cost model, which is a commonly accepted simulation method for functional connectivity, is a good model that can be used to integrate species behavior types in an eco-network plan. This model aims to determine species dispersal preferences among different land use types (Adriaensen *et al*., 2003). Although the current study did not cover all of the species behavior types associated with landscape pattern, species behavior patterns were integrated in the eco-network plan. Species behavior types that respond to landscape pattern should be considered in an eco-network plan to establish an effective landscape plan for biodiversity conservation.

5 Conclusions

Habitat area threshold is a critical parameter for habitat extraction and eliminates noisy patches. Short-distance dispersal avoids unnecessary corridor planning and saves valuable land resources. Various species have different requirements for conservation because of their varying behavior characteristics; thus, different species should be considered separately in an eco-network plan. Species behavior parameters should be considered for quantitative planning to establish an effective landscape for species conservation. Ecoprofiling can be used to group species with similar behavior types and conservation requirements. However, the conservation of specific species is inefficient because of the different eco-network pattern requirements of different ecoprofiles. A combination of ecoprofile and least-cost model that considers species behavior can cover many species in conservation and quantitatively develop a practical eco-network plan.

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