ISSN: 2538-2152; ECOPERSIA 2024;12(4):317-328.

Impact of Climate Change on The Habitat of the Eurasian Otter in the Southwest of Iran

A R T I C L E I N F O

Article Type
Original Research

Authors
Zahra Nazari, *M.Sc.*[1]
Olyagholi Khalilipour, *Ph.D.*[2*]
Mohammad Reza Ashrafzadeh, *Ph.D.*[3]
Soheil Saidian, *Ph.D.*[4]

How to cite this article
Nazari Z., Khalilipour O., Ashrafzadeh MR,. Saidian S. Impact of Climate Change on The Habitat of the Eurasian Otter in the Southwest of Iran. ECOPERSIA 2024;12(4): 317-328.

DOI:
10.22034/ECOPERSIA.12.4.317

[1] M.Sc. Student, Department of Environmental science, Faculty of Marine Natural Resources, Khorramshahr University of Marine science and technology, Khorramshahr, Iran.
[2] Assistant Professor, Department of Environmental Science, Faculty of Marine Natural Resource, Khorramshahr University of Marine Science and Technology, Khorramshahr, Iran.
[3] Associate Professor, Department of Environmental Science, Faculty of Natural Resources and Earth Sciences, Shahrekord University, Shahrekord, Iran.
[4] Assistant Professor, Department of Basic Sciences and General Courses, Faculty of Economics and Management, Khorramshahr University of Marine Science and Technology, Khorramshahr, Iran.

*** Correspondence**
Address: Assistant Professor, Department of Environmental Science, Faculty of Marine Natural Resource, Khorramshahr University of Marine Science and Technology, Khorramshahr, Iran.
Tel: +989163081169
Email: o.khalilipour@kmsu.ac.ir

Article History
Received: May 5, 2024
Revised: October 27, 2024
Accepted: October 28, 2024
Published: November 30, 2024

A B S T R A C T

Aims: This research examined climate change's impact on the Eurasian otter's habitat (*Lutra lutra*) in Khuzestan Province based on habitat modeling in R regarding climate scenarios and the MRI-ESM2-0 general circulation model.
Materials & Methods: 72 points were recorded, and ten climatic and environmental variables were used as inputs for the models. The ROC curve, TSS, and Kappa coefficient were used to assess model accuracy using three different methods.
Findings: In the ROC model, AUC 0.7–0.8 indicates a suitable model, AUC 0.8–0.9 indicates a robust model, and AUC > 0.9 indicates a powerful model. In the TSS model,> 0.75 indicates excellent diagnostic power, 0.4–0.75 indicates good, and < 0.4 indicates weak diagnostic power. The Kappa coefficient (0.39–0.98) shows good prediction accuracy. The RF and GBM were the best for determining the habitat of the Eurasian otter in Khuzestan Province. River distance, BIO1, and BIO3 had the most significant role in habitat suitability. A total of 9176.185 km^2 of Khuzestan Province was identified as a suitable habitat. The prediction of the species' distribution changes based on SSP126, SSP370, and SSP585 showed that this species' habitat would decrease until 2070.
Conclusion: Climate change significantly affects the distribution of the Eurasian otter. Similar to other studies on animal and plant species, it leads to habitat reduction and alterations in habitat ranges.

Keywords: Climate change; Eurasian Otter; Suitability; General circulation models.

CITATION LINKS

[1] Cianfrani C., Le Lay G., Maiorano L ... [2] Bellard C., Bertelsmeier C., Leadle ... [3] Ebrahimi A., Farashi A., Rashki A. ... [4] Karami, M., Mirzaei, I., Hamzehpour ... [5] Ansari A. Habitat quality evaluatio ... [6] Mirzaei R., Karami M., Danehkar A., ... [7] Eshagh Nimvari S., Naderi S., Mirza ... [8] Masoodian S.A. Temperature trends i ... [9] Dayton G.H, Fitzgerald L.A. Habitat ... [10] Guisan A., Zimmermann N.E. Predicti ... [11] Rashidi P., Makmom A.A., Mahiny A.S ... [12] Houghton J.T., Ding Y., Griggs D.J. ... [13] Archis J.N., Akcali C., Stuart B.L. ... [14] Araújo M.B., New M. Ensemble foreca ... [15] Kaddo J.R. Parkland College Climate ... [16] Potta S. Application of stochastic ... [17] Nazmfar H., Alibakhshi A. Assess th ... [18] Behroozi Rad B. Wetlands of Iran, N ... [19] Thuiller W., Lafourcade B., Engler ... [20] R Core Team. R: A language and envi ... [21] Woodman S.M., Forney K.A., Becker E ... [22] Václavík T., Meentemeyer R.K. Equil ... [23] Simpson M., Prots B. Predicting the ... [24] Marmion M., Luoto M., Heikkinen R.K ... [25] Kindt R. Ensemble species distribut ... [26] Allouche O., Tsoar A., Kadmon R. As ... [27] Shabani F., Kumar L., Ahmadi M. Ass ... [28] Haidarian M., Tamartash R., Jafaria ... [29] Ashrafzadeh M.R., Naghipour A.A., H ... [30] Ashrafzadeh M.R, Naghipour A.A, Hai ... [31] Bedia J., Herrera S., Gutiérrez J.M ... [32] Hirzel A. When GIS comes to life. L ... [33] Pramanik M., Paudel U., Mondal B., ... [34] Olivier F., Wotherspoon S.J. Modell ... [35] Saavedra Bendito D. Reintroduction ... [36] Kafash A., Kaboli M., Köhler G. Com ... [37] Pedroso N.M., Marques T.A., Santos- ... [38] Karami M., Dargahi M.D., Hamzepour ... [39] Segurado P., Araujo M.B. An evaluat ... [40] Sangoony H., Vahabi M., Tarkesh M., ... [41] Breiman L. Random forests. Mach. Le ... [42] Elith J., Leathwick J.R., Hastie T. ... [43] Cheng L., Lek S., Lek-Ang S., Li Z. ... [44] Sahragard H.P., Chahouki M.Z. An ev ... [45] Naghipour Borj A.A., Haidarian Agha ... [46] Haidarian-Aghakhani M., Sangoony H. ... [47] Ashrafzadeh M.R., Shojaei Z., Shalo ... [48] Solgi E., Ghasempouri S.M., Esmaili ... [49] Khosravi R., Hemami M.R., Malakouti ... [50] Erlinge S. Territoriality of the ot ... [51] Edenhofer O., Pichs-Madruga R., Sok ... [52] Milanovich J.R., Peterman W.E., Nib ... [53] Yukimoto S., Kawai H., Koshiro T., ... [54] Zarrin A., Dadashi-Roudbari A., Has ... [55] McCluskie A.E. Temperature-mediated ... [56] Garcês A., Pires I. Biological and ... [57] Tolrà A., Ruiz-Olmo J., Riera J.L. ...

Introduction

Climate changes resulting from human activities are occurring at a high pace, and most species cannot adapt to them, thus resulting in possible extinction. Predictions show that by the end of this century, we will lose a large part of global biodiversity [1,2]. Iran is not exempt from this issue, with endangered species found in most parts of the country [3]. Climate change has severely affected the Eurasian otter population in Khuzestan Province [4]. They are classified as "Near Threatened" (NT) due to their continuous population decline [1]. Studies have shown that this species does not have a high density in most rivers and wetland systems of Iran [5]. Despite their essential role in the functioning of the ecosystem, there are many threats to this species in Iran. Currently, the most significant factors threatening the Eurasian otters in Khuzestan Province are the destruction of water habitats due to anthropogenic changes, water pollution from chemical fertilizers and pesticides in agriculture, animal husbandry, fishing, and climate change [6,7]. Tolrà et al. (2024) revealed that human activities, such as pollution and habitat modification, significantly impact the habitat selection of Eurasian otters. These disturbances can lead to habitat fragmentation and reduced availability of suitable environments for otters, affecting their population dynamics and overall health. Additionally, climate change exacerbates these issues by altering water temperatures and flow patterns, further stressing otter populations [56]. In recent years, climatic change has led to drying wetlands and rivers in Khuzestan Province, which harm this species' habitat and ecosystem [8]. The same factors at national and international levels have caused population declines [5, 6, 7, 37, 47]. This species coexists with the smooth-coated otter in the Hur-al-Azim wetland in the western part of the province. However, due to the scarcity of smooth-coated otters in Hur-al-Azim and the lack of confirmed data regarding their presence in the Arvand River, accurate details about the overlap between Eurasian and smooth-coated otter habitats remain uncertain. To improve the population of this species in Khuzestan Province, it is necessary to prepare a comprehensive program to modify, improve, and restore their habitat in the study area. Considering the limited information about the status and distribution of this species in the study area, this endeavor attempts to investigate habitat suitability for this species and changes in habitat suitability due to climate change. On the other hand, knowledge of the changing process of ecosystems, especially wetlands, can predict the future status of this animal. Studying habitat suitability for management purposes, providing protection, and presenting habitat maps via this method is rare in Iran. Such studies can serve as a model for applying new management methods. Habitat suitability modeling helps wildlife managers identify threats to this species' population and habitats. It is impossible to manage a species without knowledge of significant environmental factors, such as the relationship between the species and their habitat [9]. The digitization of these relationships through habitat suitability models, like modeling the effects of climate change on wildlife habitats and applying the results, can lead to species protection [10]. One method for assessing the risk of wildlife extinction and spatial planning for conservation strategies is to predict species' response to climate change in different geographical areas [11]. Many recent studies regarding modeling the effects of climate change on species' distribution ranges focus on predicting future geographical distributions. Climate change affects species' geographical distribution and stability [12, 13]. Predicting future

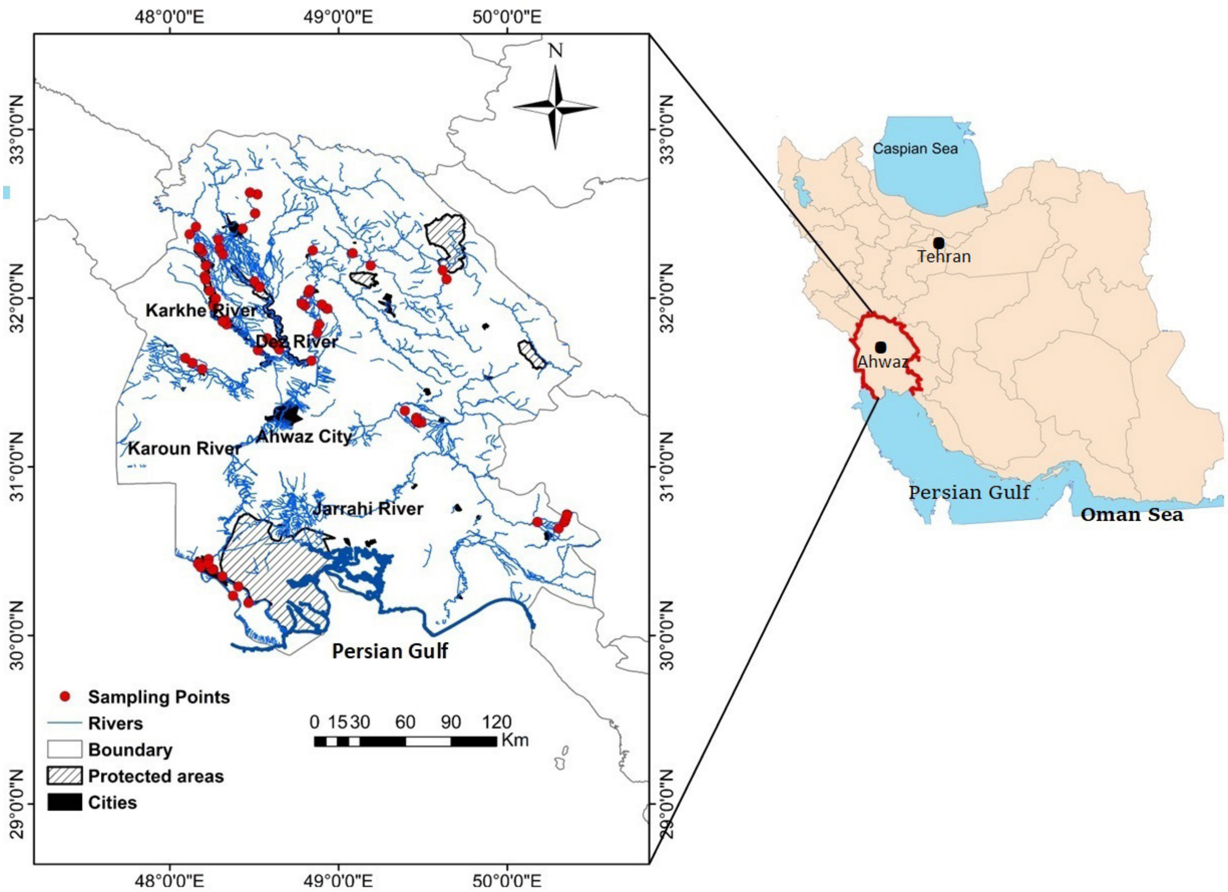

Figure 1) Map of the study area and geographic location of sampling points in Khuzestan Province, Southwestern Iran. This study made efforts to collect samples from all the areas under investigation.

climates relies on numerical computer general circulation models [14]. These models operate based on information related to the general conditions of the Earth, which are published in the form of climate scenarios [15]. However, general circulation models are robust and reliable tools for increasing knowledge about factors affecting climate and improving the ability to predict future climate patterns [16]. Although this area falls within the species ' range, there is no comprehensive research on the *Lutra lutra* species in Khuzestan Province, located in southwestern Iran. Our research seeks to answer the following questions: (i) Which areas are considered suitable habitats for the *Lutra lutra* in southwestern Iran? (ii) How might the species' distribution change under climate change scenarios by 2070? (iii) To what extent will a suitable habitat overlap with existing conservation areas in the future?

Materials & Methods

Study Area: Khuzestan Province, located in southwestern Iran, has the following geographical coordinates: Latitude: 31.43601490 (N), Longitude: 49.04131200 (E). The total area of Khuzestan Province is approximately 64,055 square kilometers. The north and east of it are covered by the Zagros mountains, whose heights decrease toward the southwest and appear as sloping hills in the southern areas [17]. This Province has many rivers, the most important of which are the Karoon, Karkheh, Dez, Zohre, Maroon, and Jarrahi. It also has significant wetlands, such as the Shadgan and Hor-al-Azim Wetlands, which are considered Eurasian otters' main habitats. The Shadgan Wetland is located at the southern end of Khuzestan Province at the terminus of the Jarrahi River. At the same time, the Hor-al-Azim Wetland is situated in the western part, at the end of the Karkhe River in the Azadegan plain border area [18].

Eurasian Otter Records: To determine habitat suitability for this species, presence points were identified throughout Khuzestan Province between 2019 and 2021. Three methods were used to collect the occurrence data of the species: 1) the direct observation of species by authors and georeferenced observations by the personnel of the Department of Environment (DOE) of Iran, 2) indirect signs of species such as scats and footprints along with documented human reports, and 3) data obtained from other studies. All observations and signs were recorded using a GPS. Seventy-two records were used for modeling after removing invalid data with uncertainty. Many sites across the Province were visited to find reliable records (Figure 1). The presence localities were filtered to a minimum distance of 5 kilometers [49] from each other to mitigate spatial dependence.

Habitat Variables: In this study, 19 temperature and precipitation climate variables were extracted from https://chelsa-climate.org. These variables are related to two scenarios: the current period (1981-2010) and future climate scenarios (2041-2070), as shown in Table (1). In order to reduce the effect of autocorrelation between layers, the correlation between the variables was first identified. To do so, Pearson's correlation coefficient with an R-value of < 0.7 was considered [48]. Then, four climatic variables were used in the final analysis: the average annual temperature (BIO1), isothermal index (BIO3), annual temperature range (BIO7), and seasonal rainfall changes (BIO15). In addition to climatic variables, the maps of aspect, distance from the rivers (River.dis), distance from the roads (Road.dis), distance from the villages (Village.dis), distance from irrigated agriculture (Wa.dis), and distance from wetlands (Wetland.dis) were obtained and used in preparing the final model. All environmental layers were standardized regarding extent, cell size (approximately 1 km), and coordinate system.

Climate Change: General circulation models (GCMs), which utilize different representative concentration pathways (RCPs), provide credible quantitative estimates of the future climate. RCPs are four greenhouse gas concentration scenarios [50]. Climate distribution modeling projections depend on the chosen GCM and assumptions about future atmospheric CO2 levels [51]. We selected the MRI-ESM2-0 model from the CMIP6 suite for its high performance in capturing climatic variables relevant to our study region. This model's projections closely align with observed climate patterns and trends in our area, making it suitable for assessing habitat suitability under future climate scenarios. Although using multiple models could offer a broader range of outcomes, resource constraints, and our study's specific focus led us to select the most regionally appropriate model [52, 53].

Habitat Modeling: In this study, an ensemble model approach was used for species distribution modeling based on recent data [19], employing R software version 2.1.3 [20] and the biomod2 toolbox [21]. The Generalized Linear Model (GLM), Generalized Boosting Method (GBM), Multivariate Adaptive Regression Splines (MARS), and Random Forest (RF) were used for species distribution prediction [22, 23]. The final map of suitable habitats was derived from the average predictions of these models [24]. Biomod2 offers three methods for model accuracy assessment: ROC curve, TSS, and

Kappa coefficient. All three methods were used simultaneously for better comparison and conclusions [25]. In the ROC model, an AUC between 0.7-0.8 indicates a good model; 0.8-0.9 is an excellent model, and greater than 0.9 is a powerful model. For TSS, a value above 0.75 indicates excellent diagnostic power; 0.4-0.75 is good; below 0.4 is weak [26]. A Kappa coefficient between 0.39-0.98 signifies a good prediction level of the model. TSS is more realistic and sensitive than AUC [26, 27]. To assess the impact of climate change on species distribution, an environmental threshold was specified based on ROC criteria [28, 29] and used to prepare habitat suitability maps. These maps were employed to evaluate habitat changes due to climate change by 2070 across three RCP scenarios for each GCM [24]. ArcGIS 10.5 was used to map and analyze the Eurasian otter's modeled distribution and suitable habitat.

Findings

The results showed that the random forest (RF) and Generalized Boosting Method (GBM) had the highest AUC, TSS, and Kappa values, respectively (Table 2).

These models were best suited to determining suitable and unsuitable habitats for Eurasian otters in the study area. Based on the model results, approximately 9,176 km^2 were recognized as suitable habitats for this species, comprising about 14.3% of the study area (Figures 2 and 3).

The results of this research indicated that

Table 1) The climatic variables utilized in this study were sourced from CHELSA Climate. After evaluating the correlations among these climate parameters, four were ultimately chosen.

Variables	Climatic Description	Variables	Climatic Description
BIO1	Annual Mean Temperature	BIO11	Mean Temperature of Coldest Quarter
BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp))	BIO12	Annual Precipitation
BIO3	Isothermality (BIO2/BIO7) (×100)	BIO13	Precipitation of Wettest Month
BIO4	Temperature Seasonality (standard deviation ×100)	BIO14	Precipitation of Driest Month
BIO5	Max Temperature of Warmest Month	BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO6	Min Temperature of Coldest Month	BIO16	Precipitation of Wettest Quarter
BIO7	Temperature Annual Range (BIO5-BIO6)	BIO17	Precipitation of Driest Quarter
BIO8	Mean Temperature of Wettest Quarter	BIO18	Precipitation of Warmest Quarter
BIO9	Mean Temperature of Driest Quarter	BIO19	Precipitation of Coldest Quarter
BIO10	Mean Temperature of Warmest Quarter		

Table 2) The evaluation of four applied models predicting *Lutra Lutra* distribution in Khuzestan Province using the area under the ROC curve (AUC), true skill statistic (TSS), and Kappa coefficient.

	RF	MARS	GLM	GBM	Mean
AUC	1.00	0.92	0.90	0.99	0.95
TSS	0.99	0.79	0.69	0.96	0.86
Kappa	0.98	0.47	0.39	0.83	0.67

among the environmental factors used, the most significant role in the suitability of the Eurasian otter's habitat was attributed to the distance from the rivers (River.dis), followed by the average annual temperature (BIO1) and isothermality (BIO3), respectively (Table 3).

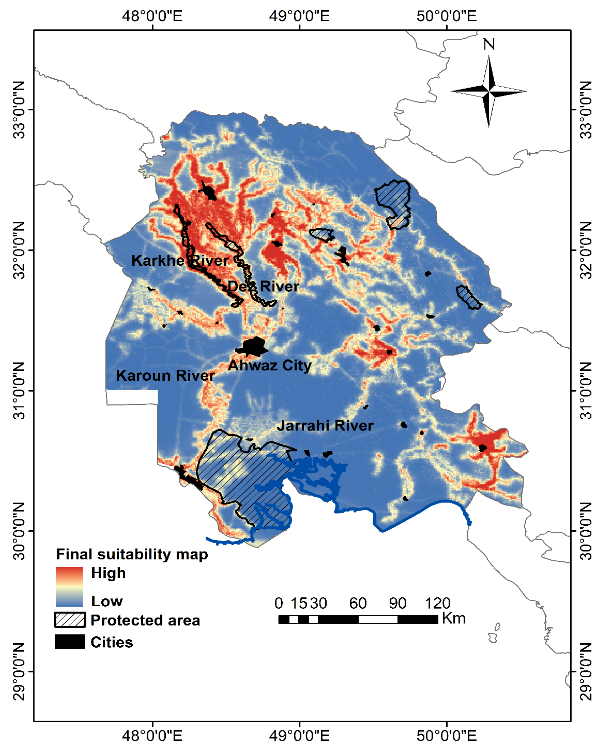

Figure 2) The final suitability map of the *Lutra lutra* habitat in Khuzestan Province based on the current scenario. Riverbanks were identified as the optimal habitat for this species.

The results of an ensemble model based on future scenarios indicated a decrease in the suitable habitat for the Eurasian otter species in Khuzestan Province (Figure 4). According to the SSP126 scenario (the optimistic greenhouse gas emission scenario), approximately 10.37% of the ideal habitat will be lost, while about 1.28% will be added to the suitable habitat for this species. Similarly, under the SSP585 scenario (the very pessimistic greenhouse gas emissions scenario), about 11.58% of the suitable habitat will be lost, and 1.47% will be added. Overall, based on all three scenarios, the expected habitat changes are negative (Table 4).

Discussion

Habitat Suitability Modeling: Habitat suitability modeling is a tool used in ecology to protect and manage species and to resolve conflicts between humans and wildlife [30, 31]. It also provides valuable information about the relationship between species and their habitats [32]. This research investigated the suitability of the habitat of the Eurasian otter (*Lutra lutra*) in Khuzestan Province. The results indicated that 9,176.185 square kilometers of the area (3.14 percent) are suitable habitats for the Eurasian otter. The

Table 3) The relative contribution of environmental factors used in the different models to study the geographical distribution of the Eurasian otter.

	GBM	GLM	RF	MARS	Average Relative Contribution in Models (%)
River.dis	48.89	44.73	25.94	37.40	39.24
Bio1	17.59	8.24	5.25	23.28	13.59
Bio3	13.72	2.51	19.70	3.24	9.79
Bio7	4.87	12.11	17.90	0.00	8.72
Road.dis	2.99	6.16	7.72	12.50	7.34
Bio15	1.88	0.00	3.94	18.86	6.11
Village.dis	5.64	7.60	7.88	0.00	5.28
Wa.dis	1.88	13.69	2.13	0.00	4.43
Aspect	0.66	1.00	6.08	4.96	3.18
Wetland.dis	1.88	3.94	3.45	0.00	2.32

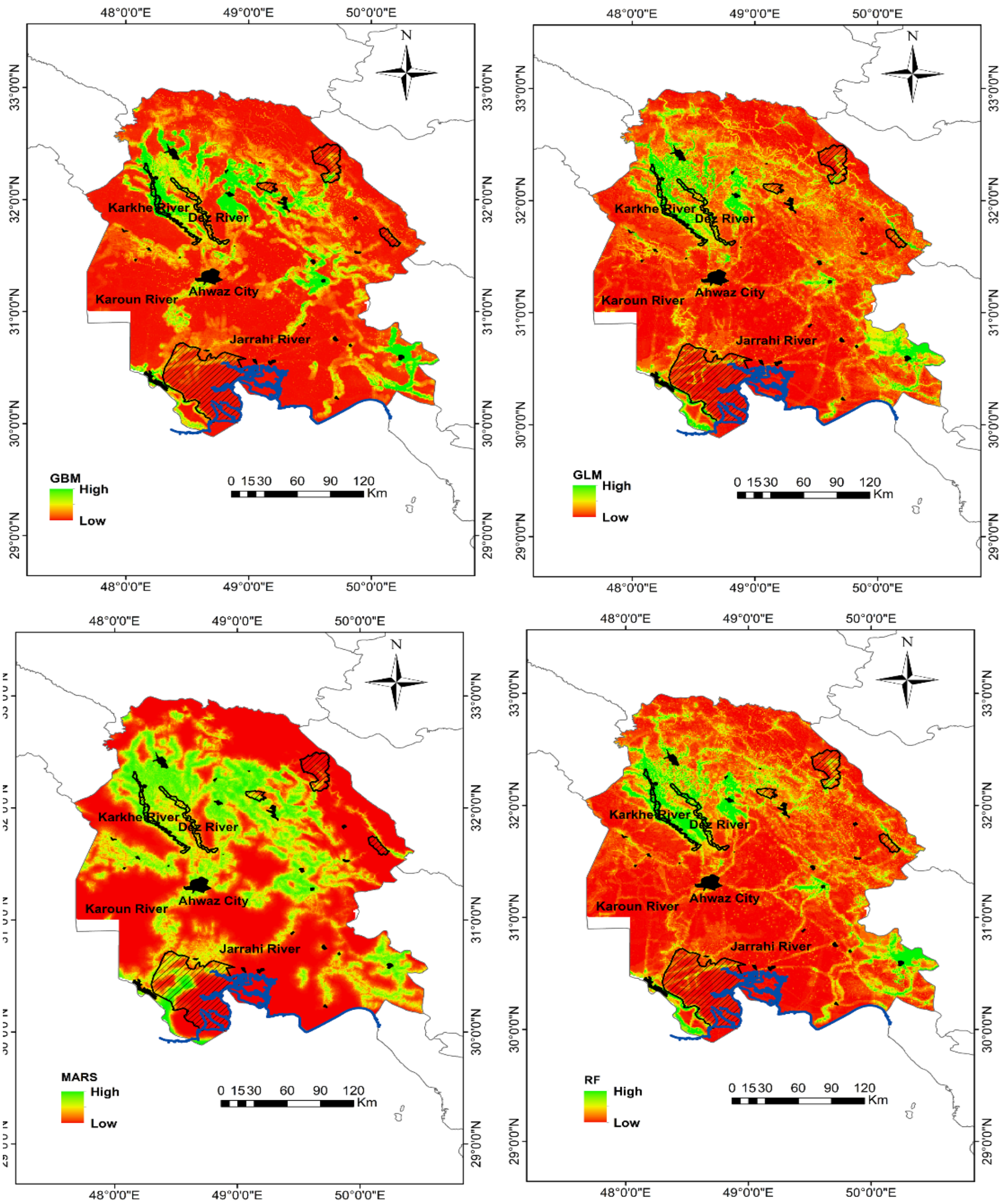

Figure 3) Current geographical distribution maps of Eurasian otter in Khuzestan Province applying GBM, GLM, MARS, and RF models in the study area.

northern, northeastern, and small areas of southeastern Khuzestan Province suit this species. This species inhabits rivers and the margins of lakes and wetlands in the Province [6, 5]. The droughts of recent decades have reduced water levels in rivers and wetlands, leading to a decrease in aquatic organisms, which are food sources for the Eurasian otter, posing the most significant threat to this species. Its primary diet consists of fish, but it can also consume aquatic invertebrates, such as crabs and oysters, as well as terrestrial prey, including mammals, birds, and insects [33]. In the long term, human presence, habitat destruction, and even, to a certain extent, water pollution lead to changes in habitat dynamics and damage to the ecosystem [34], but in the short term, they are tolerable for this species. However, a food shortage, even for a short period, is intolerable and elicits a negative response from this species [33]. Establishing protected areas contributes to the restoration of wetland ecosystems needed by the Eurasian otter [33], so increasing protected areas can significantly impact the stability and restoration of this species' population. In protected areas, despite an overall decrease in habitat suitability across the entire region, an increase in suitability percentage is observed across all scenarios, as indicated by Table (5).

Climate Change Effect: The results showed that among environmental factors affecting habitat suitability for the Eurasian otter, distance from rivers (a non-climatic variable) and average annual temperature and isothermality (climatic variables) are the most significant. They account for 62.62% of the relative contribution to model construction. Temperature, a primary element of climate formation, can significantly alter climate structure through fluctuations [35]. Previous studies on this species have shown that increased temperatures and habitat destruction are critical factors in reducing Eurasian otter presence in their habitats [6, 36]. A study on Eurasian otter foraging behavior indicates that changes in water temperature can significantly affect their metabolic costs and behavior [54]. Another study focuses on habitat suitability in South Korea, examining factors like temperature seasonality and the precipitation of the wettest month. These factors are crucial for understanding habitat preferences [55]. These studies suggest climate change impacts Eurasian otter habitats differently depending on the region. However, temperature changes and water availability significantly affect their distribution and behavior. Climate change is essential in reducing wildlife diversity, directly affecting the organisms' physiological, biological, and reproductive traits or indirectly through habitat quality reduction and food resource loss [6]. On the other hand, increasing world population growth, changes in land use, habitat loss, and water pollution exacerbate these impacts [37]. The evaluation of suitability models using AUC, TSS, and Kappa methods revealed that random forest (RF) and Generalized Boosting Method (GBM) models are optimal for

Table 4) Changes in the size of the suitable habitats (square kilometers) of the Eurasian otter until 2070 under different climate scenarios and general circulation model MRI-ESM2-0.

	Presence	Absence	New Habitat		Lost Habitat		
	Stable	Stable	Area	Percentage	Area	Percentage	Changes in the Habitat of the Species
sSP126 scenario	2530.82	54059.82	820.98	1.28	6645.35	10.37	-9.09
SSP370 scenario	2526.40	54085.64	795.17	1.24	6649.78	10.38	-9.13
SSP585 scenario	1755.57	53937.11	942.69	1.47	7420.61	11.58	-10.11

Table 5) The percentage of suitable and unsuitable habitats for Eurasian otters in the protected area of Khuzestan Province was assessed based on the current period and the sSP126, SSP370, and SSP585 scenarios until 2070. This analysis is related to the general circulation model MRI-ESM2-0.

	Now	SSP126	SSP370
Suitable	3.6	4.52	5.28
Unsuitable	96.4	95.48	94.72

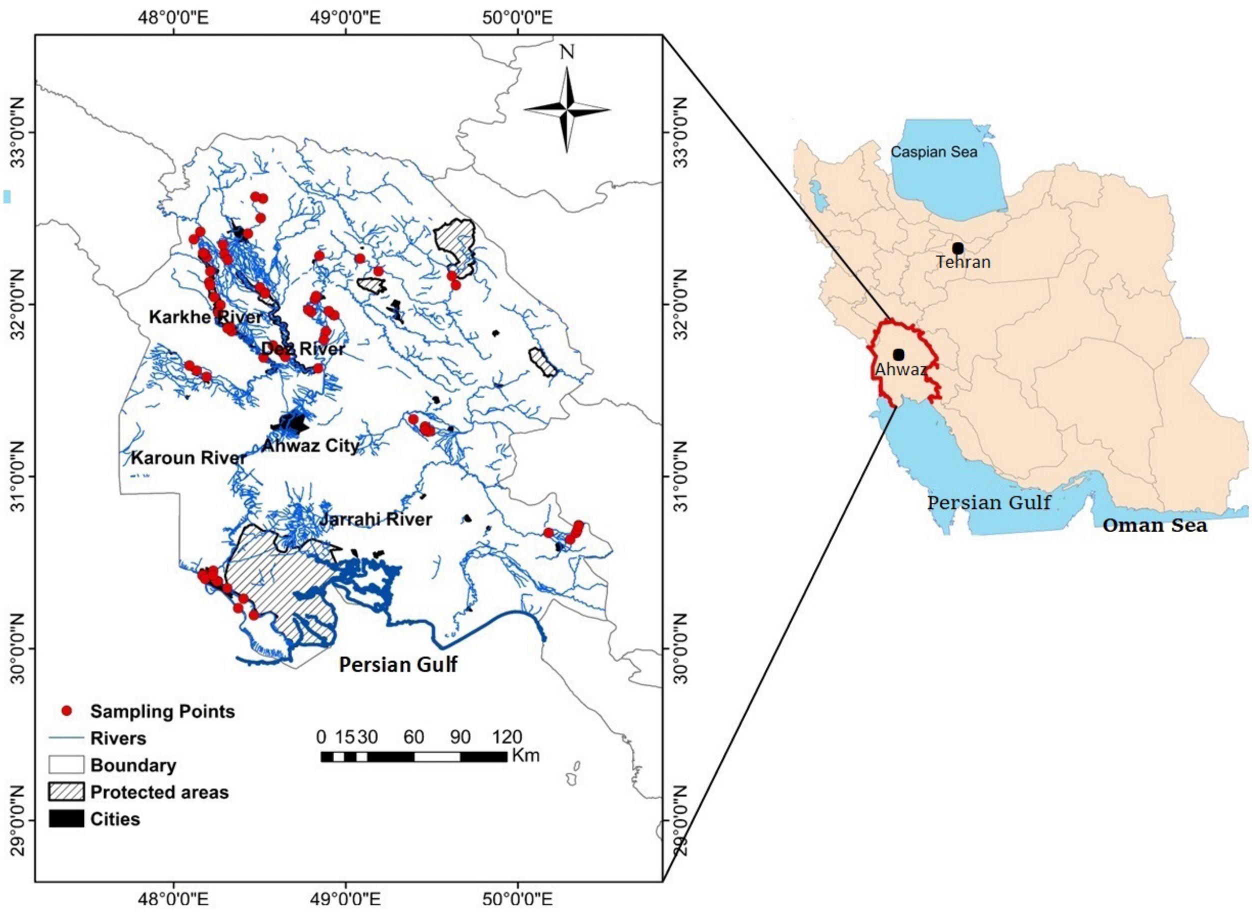

Figure 4) Changes in the geographical distribution of the Eurasian otter based on SSP126 scenario (A), SSP370 scenario (B), and also based on SSP585 scenario (C) until the year 2070 related to the general circulation model MRI-ESM2-0.

determining the climatic habitat of Eurasian otters in Khuzestan Province. Studies on other species (44 species of amphibians and reptiles [38] and some plants [39]) confirm these findings. The RF and GBM models accurately identify suitable and unsuitable climatic areas for species presence. The RF model generates predictions by creating thousands of trees and averaging them [40, 41]. The performance examination of different models revealed that the random forest model is the most accurate and efficient compared to others [42, 43, 44, 45, 46, 47].

The best and most essential conservation plans for the Eurasian otter in Khuzestan Province involve a combination of strategies: 1- Enhancing water conditions for fish, thereby making habitats more suitable for Eurasian otters, which includes establishing and stocking fish ponds. 2- Implementing guidelines that address Eurasian otter biology and conservation issues, including practical measures for conservation projects. 3- Protecting and restoring habitats crucial for Eurasian otter survival, such as clean rivers, wetlands, and coastal areas, and Ensuring an adequate water supply for these habitats. 4- Reducing water pollution through better waste management practices and stricter pollution regulations. 5- Resolving conflicts with human activities, such as fish farming, by seeking mutually beneficial solutions. 6- Conducting ongoing research to deepen the understanding of Eurasian otter needs and monitoring populations to gauge conservation progress. These strategies should be tailored to the specific needs of the Eurasian otter populations in the regions.

Conclusion

In this research, the consequences of climate change were investigated according to three scenarios of SP126, SSP585, and SSP370—until 2070 regarding the distribution of the Eurasian otter. The results showed that climate change affects the presence of this species. Based on the results, a range of suitable habitats for the Eurasian otter will become unsuitable due to climate change. Based on the climate scenarios studied in 2070, according to the sSP126 scenario, about 10.37%, the SSP370 scenario, about 10.38%, and the SSP585 scenario, about 11.58% of the standard and currently suitable habitat of the Eurasian otter will most likely be unsuitable in the future. Therefore, like other studies on animal and plant species, it can be said that climate change causes habitat reduction and changes in the range of habitats. Studying the habitat of the Eurasian otter in Khuzestan Province and the reactions of this species to climate change will lead to a better understanding of its habitat needs. Therefore, it is necessary to implement a conservation plan based on suitable habitats today and in the future to increase the extent of protected areas so that the distribution and population of this species face fewer threats.

Conflicts of Interests

All authors declare that they have no conflicts of interest in the publication of this paper.

References

1. Cianfrani C., Le Lay G., Maiorano L., Satizábal H.F., Loy A., Guisan A. Adapting global conservation strategies to climate change at the European scale: the otter as a flagship species. Biol. Conserv. 2011; 144(8): 2068-2080.
2. Bellard C., Bertelsmeier C., Leadley P., Thuiller W., Courchamp F. Impacts of climate change on the future of biodiversity. Ecol. Lett. 2012; 15(4): 365-377.
3. Ebrahimi A., Farashi A., Rashki A. Habitat suitability of Persian leopard (Panthera pardus saxicolor) in Iran in future. Environ. Earth Sci. 2017; 76(1):1-10.
4. Karami, M., Mirzaei, I., Hamzehpour, M. Status Of Eurasian Otter (Lutra lutra) in Iran. IUCN Otter Spec. Group Bull. 2006: 23 (1): 27-33.
5. Ansari A. Habitat quality evaluation for the Eurasian Otter (Lutra lutra)(Class: Mammalia, Family: Mustelidae) in Markazi Province. J. Anim. Res. 2021; 34(2): 69-81.
6. Mirzaei R., Karami M., Danehkar A., Abdoli A. Study of otter (Lutra lutra) Distribution Along Jajrood River. Environ. Sci. 2008; 6(2): 33-42.
7. Eshagh Nimvari S., Naderi S., Mirzajani A. Investigating the presence and diet of otter (Lutra lutra) in the estuary region of eastern rivers of Guilan Province: Polrood, Khoshkrod and Acharod. J. Nat. Environ. 2022; 75(4): 716-732.
8. Masoodian S.A. Temperature trends in Iran during the last half-century. Geo. Dev. 2004; 2(3): 89-106.
9. Dayton G.H., Fitzgerald L.A. Habitat suitability models for desert amphibians. Biol. Conserv. 2006; 132(1): 40-49.
10. Guisan A., Zimmermann N.E. Predictive habitat distribution models in ecology. Ecol. Model. 2000; 135(2-3): 147-186.
11. Rashidi P., Makmom A.A., Mahiny A.S., Moradi H.V., Firuz R.M., Amanollahi J., Tabrizi A.M., Shahbazi H. An overview of different modeling approaches to prediction of the likely effects of climate change on range shifts of species. Int. J. Phys. Sci. 2012; 7(12): 1878-1883.
12. Houghton J.T., Ding Y., Griggs D.J., Noguer M., Van der Linden P.J., Dai X., Maskell K., Johnson C. Climate change 2001: the scientific basis: contribution of Working Group I to the third assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press. 2001:881p.
13. Archis J.N., Akcali C., Stuart B.L., Kikuchi D., Chunco A.J. Is the future already here? The impact of climate change on the distribution of the eastern coral snake (Micrurus fulvius). PeerJ. 2018; 6(1): 1-24.
14. Araújo M.B., New M. Ensemble forecasting of species distributions. Trends Ecol. Evol. 2007; 22(1): 42-47.
15. Kaddo J.R. Parkland College Climate Change: Causes, Effects, and Solutions. 2016. 165.
16. Potta S. Application of stochastic downscaling techniques to global climate model data for regional climate prediction. Louisiana State University and Agricultural & Mechanical College; 2004:167p.
17. Nazmfar H., Alibakhshi A. Assess the spatial development of regional inequality Case study: the

Khuzestan Province. Spat. Plan. 2014; 14(4) :99-114.
18. Behroozi Rad B. Wetlands of Iran, National Geographical Organization Press. First Edition. 2008: 812p. (In Persian)
19. Thuiller W., Lafourcade B., Engler R., Araújo M.B. BIOMOD–a platform for ensemble forecasting of species distributions. Ecography. 2009; 32(3): 369-73.
20. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. 2024. 97.
21. Woodman S.M., Forney K.A., Becker E.A., DeAngelis M.L., Hazen E.L., Palacios D.M., Redfern J.V. ESDM: A tool for creating and exploring ensembles of predictions from species distribution and abundance models. Methods. Ecol. Evol. 2019; 10 (11): 1923–1933.
22. Václavík T., Meentemeyer R.K. Equilibrium or not? Modelling potential distribution of invasive species in different stages of invasion. Divers. Distrib. 2012;18(1): 73-83.
23. Simpson M., Prots B. Predicting the distribution of invasive plants in the Ukrainian Carpathians under climatic change and intensification of anthropogenic disturbances: implications for biodiversity conservation. Environ. Conserv. 2013; 40(2): 167-181.
24. Marmion M., Luoto M., Heikkinen R.K., Thuiller W. The performance of state-of-the-art modelling techniques depends on geographical distribution of species. Ecol. Model. 2009; 220(24): 3512-20.
25. Kindt R. Ensemble species distribution modelling with transformed suitability values. Environ. Model. Softw. 2018; 100(1): 136-145.
26. Allouche O., Tsoar A., Kadmon R. Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). J. Appl. Ecol. 2006; 43(6): 1223-1232.
27. Shabani F., Kumar L., Ahmadi M. Assessing accuracy methods of species distribution models: AUC, specificity, sensitivity, and the true skill statistic. GJHSS-B Geography. 2018; 18(1). 1-13.
28. Haidarian M., Tamartash R., Jafarian-Jeloudar Z., Tarkesh M., Tataian M.R. The effects of climate change on the future distribution of Astragalus adscendens in central Zagros, Iran. J. Rangel. 2021; 11(2): 152-170.
29. Ashrafzadeh M.R., Naghipour A.A., Haidarian M., Khorozyan I. Modeling the response of an endangered flagship predator to climate change in Iran. Mammal. Res. 2019; 64(1): 39-51.
30. Ashrafzadeh M.R., Naghipour A.A., Haidarian M., Kusza S., Pilliod D.S. Effects of climate change on habitat and connectivity for populations of a vulnerable, endemic salamander in Iran. Global. Ecol. Conserv. 2019; 19(1): 1-13.
31. Bedia J., Herrera S., Gutiérrez J.M.. Dangers of using global bioclimatic datasets for ecological niche modeling. Limitations for future climate projections. Global. Planet. Change. 2013; 107(1): 1-12.
32. Hirzel A. When GIS comes to life. Linking landscape and population ecology for large population management modelling: the case of Ibex (Capra ibex) in Switzerland. PhD Thesis, 2001:114p.
33. Pramanik M., Paudel U., Mondal B., Chakraborti S., Deb P. Predicting climate change impacts on the distribution of the threatened Garcinia indica in the Western Ghats, India. Clim. Risk Manag. 2018; 19(1): 94-105.
34. Olivier F., Wotherspoon S.J. Modelling habitat selection using presence-only data: Case study of a colonial hollow nesting bird, the snow petrel. Ecol. Model. 2006; 195(3-4): 187-204.
35. Saavedra Bendito D. Reintroduction of the Eurasian otter (Lutra lutra) in Muga and Fluvià basins (northeastern Spain): viability, development, monitoring, and trends of the new population. PhD Thesis, Universitat de Girona; 2003: 290p.
36. Kafash A., Kaboli M., Köhler G. Comparison effect of future climatic change on the desert and mountain dwelling reptiles in Iran (Paralaudakia caucasia and Saara loricata). J. Anim. Environ. Sci. 2015; 7(3):103-108.
37. Pedroso N.M., Marques T.A., Santos-Reis M. The response of otters to environmental changes imposed by the construction of large dams. Aquat. Conserv. 2014; 24(1): 66-80.
38. Karami M., Dargahi M.D., Hamzepour M. Habitat Suitability Index Model of Common Otter (Lutra lutra) in Prohibited Hunting Area, Deylaman – Dorfak. J. Nat. Envirn. 2012; 65(1): 127-137.
39. Segurado P., Araujo M.B. An evaluation of methods for modelling species distributions. J. Biogeogr. 2004; 31(10): 1555-1568.
40. Sangoony H., Vahabi M., Tarkesh M., Soltani S. Range shift of Bromus tomentellus Boiss. as a reaction to climate change in Central Zagros, Iran. Appl. Ecol. Env. Res. 2016; 14(4): 85-100.
41. Breiman L. Random forests. Mach. Learn. 2001; 45: 5-32.
42. Elith J., Leathwick J.R., Hastie T. A working guide to boosted regression trees. J. Anim. Eco. 2008; 77(4): 802-813.
43. Cheng L., Lek S., Lek-Ang S., Li Z. Predicting fish assemblages and diversity in shallow lakes in the Yangtze River basin. Limnologica. 2012; 42(2): 127-136.
44. Sahragard H.P., Chahouki M.Z. An evaluation of predictive habitat models performance of plant species in Hoze soltan rangelands of Qom Province. Ecol. Model. 2015; 309(1): 64-71.
45. Naghipour Borj A.A., Haidarian Aghakhani M., Sangoony H. Application of ensemble modelling method in predicting the effects of climate change on the distribution of Fritillaria imperialis. J.

Plant. Res. 2019; 32(3): 747-758.

46. Haidarian-Aghakhani M., Sangoony H. Predicting the impact of climate change on the distribution of Pistacia atlantica in the Central Zagros. J. Plan. Ecos. Conserv. 2019; 6(13): 197-214.
47. Ashrafzadeh M.R., Shojaei Z., Shaloei F., Naghipour A.A., Heidarian M. Modeling Current and Future Potential Distributions of Caspian Pond Turtle (Mauremys caspica) under Climate Change Scenarios. Iran. J. Appl. Ecol. 2022; 10(4): 39-51.
48. Solgi E., Ghasempouri S.M., Esmaili Sari A. Mercury Levels in the River Otters (Lutra lutra) of Iran: Feasibility of Back Calculation for Trace Elements Using Old Stuffed Specimens. ECOPERSIA 2013; 1(1): 1-10.
49. Khosravi R., Hemami M.R., Malakoutikhah S., Ashrafzadeh M.R., Cushman S.A. Prey availability modulates predicted range contraction of two large felids in response to changing climate. Biol. Conserv. 2021; 255: 109018.
50. Erlinge S. Territoriality of the otter Lutra lutra L. Oikos. 1968; 1: 81-98.
51. Edenhofer O., Pichs-Madruga R., Sokona Y., Agrawala S., Bashmakov I.A., Blanco G., Broome J., Bruckner T. Summary for policymakers. In: Climate Change 2014: Mitigation of Climate Change. IPCC Working Group III Contribution to AR5. Cambridge University Press. 2014:1435.
52. Milanovich J.R., Peterman W.E., Nibbelink N.P., Maerz J.C. Projected loss of a salamander diversity hotspot as a consequence of projected global climate change. PloS one 2010; 16; 5(8):e12189..
53. Yukimoto S., Kawai H., Koshiro T., Oshima N., Yoshida K., Urakawa S., Tsujino H., Deushi M., Tanaka T., Hosaka M., Yabu S. The Meteorological Research Institute Earth System Model version 2.0, MRI-ESM2. 0: Description and basic evaluation of the physical component. J. Meteorol. Soc. Jpn. Ser. II. 2019; 97(5): 931-965.
54. Zarrin A., Dadashi-Roudbari A., Hassani S. Future changes in precipitation extremes over Iran: Insight from a CMIP6 bias-corrected multi-model ensemble. Pure. Appl. Geophys. 2022;179 (1): 441-464.
55. McCluskie A.E. Temperature-mediated shifts in the foraging behaviour of the Eurasian otter, Lutra lutra L. Thesis, University of Glasgow (United Kingdom); 1998: 254p.
56. Garcês A., Pires I. Biological and Conservation Aspects of Otter Mortality: A Review. Conservation 2024; 4(2):307-318.
57. Tolrà A., Ruiz-Olmo J., Riera J.L. Human disturbance and habitat structure drive Eurasian otter habitat selection in heavily anthropized river basins. Biodivers. Conserv. 2024; 33(5): 1683–1710.