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Identifying Key Habitats to Conserve the Threatened Brown Bear in Northern Iran[1]

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Abstract—Many factors such as human activities threat brown bears (*Ursus arctos*) in Southern Asia, and limit it to small populations in remote and rocky mountainous regions. Brown bears are generally studied in North America and Europe, but there is little information about its conditions and requirements for survival in Asia. During the recent years, brown bear populations in Iran have decreased sharply. Therefore, they are now officially listed as a threatened species in local scale. Therefore, we tried to recognize brown bear habitat relationships in northern Iran using species distribution model (SDM). Maxent method was applied using multi-scale approach to predict suitable habitats and habitat relationships of the species. Our results revealed that the predictive ability of environment variables and species distribution maps varied across scales strongly. Also, our findings showed that identifying a proper scale is important issue to improve habitat modeling accuracy. Only 17% of the protected areas was found suitable for brown bear and divided to 5.1% poor, 8.8% suitable, and 3.1% high-quality habitat. Consequently, it is suggested that the protected area of northern Iran reconsiders with interventions aimed at maintaining suitable habitats of brown bear.

Keywords: brown bears, Maxent, multi-scale, habitat modelling, *Ursus arctos*

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INTRODUCTION

Many factors such as human activities endanger brown bears (*Ursus arctos*) in Southern Asia, and decrease its populations and restrict it to small populations in remote and rocky mountainous areas [1]. In most cases, brown bears are studied in North America and Europe, but there is a little knowledge about their conditions and requirements for survival in Asia [2]. During the recent years, brown bear populations in Iran have decreased sharply. Therefore, they are now officially listed as a threatened species under national legislation [3]. The main sources of concern about this species are both natural and anthropogenic sources that cause habitat destruction, alteration and fragmentation, anthropogenic sources, such as towns [4, 5], transportation corridors [6–8] and forestry clear cuts [9, 10] and natural source, such as drought and forest fire [11]. Knowing the relationships between environmental factors and species distribution is one of the important issue in habitat conservation and management [12, 13].

In the last two decades, species distribution models (SDMs) of plants and animals has grown increasingly. SDMs can determine effects of anthropogenic and natural variables on patterns of species distribution at different scales. However, some limitations still preclude the use of SDMs in many theoretical and practical applications [14]. One of the central tenets of SDMs is scale effect on SDMs accuracy [15] and scaling analysis is important to unravel the species–habitat relationships [16–18]. Several studies have conducted to assess the influence of scale on the accuracy of SDMs, but a multiple scales within the same analysis have used in a few of them (among others, see [19, 20]).

Therefore, in this study we used a multi-scale approach for the analysis of brown bear habitat relationships in northern Iran. Our goals were (1) to identify the environmental variables with a largest influence for determining brown bear distribution, (2) to assess the effect of scale on habitat modeling accuracy, and (3) to compare the multi-scale approach to a single-scale approach and evaluate the differences relating to predictive performance.

MATERIALS AND METHODS

Study Area

Hyrcanian forests in northern Iran (Fig. 2) are a dominating habitat and also brown bears existed primarily in this type of habitat [3]. Therefore, we limited our study to these forests. The Hyrcanian (from “Hyr-

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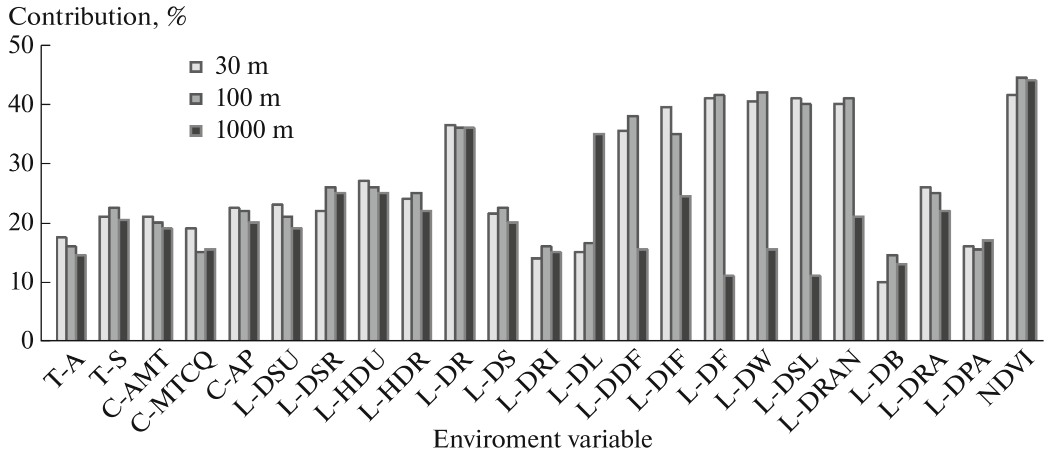

Fig. 1. Importance of environmental variables for Maxent models at 30, 100 and 1000 m scale.

cania," the Greek form of an old Iranian word to describe the region of Gorgan) forests stretch in an arc along the southern shores of the Caspian Sea from the Talish region in Azerbaijan (at longitude 48° E) to Golestan National Park in Iran (at longitude 56° E) and between latitudes 38°55′ N in Azerbaijan Republic and 35°05′ N in Iran. These forests are located in Gilan, Mazandaran and Golestan provinces. This region covers approximately 50000 km^2. The forest zone displays a high habitat heterogeneity grading from sandy coastal shores along the Caspian Sea, because it limited by the Caspian sea shores in north and the Alborz Mountain range in south. The natural forest vegetation is temperate deciduous broadleaved forest [21]. This region is an important habitat for many mammal such as Caucasus leopard (*Panthera pardus ciscaucasica*), lynx (*Lynx lynx*), brown bear (*Ursus arctos*), and wolf (*Canis lupus*), also migratory bird species that them are migrating between Russia and Africa. These ancient broadleaf and mixed lowland and mountain forests cover 1.8 million ha form unique and diverse communities and housing many endemic and threatened tree, mammal and bird species such as Caucasus leopard (*Panthera pardus ciscaucasica*), lynx (*Lynx lynx*), brown bear (*Ursus arctos*), wolf (*Canis lupus*), and also migratory bird species that them are migrating between Russia and Africa. Hyrcanian forests are listed by the World Wide Fund for Nature (WWF) as a Global 200 Ecoregion, and by BirdLife International as an important bird area (IBA) [22].

Species Sampling

The location of brown bear feces is the sign of their presence throughout the region. Other signs (e.g. hairs, tracks) were not easy to find along the transect routes. Consequently, we only used scats as location of brown bear presence. In our opinion, important habitats of brown bear were represented by scats, because this species generally do not defecate in particular areas, except for concentrations at bed sites [23], which could bias our results. Most of the researcher use feces in wildlife investigations to estimate abundance and species richness. Our study area was divided into ten blocks (each blocks was included one transect with 40 m wide and 20–40 km wide that contains nearly all elevation ranges and habitat types) which was outlined by major rivers and then a team of 2–3 people searched for brown bear feces. Transect routes stretch from a central road to border areas and then return to the starting point. Sampling was done in January–December 2014 that 87 excrement clusters were detected.

Environmental Predictor Variables

Land cover/land use characteristics, climatic variables, and topographies (Table 1) are environmental variables that obtained on 30m spatial resolution. For resample the data layers to different scales in IDRISI Selva, i.e. 30, 100 and 1000 m, both Mean function for continuous variables, and majority function for categorical variables were used. Land use/land cover data were obtained from the Iranian Forests, Range and Watershed Management Organization (IFRWO) (http://frw.org.ir). Normalized difference vegetation index (NDVI) was obtained from 30m Landsat Enhanced Thematic Mapper Plus (ETM+) image in 2015. For obtaining human density, the data from the Statistical Center of Iran was interpolated (www.amar.org.ir) in 2015. Digital elevation model (DEM) that used to produce topographic variables, was generated by the National Cartographic Center of Iran (NCC) (http://www.ncc.org.ir) at 1 : 25000 scale. Bioclimatic variables were obtained from Energy Ministry of Iran. The multicollinearity test was conducted using Pearson correlation coefficient to examine the cross-correlation. Then variables with cross-correlation coefficient value greater than ±0.8 were excluded that final list of the environmental variables is shown in Table 1.

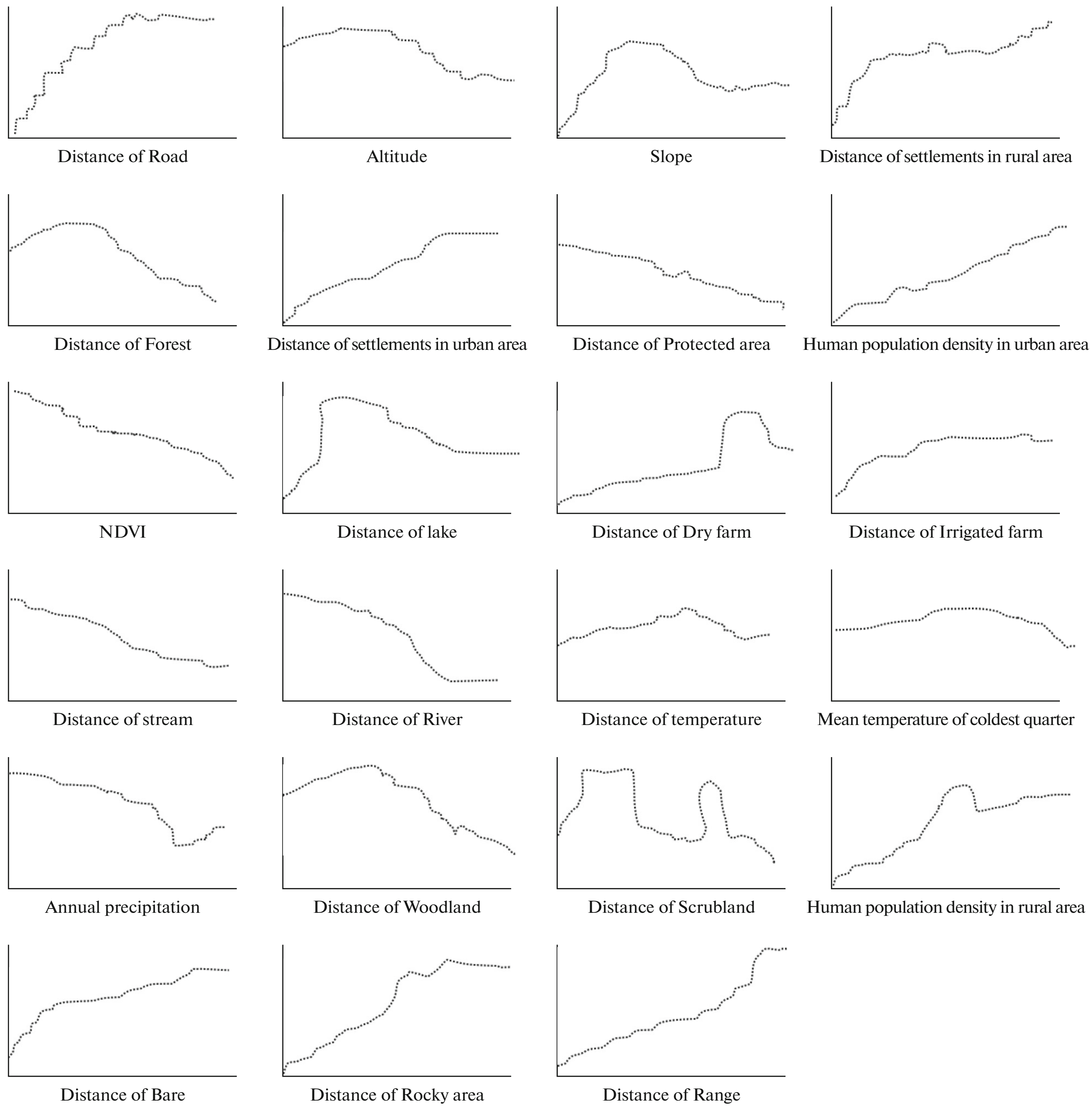

Fig. 2. Response curves of Maxent model for brown bear at scale 30 m.

Model

The maximum entropy model (Maxent version 3.3.3; http://www.cs.princeton.edu/wschapire/Maxent/) [24]. Maxent trying to ensure the closest possible method to an estimate probability of presence of species to uniform, while still subject to environmental constraints [25]. Maxent has been defined to handle interaction between response and predictor variable. In addition it can use both continuous and categorical variables. Maxent applies some features including linear, quadratic, product, threshold and hinge to predict the geographic distribution of species. Over fitting can be controlled by empirical regularization parameter in Maxent. Both response curves jackknife test applies to demonstrate, the relative importance of each individual predictor. The continuous probability maps produced by Maxent were categorized to four classes representing probability cutoffs in 25% increments. 10-fold cross-validation was used for the model validation. The results were obtained from the average about 10 times running the model for the species. AUC (the area under the curve) summarizes the overall location of the entire ROC (receiver operating characteristic) curve.

Table 1. Habitat variables considered for the distribution models

Environmental variables	Code
Topography variables	
Altitude	T-A
Slope	T-S
Climatic variables	
Annual mean temperature (°C)	C-AMT
Mean temperature of coldest quarter (°C)	C-MTCQ
Annual precipitation (mm)	C-AP
Land use/land cover variables	
Distance of settlements in urban area	L-DSU
Distance of settlements in rural area	L-DSR
Human population density in urban area	L-HDU
Human population density in rural area	L-HDR
Distance of Road	L-DR
Distance of stream	L-DS
Distance of River	L-DRI
Distance of lake	L-DL
Distance of Dry farm	L-DDF
Distance of Irrigated farm	L-DIF
Distance of Forest	L-DF
Distance of Woodland	L-DW
Distance of Scrubland	L-DSL
Distance of Range	L-DRAN
Distance of Bare	L-DB
Distance of Rocky area	L-DRA
Distance of Protected area	L-DPA
NDVI	NDVI

Table 2. Habitat predictions' evaluation for brown bear in northern Iran

Scale	AUC	SD
30 m	**0.93**	**0.002**
100 m	0.81	0.003
1000 m	0.73	0.002

The highest values of AUC were highlighted in bold.

This measure was used to evaluate the model performance that varies between 0 and 1. The accuracy of 0.5 in AUC is low and does not perform better than random while a value of 1 indicates a perfect predictive ability for models.

RESULTS

In this study, Maxent significantly presented greater performance than random at all three scales (Table 2). All results from AUC model evaluation showed that scale 30 m performed averagely better than other scales (Table 2). The results that obtained from Maxent model indicated that the scale had a large effect on the importance of some environmental variables (Fig. 1). The distances of dry farm, irrigated farm, forest, woodland, scrubland and range are shown by these results. In addition, the effect of distance of these areas was more noticeable to 30 and 100 m spatial resolution, while the effect of distance of lake was inversely more noticeable to 1000 m spatial resolution (Fig. 1). The probability of brown bear presence was predicted strongly by NDVI (normalized difference vegetation index). The response curves produced by different scales of predictor variables were almost at the same (Fig. 2). Many factors such as increasing distance of bare, rocky area, range, road, urban, and rural settlements and decreasing population density influence habitat suitability in positive way, while increasing distance of forest, woodland, protected area, NDVI, stream, river, altitude and slope had a negative effect on habitat suitability (Fig. 2). The Brown bear habitat suitability map is shown in Fig. 3. These results indicated that a large part of northern Iran might be a suitable habitat for the brown bear. Maxent analysis showed that the northern part of our study area seems to host much higher-quality habitat than the southern part of our study area.

DISCUSSION

Although Maxent is known to be consistent across a wide range of spatial resolutions but, our results showed that the significant changes of some variables in predictive ability are depended to the scale [24, 26–28]. In this study, the best predictive scale was 30 m that selected between other scales. Our findings strongly revealed that identifying an appropriate scale is important issue to forecast brown bear distribution. Only recent studies focus on scale dependence in habitat modeling, while most studies that have considered scale have assessed a series of models in which all variables were at the same scale, which differed between models. Our analyses and similar work on other species [e.g. 17, 18, 29] suggest that for obtaining valid predictions of species distribution, it is important to optimize the scale of analysis independently. This supports the knowledge that species presence in a site isn't necessarily influenced by the effects of habitat at any one single scale [17, 18, 30].

Our study demonstrated that many factors such as increasing distance of bare, rocky area, range, road, settlements in the urban and rural area and decreasing population density have a positive effect on habitat suitability. In the other words, this species tends to stay away from troubled areas disturbed regions due to high-intensity human activities such as road, settlements in urban and rural area and ranges. In contrast, with mentioned factors that can develop habitat suitability, increasing distance from forest, woodland,

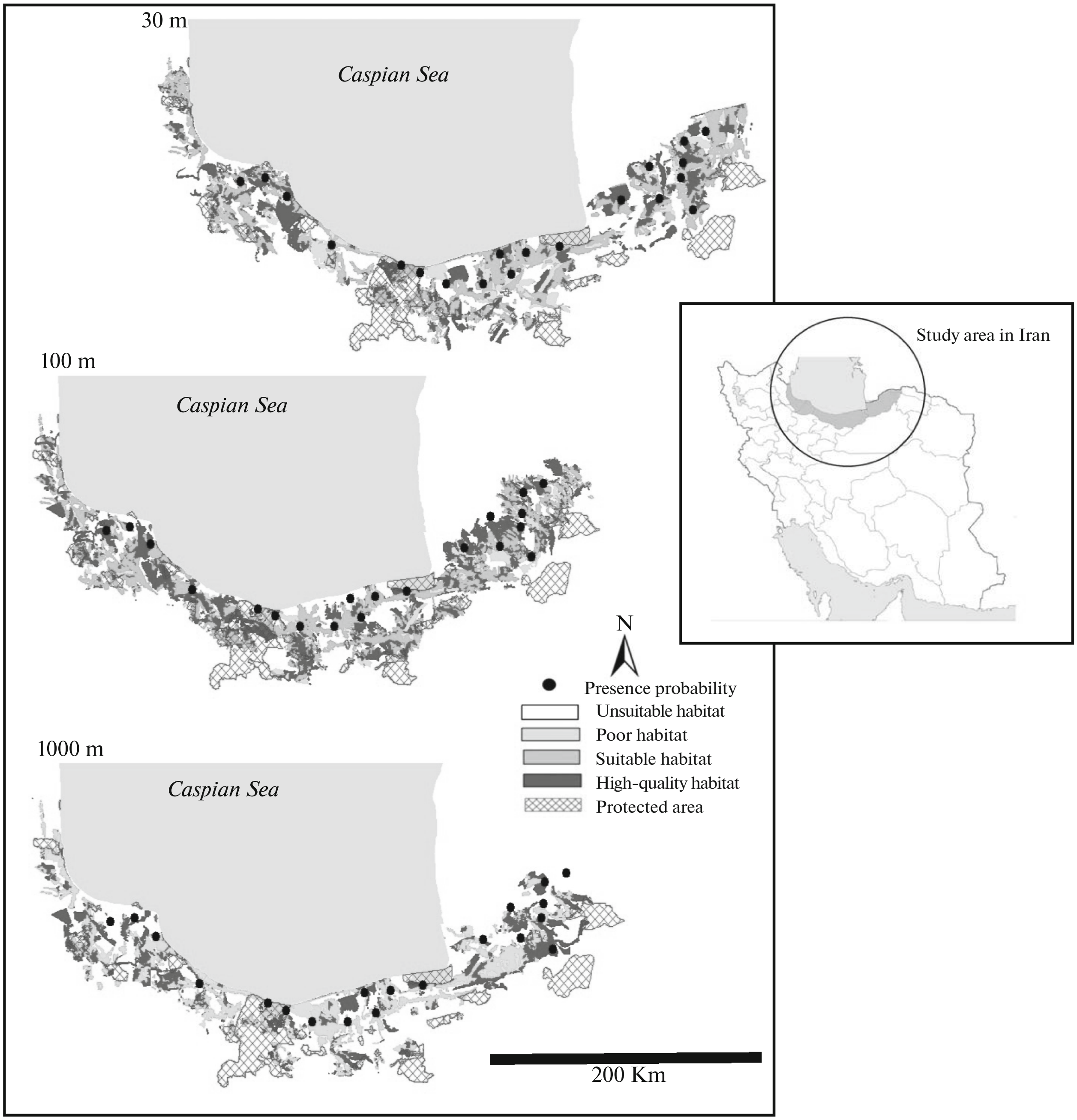

Fig. 3. Habitat suitability map of brown bear in northern Iran.

protected area, stream, river and NDVI can decrease habitat suitability, this means above parameters may offer security and cover for resting and hiding and subsequently increasing the foraging opportunities in the areas [31–34]. Therefore, higher relative bears can be seen in that areas which are in consistent with the individual habitat selection patterns referred in previous studies [35, 36].

Defining and managing protected areas for particular species can be performed by applying habitat model analysis. Figure 3 clearly shows one of the main threats for brown bear that more than 80% of the distribution range of this species is outside of the protected areas. Nowadays, selecting protected area and conservation planning is based on national conservation policies in many countries around the world that brown bears in Iran have a high priority for protection.

Based on our findings, the bear suitable habitat must be protected in new protected areas within the suitable area (Fig. 3) Moreover, human disturbances such as new human settlements and various infrastructures such as dams, roads, power supplies, etc. should be avoided.

Habitat suitability maps are also useful as decision-making instrument for evaluating future developments within the protected areas and predicting future expansion of brown bears [37]. Only 17% of the protected areas was found suitable for brown bear and divided to 5.1% poor, 8.8% suitable, and 3.1% high-quality habitat. Consequently, it is suggested that the protected area of northern Iran reconsiders with interventions aimed at maintaining suitable habitats of brown bear and defined new wildlife reserves to protect the species in the north of Iran.

REFERENCES

1. Servheen, C., *The Status and Conservation of the Bears of the World,* International Association for Bear Research and Management Monograph Series, no. 2, 1990.
2. Servheen, C., Herrero, S., and Peyton, B., *Status Survey and Conservation Action Plan for Bears. IUCN/SSC Bear and Polar Bear Specialist Groups,* Gland, Switzerland: IUCN, 1999.
3. Ziaie, H., *A Field Guide to Mammals of Iran,* 2nd ed., Tehran: Iran Wildlife Center, 2008.
4. Nellemann, C., Støen, O.G., Kindberg, J., Swenson, J.E., Vistnes, I., Ericsson, G., Katajisto, J., Kaltenborn, B.P., Martin, J., and Ordiz, A., Terrain use by an expanding brown bear population in relation to age, recreational resorts and human settlements, *Biol. Conserv.,* 2007, vol. 138, pp. 157–165.
5. Martin, J., Basille, M., Van Moorter, B., Kindberg, J., Allainé, D., and Swenson, J.E., Coping with human disturbance: Spatial and temporal tactics of the brown bear (*Ursus arctos*), *Can. J. Zool.,* 2010, vol. 88, pp. 875–883.
6. Kaczensky, P., Knauer, F., Krze, B., Jonozovic, M., Adamic, M., and Gossow, H., The impact of high speed, high volume traffic axes on brown bears in Slovenia, *Biol. Conserv.,* 2003, vol. 111, pp. 191–204.
7. Wielgus, R.B. and Vernier, P., Grizzly bear selection of managed and unmanaged forests in the Selkirk Mountains, *Can. J. Forest. Res.,* 2003, vol. 33, pp. 822–829.
8. Graves, T.A., Kendall, K.C., Royle, J.A., Stetz, J.B., and Macleod, A.C., Linking landscape characteristics to local grizzly bear abundance using multiple detection methods in a hierarchical model, *Anim. Conserv.,* 2011, vol. 14, pp. 652–664.
9. Waller, J.S., Grizzly bear use of habitats modified by timber management, *MS Thesis,* Bozeman, MT: Montana State Univ., 1992.
10. McLellan, B.N. and Hovey, F.W., Habitats selected by grizzly bears in a multiple use landscape, *Wildl. Manag.,* 2001, vol. 65, no. 1, pp. 92–99.
11. Singer, F.J., Schreier, W., Oppenheim, J., and Garton, E.O., Drought, fires, and large mammals, *BioScience,* 1989, vol. 39, pp. 716–722.
12. Guisan, A. and Zimmermann, N.E., Predictive habitat distribution models in ecology, *Ecol. Model.,* 2000, vol. 135, pp. 147–186.
13. Pearce, J.L. and Boyce, M.S., Modelling distribution and abundance with presence-only data, *J. Appl. Ecol.,* 2006, vol. 43, pp. 405–412.
14. Guisan, A. and Thuiller, W., Predicting species distribution: Offering more than simple habitat models, *Ecol. Lett.,* 2005, vol. 8, no. 9, pp. 993-1009.
15. Williams, K.J., Belbin, L., and Austin, M.P., Which environmental variables should I use in my biodiversity model?, *Int. J. Geogr. Inf. Syst.,* 2012, vol. 26, pp. 2009–2047.
16. Moudry, V. and Simova, P., Influence of positional accuracy, sample size and scale on modelling species distributions: A review, *Int. J. Geogr. Inf. Syst.,* 2012, vol. 26, pp. 2083–2095.
17. Shirk, A.J., Wasserman, T.N., Cushman, S.A., and Raphae, M.G., Scale dependency of American marten (*Martes americana*) habitat relationships, in *Biology and Conservation of Martens, Sables, and Fishers: A New Synthesis,* Ithaca, NY: Cornell Univ. Press, 2012.
18. Wasserman, T.N., Cushman, S.A., Wallin, D.O., and Hayden, J., Multi-scale habitat relationships of *Martes americana* in northern Idaho, U.S.A., Res. Pap. RMRS-RP-94, Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station, 2012.
19. Swindle, K.A., Ripple, W.J., Meslow, E.C., and Shafer, D., Old-forest distribution around spotted owl nests in the central Cascade Mountains, Oregon, *J. Wildl. Manag.,* 1999, vol. 63, pp. 1212–1221.
20. Dunk, J.R., Zielinski, W.J., and Preisler, H.K., Predicting the occurrence of rare mollusks in northern California forests, *Ecol. Appl.,* 2004, vol. 14, pp. 713–729.
21. Joosten, H., The late-Holocene vegetation history of the Central Caspian (Hyrcanian) forests of northern Iran, *Holocene,* 2008, vol. 18, no. 2, pp. 307–321.
22. Heshmati, G.A., Vegetation characteristics of four ecological zones of Iran, *Int. J. Plant. Prod.,* 2007, vol. 1, pp. 215–224.
23. Menges, V., Influence of season, sex, age and behavior on the defecation rate of brown bears (*Ursus arctos*) in south-central Sweden, *M.S. Thesis,* Edinburgh, Scotland: Edinburgh Napier Univ., 2011.
24. Phillips, S.J., Anderson, R.P., and Schapire, R.E., Maximum entropy modeling of species geographic distributions, *Ecol. Model.,* 2006, vol. 190, pp. 231–259.
25. Elith, J., Phillips, S.J., Hastie, T., Dudik, M., Chee, Y.E., and Yates, C.J., A statistical explanation of MaxEnt for ecologists, *Divers. Distrib.,* 2011, vol. 17, pp. 43–57.
26. Li, B., Ma, J., Hu, X., Liu, H., and Zhang, R., Potential geographical distributions of the fruit flies *Ceratitis capitata, Ceratitis cosyra,* and *Ceratitis rosa* in China, *Econ. Entomol.,* 2009, vol. 102, pp. 1781–1790.
27. Tittensor, D.P., Baco, A.R., Brewin, P.E., Clark, M.R., Consalvey, M., Hall-Spencer, J., Rowden, A.A., Schlacher, T., Stocks, K.I., and Rogers, A.D., Predicting global habitat suitability for stony corals on seamounts, *Biogeography,* 2009, vol. 36, pp. 1111–1128.
28. Tong, R., Purser, A., Guinan, J., and Unnithan, V., Modeling the habitat suitability for deep-water gorgonian corals based on terrain variables, *Ecol. Inform.,* 2013, vol. 13, pp. 123–132.
29. Thompson, C.M. and McGarigal, K., The influence of research scale on bald eagle habitat selection along the

lower Hudson River, New York (USA), *Landsc. Ecol.,* 2002, vol. 17, pp. 569–586.

30. Sanchez, M.C., Cushman, S.A., and Saura, S., Scale dependence in habitat selection: The case of the endangered brown bear (*Ursus arctos*) in the Cantabrian Range (NW Spain), *Int. J. Geogr. Inf. Sci.,* 2014, vol. 28, no. (8), pp. 1531–1546.
31. Apps, C.D., McLellan, B.N., Woods, J.G., and Proctor, M.F., Estimating grizzly bear distribution and abundance relative to habitat and human influence, *Wildl. Manag.,* 2004, vol. 68, no. 1, pp. 138–152.
32. Blanchard, B.M., Grizzly bear: Habitat relationships in the Yellowstone area, *Int. Conf. Bear Res. Manag.,* 1980, vol. 5, pp. 118–123.
33. Herrero, S., Aspects of evolution and adaptation in American black bear (*Ursus americanus* Pallus) and brown and grizzly bears (*Ursus arctos* Linne) of North America, *Int. Conf. Bear Res. Manag.,* 1972, vol. 2 pp. 221–231.
34. Gibeau, M.L., Herrero, S., McLellan, B.N., and Woods, J.G., Managing for grizzly bear security areas in Banff National Park and the Central Canadian Rocky Mountains, *Ursus,* 2001, vol. 12, pp. 121–130.
35. Nielsen, S.E., Boyce, M.S., and Stenhouse, G.B., Grizzly bears and forestry: 1. Selection of clearcuts by grizzly bears in west-central Alberta, Canada, *For. Ecol. Manag.,* 2004, vol. 199, pp. 51–65.
36. Stewart, B.P., Nelson, T.A., Wulder, M.A., and Nielsen, S.E., Impact of disturbance characteristics and age on grizzly bear habitat selection, *Appl. Geogr.,* 2012, vol. 34, pp. 614–625.
37. Van Gils, H., Westinga, E., Carafa, M., Antonucci, A., and Ciaschetti, G., Where the bears roam in Majella National Park, Italy, *J. Nat. Conserv.,* 2014, vol. 22, no. 1, pp. 23–34.